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NEW APPROACHES TO GROUNDWATER VULNERABILITY



ABSTRACTS

Edited by

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CONTENTS

I. PREFACE	1
II. ABSTRACTS	
RISK OF GROUNDWATER CONTAMINATION FROM HYDROCARBON SOURCES IN KADUNA METROPOLIS, NORTHWEST NIGERIA <i>M.S. Ahmed, A.I. Tanko, M.M. Badamasi & A. Abdulhamid</i>	5
GROUNDWATER VUNERABILITY AND RISK ASSESSMENT IN KADUNA METROPOLIS, NORTHWEST NIGERIA <i>M.S. Ahmed, A.I. Tanko, M.M. Badamasi & A. Abdulhamid</i>	6
ASSESSMENT OF GROUNDWATER RESOURCES VULNERABILITY OF PART OF AKURE METROPOLIS, SOUTH WESTERN NIGERIA FROM ELECTRICAL RESISTIVITY MEASUREMENT <i>Akinniyi Akinsunmade & Sylwia Tomecka-Suchoń</i>	7
THE TWOFOLD EXPLOIT OF DRAINAGE CHARACTERISTICS IN GROUNDWATER POTENTIAL MODELLING USING REMOTE SENSING AND GIS: AN EXAMPLE FROM DENGI AREA, NORTHCENTRAL NIGERIA <i>A.S. Arabi, O. A. Adeyeye & A. E. Ikpokonte</i>	8
THE VULNERABILITY TO POLLUTION OF THE MAIN GROUNDWATER RESERVOIR (MGR) No 417 – KIELCE <i>Katarzyna Białecka & Dorota Kaczor-Kurzawa</i>	9
RISK PERCEPTION AND COMMUNICATION OF ARSENIC CONTAMINATED GROUNDWATER: BALLIA, UTTAR PRADESH, INDIA <i>Camellia Biswas</i>	10
MEANDER EFFECT ON RIVER-AQUIFER INTERACTIONS <i>Uğur Boyraz & Cevza Melek Kazezyılmaz-Alhan</i>	11
SIMULATION OF RIVER-AQUIFER INTERACTIONS VIA EXPERIMENTAL METHODS <i>Uğur Boyraz & Cevza Melek Kazezyılmaz-Alhan</i>	12
PLACING A RESERVE DRINKING WATER SOURCE IN AN URBAN AREA - CRAZY IDEA OR NECESSITY? <i>Branka Bracic Zeleznik & Barbara Cencur Curk</i>	13
COMPLEXITY VS FEASIBILITY IN AQUIFER VULNERABILITY MAPPING – CHALLENGES AND POTENTIALS <i>Stefan Broda, Michael Liebhold & Jörg Reichling</i>	14
ACVM (AQUIFER COMPREHENSIVE VULNERABILITY MAPPING) - A NEW WIDE CONCEPT OF AQUIFER VULNERABILITY <i>Salvatore Carrubba, Alice Aureli & Matthew Lagod</i>	15
VULNERABILITY OF WATER RESOURCES TO CLIMATE CHANGE IN SOUTH-EAST EUROPE <i>Barbara Cencur Curk</i>	16
APPLICATION OF THE “PRK PLUS” APPROACH TO EVALUATE THE SENSITIVITY OF THE COASTAL AQUIFER OF GHISS - NEKKOUR AGAINST POLLUTION <i>Hinde Cherkaoui Dekkaki, Taoufik Kouz, Soukaina Mansour & Taoufik Mourabit</i>	17

THE KOZŁOWA GÓRA DRINKING WATER RESERVOIR'S CATCHMENT AS A PILOT AREA IN A MULTI ASPECT SURVEY IN ORDER TO ASSESS THE IMPACT OF LAND USE MANAGEMENT AND CLIMATE CHANGE ON GROUNDWATER RESOURCES <i>Joanna Czekaj, Mirosława Skrzypczak, Dorota Grabala, Ewa Kaczkowska, Sabina Jakóbczyk-Karpierz, Hanna Rubin, Krystyn Rubin, Sławomir Sitek, Piotr Siwek, Kinga Ślósarczyk & Andrzej J. Witkowski</i>	18
NITRATES MIGRATION IN REGIONAL GROUNDWATER RECHARGE ZONE (LWÓWEK REGION, POLAND) <i>Krzysztof Dragon</i>	19
THE MIGRATION OF PESTICIDE RESIDUES IN GROUNDWATER IN CASE OF BANK FILTRATION SITE (MOSINA-KRAJKOWO WELL SCHEME, POLAND) <i>Krzysztof Dragon, Dariusz Drożdżyński & Józef Górski</i>	20
GROUNDWATER VULNERABILITY MAPS BASED ON A MODIFIED AVI MODEL: CASE STUDIES IN SOUTHERN ITALY <i>Daniela Ducci & Mariangela Sellerino</i>	21
ASSESSING COASTAL AQUIFER VULNERABILITY TO SEAWATER INTRUSION USING GALDIT METHOD: APPLICATION TO THE SIDI MOUSSA COASTAL AQUIFER, SAHEL DOUKKALA, MOROCCO <i>Y. Echelfi; A. El Achheb & S. El Maliki</i>	22
INTEGRATION OF GEOGRAPHICAL INFORMATION SYSTEM, REMOTE SENSING, AND WATERSHED MODELING TO BEST EVALUATE RAINWATER HARVESTING POTENTIALITY IN WADI DAHAB, SOUTH SINAI	23
GROUNDWATER RECHARGE VULNERABILITY CONNECTED TO METEOROLOGICAL AND HYDROLOGICAL DROUGHT	24
LABORATORY AND NUMERICAL INVESTIGATIONS OF BIODEGRADATION POTENTIAL DURING COMBINED TREATED WASTEWATER AND RAINWATER INFILTRATION TO MINIMIZE POLLUTION RISK <i>Thomas Fichtner, Falk Haendel, Christian Engelmann, Robert Pinzinger, Peter-Wolfgang Graeber, René Blankenburg, Claudia Kuke, Rudolf Liedl, Bernd Maertner & Holger Mansel</i>	25
TRACKING OF GEOLOGICAL STRUCTURES AND DETECTION OF THERMAL INTRUSION BY GEOELECTRICAL METHODS IN THE HIGHLANDS OF BOLIVIA <i>Étzar Gómez, Emil Svensson, Torleif Dahlin, Gerhard Barmen & Jan-Erik Rosberg</i>	26
EDIT: A NOVEL GEOELECTRICAL AND GEOMORPHOLOGICAL BASED METHOD FOR GROUNDWATER VULNERABILITY IN ALLUVIAL FANS <i>Andres Gonzales Amaya</i>	27
GROUNDWATER VULNERABILITY TO POLLUTION. CLIMATE CHANGE SCENARIOS IN YUCATAN, MEXICO	28
INITIAL ESTIMATION OF AQUIFER VULNERABILITY BASED ON ARTIFICIAL TRACER EXPERIMENT (BRDA OUTWASH PLAIN, POMERANIAN REGION, NORTHERN POLAND) <i>Anna Gumuła-Kawęcka, Adam Szymkiewicz, Beata Jaworska-Szulc, Małgorzata Pruszkowska-Caceres & Wioletta Górczewska-Langner</i>	29

GROUNDWATER VULNERABILITY MAPS FOR POLICY SUPPORT ON PESTICIDES <i>Griet Heuvelmans, Ingeborg Joris, Jef Dam & Kris Van den Belt</i>	30
MetQ: A METHOD FOR DETERMINING THE AQUIFER CONTAMINATION RISK APPLIED IN THE METROPOLITAN REGION OF SÃO PAULO (BRAZIL)	31
GROUNDWATER RECESSION CURVE ANALYSIS AND RECHARGE ESTIMATION FOR THE MOUNTAINOUS FRACTURED ROCK ENVIRONMENT: A CASE STUDY IN THE MID- AND UPPER-JHUOSHUEI RIVER BASIN IN CENTRAL TAIWAN <i>Shih-Meng Hsu & J. F. Lee</i>	32
AQUIFER VULNERABILITY ASSESSMENT TO NITRATE CONTAMINATION USING GIS-BASED DRASTIC AND SOLUTE TRANSPORT MODEL	33
THE EFFECT OF DROUGHT ON THE PABDEH KARSTIC AQUIFER, SOUTHWEST IRAN <i>N. Kalantari, A. Nadri, H. Zarei & F. Kalantari</i>	34
GROUNDWATER POLLUTION ASSESSMENT IN URBAN AREAS OF QOM CITY IRAN <i>N. Kalantari, M.H. Rahimi & F. Kalantari</i>	35
SIMULATION OF REACTIVE TRANSPORT IN FRACTURED GEOLOGIC MEDIA USING RANDOM WALK PARTICLE TRACKING	36
ASSESSMENT OF CONTAMINATED SHALLOW DRINKING GROUNDWATER IN AN AGRICULTURAL AREA OF SOUTH KOREA <i>MoonSu Kim, Minkyong Lee, Inkyu Shin, JongYeon Hwang, HunJe Jo, SunHwa Park & HyunKoo Kim</i>	37
PRACTICAL ESTIMATING METHOD OF GROUNDWATER LEVEL VARIATION FOR URBAN FOUNDATION STRUCTURES NEAR THE FLUVIAL AREA <i>Incheol Kim, Garam Kim, Jinh Kim, Wonseok Choi, Junhwan Lee & Junhwan Lee</i>	38
INTERPRETATION OF GROUNDWATER LEVEL FLUCTUATIONS IN TERMS OF VULNERABILITY <i>Agnieszka Kowalczyk</i>	39
AN ASSESSMENT OF THE OPEN LOOP HEAT PUMP OPERATION BY THE TOUGH2 MODELLING SOFTWARE <i>David Krčmář, Tibor Kovács, Renáta Fláková, Zlatica Ženišová & Kamila Hodasová</i>	40
ASSESSING VULNERABILITY OF GROUNDWATER TO CONTAMINATION IN RESPONSE TO GROUNDWATER DEPTH VARIABILITY	41
A PRELIMINARY ASSESSMENT OF THE GEOLOGICAL FACTORS AFFECTING GROUNDWATER QUALITY AROUND TOSHAM, A PART OF MALANI IGNEOUS SUITE, INDIA.	42
AQUIFER VULNERABILITY AND RISK ASSESSMENT IN THE PANNONIAN PART OF CROATIA <i>Ozren Larva, Tamara Marković & Željka Brkić</i>	43
USE OF KARST SPRINGS' MASTER RECESSION CURVES IN VULNERABILITY ASSESSMENT AND ITS VALIDATION BY TRANSFER OF PRECIPITATION $\delta^{18}\text{O}$ SIGNAL <i>Peter Malík</i>	44
ORIGIN OF NITRATE IN CHALK GROUNDWATER FROM NITRATE N AND O STABLE ISOTOPIC SIGNATURES <i>Josephine McSherry, Jared West & Simon Bottrell</i>	46

HYDRAULIC CHARACTERIZATION AND MODELLING CONTAMINANT TRANSPORT IN A PERMIAN DOLOMITIC LIMESTONE, THE SPEN FARM STUDY CASE (NE ENGLAND, UK) Giacomo Medici, L. Jared West & Steven Banwart	47
APPLICATION OF NEURAL NETWORKS FOR THE DEVELOPMENT OF AN INTEGRATED KARST AQUIFER VULNERABILITY MODEL (IKAV)	48
VULNERABILITY ASSESSMENT AND HYDRODYNAMIC ANALYSIS FOR AREAS WITH SCARCE INPUT DATA - CASE STUDY OF KARST AQUIFER "GRAPA" IN SE SERBIA	49
CONSIDERATIONS FOR GROUNDWATER FLOW CONSERVATION METHODS IN UNDERGROUND CONSTRUCTION WORKS Makoto Nishigaki	50
GROUNDWATER RISK ASSESSMENT BY LWPI DUE TO LANDFILL LEACHATE IMPACT Vahid Nourani, Dominika Dąbrowska & Marek Sołtysiak	51
WATERPROTECT – INNOVATIVE TOOLS ENABLING DRINKING WATER PROTECTION IN RURAL AND URBAN ENVIRONMENTS Marzena Nowakowska, Anna Kuczyńska & Małgorzata Woźnicka	52
EVALUATION OF THE COMPARISON OF FOUR GROUNDWATER VULNERABILITY METHODOLOGIES: A CASE STUDY OF DAHOMEY BASIN SHALLOW AQUIFERS Saheed Adeyinka Oke	53
ADSORPTION AND DESORPTION PARAMETERS OF ERYTHROMYCIN MIGRATION IN SATURATED POROUS MEDIA BASED ON COLUMN TESTS Monika Okońska & Katarzyna Pietrewicz	54
SCALE EFFECTS IN STATISTICAL BASED GROUNDWATER VULNERABILITY MODELS? A CASE STUDY ON CONTINENTAL-SCALE OF AFRICA Issoufou Ouedraogo & Marnik Vanclooster	55
ASSESSING GROUNDWATER VULNERABILITY FOR NITRATE POLLUTION IN THE BRUSSEL'S CAPITAL REGION (BELGIUM) USING STATISTICAL MODELLING APPROACHES S. Petit, P. Bogaert, A. Lietaer & M. Vanclooster	57
POTENTIAL CHANGES IN VULNERABILITY OF FRACTURED CARBONATE AQUIFERS IN CENTRAL ITALY AFTER THE 2016-17 SEISMIC SEQUENCE M. Petitta, F. Banzato, D. Barberio, M. Berbieri, A. Lacchini, V. Marinelli, S. Passaretti & C. Sbarbati	58
GROUNDWATER VULNERABILITY MAPPING APPROACH AT SPRING / WELL CATCHMENT SCALE AS A TOOL TO BETTER FORECAST THE IMPACT OF CONTAMINATION IN POROUS MEDIA Alain Pochon & Michael Sinreich	59
KARST AQUIFER CRITERIA TO DEFINE CONTAMINANT ATTENUATION POTENTIAL AND GROUNDWATER VULNERABILITY Alain Pochon, Michael Sinreich & François Zwahlen	60
INITIAL ASSESSMENT OF GROUNDWATER POLLUTION IN THE PUCK MUNICIPALITY AREA Dawid Potrykus, Anna Gumuła-Kawęcka, Beata Jaworska-Szulc, Małgorzata Pruszkowska-Caceres & Adam Szymkiewicz	61
OCCURRENCE OF URANIUM IN GROUNDWATER IN CRYSTALLINE BASEMENT AQUIFERS OF AMBAJI REGION, NORTH GUJARAT, INDIA	62

NITRATE VULNERABILITY ASSESSMENTS ON LOCAL SCALE FOR HALF A COUNTRY	63
GROUNDWATER MANAGEMENT WITH DEEP SEALING WALLS <i>Thomas Reimann, Rudolf Liedl, Peter-Wolfgang Gräber, Jinxing Guo & Stefan Fisch</i>	64
SPECIFIC GROUNDWATER VULNERABILITY TO ACID MINE DRAINAGE AT A REGIONAL SCALE: CASE STUDY OF WITBANK COALFIELD, SOUTH AFRICA	65
DESIGN AND MAINTENANCE OF A RECHARGE WELL TO PREVENT CLOGGING <i>Takaaki Shimizu</i>	66
COUPLING INTRINSIC VULNERABILITY WITH BACTERIA-SPECIFIC CONCEPTS <i>Michael Sinreich & Alain Pochon</i>	67
ASSESSING IRRIGATION IMPACT ON SOUSS-MASSA GROUNDWATER VULNERABILITY USING DRASTIC METHOD <i>Tarik Tagma, Youssef Hsissou, Mohammed Hsaissoune, Zineb Lgourna, Jalal Moustadraf, Said Boutaleb & Lhousseine Bouchaou</i>	68
GROUNDWATER RECHARGE ESTIMATION AND IRRIGATION WATER MANAGEMENT USING SOIL MOISTURE INDEX ACROSS VARIABILITY SATURATED ZONE <i>Anooja Thomas, Brijesh Kumar Yadav & Vivekanand Singh</i>	69
ASSESSING O ₂ REDUCTION RATES TO EVALUATE NITRATE VULNERABILITY OF A POROUS AQUIFER <i>Lisa Wild, Bernhard Mayer & Florian Einsiedl</i>	70
OVERVIEW OF APPLICATION OF SOIL AND ITS PROPERTIES FOR GROUNDWATER VULNERABILITY ASSESSMENT <i>Andrzej J. Witkowski & Jacek Rózkowski</i>	71
IMPORTANCE OF GEOLOGICAL ASPECTS OF KARSTIC AQUIFER FOR VULNERABILITY ASSESSMENT: CASE STUDY OF UČJA VALLEY, NW SLOVENIA <i>Petra Žvab Rožič</i>	72
LAGTIME OF RIVER SYSTEMS TO CHANGES IN CONTAMINATION LOAD ON CATCHMENTS: TIMESCALE-BASED VULNERABILITY CONCEPT <i>Anna J. Żurek, Kazimierz Rózański & Stanisław Witczak</i>	73
III. AUTOR INDEX	74

Preface

The International conference on "New Approaches to Groundwater Vulnerability" is the third conference on contemporary groundwater vulnerability issues to be organised in Ustroń, Poland. The previous two were also held in Ustroń in 2004 and 2015. Participants of previous conferences suggested transforming this monothematic conference into a cyclical event organized every three years. To meet these suggestions, the current conference was organized. It should also be emphasized that this conference is part of the celebrations of the 50th anniversary of the University of Silesia and is organized under the honorary patronage of his Magnificence Rector of the University of Silesia Professor Dr. Hab. Andrzej Kowalczyk. There were approximately 90 people from 27 countries who participated in the conference. The organizers received 80 abstracts. The subject of abstracts concerned nine major conference topics:

- Development of the vulnerability concept
- Groundwater vulnerability assessment in urbanised and heavily transformed mining areas
- Groundwater vulnerability and groundwater pollution risk
- Groundwater recharge and its role in vulnerability assessment
- Vulnerability in karst areas
- Application of GIS tools and modelling in GW vulnerability assessment
- Groundwater vulnerability assessment according to climate change and efficient land use management
- Vulnerability assessment role in sustainable water management
- Groundwater vulnerability mapping and its practical application.

As many articles referred to karstic areas, a special conference session focusing on groundwater vulnerability assessment for karstic areas has been organised. Also, one special session has been dedicated to groundwater vulnerability to nitrate pollution. A number of articles were concerned with the extensive problem of groundwater recharge and the risk of groundwater contamination. An additional session was organized devoted to international and important national projects regarding the issues of groundwater protection and sustainable management. The conference program included seven thematic sessions (32 oral presentations), a poster session (28 posters) and a field trip.

Finally, sixty seven accepted abstracts, relevant to the topic of the conference are published in this conference volume. All the abstracts are arranged alphabetically by the first author's name. The author index is given on pages 74-75. Submitted abstracts have been checked by members of the Scientific Committee, mainly in terms of content, but not in terms of linguistic correctness. I would like to thank all members of the Scientific Committee for their tremendous efforts in reviewing abstracts.

As post-conference publications, about 30 of the most outstanding papers will be published; about 20 of these by Taylor & Francis in a special volume of IAH Selected Papers and about 10 papers in a special issue of Environmental Earth Sciences.

An important and measurable publication achievement of the previous two conferences was the publication in 2007 of the special issue of Environmental Geology covering 10 papers and in 2016 of the special issue of Environmental Earth Sciences, which also consisted of 10 papers. In

this context, I would like to warmly thank Dr. James (Jim) LaMoreaux for his kindness and help in the publication of the previous special issue of Environmental Earth Sciences, containing the most valuable articles delivered at the conference in 2015. At the same time, I would like to thank Jim for kindly agreeing to publish and promise of help in the editing of another special issue of Environmental Earth Sciences dedicated, in accordance with the title of the current conference, to new approaches to groundwater vulnerability.

On this occasion, I would also like to remind you of the extremely kind Dr. Philip E. LaMoreaux, Sr. - a deceased family senior, a prominent karst expert who initiated fruitful cooperation of conference organizers with Environmental Geology and later with Environmental Earth Sciences.

Another important effect of these conferences (apart from the printed three abstract books) was the publication in 2007 of Vol. 11 of IAH Selected Papers under the title "Groundwater Vulnerability Assessment and Mapping". This book includes 23 very good papers presented at the first conference in 2004.

Unfortunately, after the previous conference in 2015, despite many abstracts and numerous presentations sent, the organizers did not receive enough full papers to publish the next volume of IAH Selected Papers. I hope that this time the authors will provide the right amount of valuable papers which will enable the preparation for printing of the mentioned book. In a planned new volume of IAH SP, in addition to the new manuscripts, several already reviewed papers from the previous conference will also be published.

With reference to the previous volume of IAH SP and the planned new one, I would like to express my sincere thanks to Nick S. Robins (Editor-in-Chief IAH Book Series) and Janaap Blom (Senior Publisher at Taylor & Francis) for excellent cooperation, understanding and kind help in publishing Volume 11 and declaration of cooperation when publishing the next volume 24.

On behalf of the Scientific and Organising Committees, I would like to thank all the sponsors of the conference for their generous help. I would like to address special thanks to UNESCO International Hydrological Program and personally to Dr. Alice Aureli for financial support and covering the costs of participation of eight scientists from developing countries. Also, I would like to address special thanks to DHI WASY for organizing special presentation of the possibilities of the latest version of FEFLOW.

I would like to thank Dorota Grabala and Jacek Wróbel for their professional efforts in the editorial work of this volume. I also wish to thank all my colleagues from the Organising Committee of the conference, particularly Ms Joanna Czekaj (conference secretary) for making the conference a success.

Andrzej J. Witkowski
Chairman of the Scientific Committee

ABSTRACTS



RISK OF GROUNDWATER CONTAMINATION FROM HYDROCARBON SOURCES IN KADUNA METROPOLIS, NORTHWEST NIGERIA

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Keywords: groundwater, hydrocarbon, risk, GIS

Several human activities impact negatively on groundwater resources. Kaduna metropolis, like other major cities in Nigeria, lack adequate portable water supply to cater for its growing population. Groundwater development serves as the quickest means of augmenting the deficit in water supply in the area. Threats to the groundwater quality is however heightened by the uncontrolled land use among which includes hydrocarbons handling. Major hydrocarbon contaminants sources in the area include petrol (filling) stations, refining operation, automobile shops and petroleum products pipeline. Qualitative assessment of groundwater contamination risk from each of these sources was conducted using a rating technique and mapped within geographical information system framework. Parameters considered include the physical properties of the locations such as the soil type, groundwater vulnerability, proximity to surface and groundwater sources; methods of handling hydrocarbons as well as its containments. Each category has been classified into low, moderate and high risk to groundwater and symbolized in green, yellow and red colours respectively on the maps. The assessment indicated that groundwater is at risk of contamination from these sources. This may expose the users to various health complications associated with the ingestion of some hydrocarbon components such as cancer and central nervous system malfunction. Proper monitoring and supervision, land use planning and public awareness campaign are recommended.

GROUNDWATER VUNERABILITY AND RISK ASSESSMENT IN KADUNA METROPOLIS, NORTHWEST NIGERIA

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Keywords: groundwater, vulnerability, risk, hazard, GIS

DRASTIC index and GOD models were applied in the assessment of groundwater vulnerability to contamination in Kaduna metropolis, Nigeria. DRASTIC index evaluates the contributions of seven environmental parameters (Depth to water level, net Recharge, Aquifer media, Soil media, Topography, Impact of vadose zone, and Hydraulic Conductivity) in the protection of groundwater against contamination. GOD model on the other hand, assesses the significance of groundwater confinement in the aquifer (G), overlying lithology (O) and depth to groundwater level (D) in determining the susceptibility of groundwater to contamination. For the risk assessment, the EU COST Action 620 approach to hazard and risk analysis was applied. Unclassified and classified hazard (contaminants sources) maps of the area were produced. Pollution potentials in the area was found to be generally moderate to low. Using the overlay operation of Arc GIS, the two vulnerability maps generated were each merged with the classified hazard map to produce the groundwater contamination risk maps of the area according to the two models. High contamination risk was found around the Kaduna refinery, the two dumpsites of Mando and Kakau as well as most parts of the residential areas. It is recommended that, strict control measures be put in place when locating land uses with high potential hazards in areas with relatively high vulnerability.

ASSESSMENT OF GROUNDWATER RESOURCES VULNERABILITY OF PART OF AKURE METROPOLIS, SOUTH WESTERN NIGERIA FROM ELECTRICAL RESISTIVITY MEASUREMENT

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Keywords: Groundwater, Electrical sounding, Resistivity, Aquifer, vulnerability.VES

Groundwater resources are prone to contamination if not naturally protected from anthropogenic activities. Prospecting for groundwater resources is not only limited to identification of the aquifer but the assessment of vulnerability potential of the aquifer to contamination. This study assessed the vulnerability of the aquifer around the northern part of Akure metropolis, southwestern, Nigeria.

Sixty five vertical electrical sounding (VES) data using schlumberger array method were acquired for the study. The computer assisted VES data interpretation enables the delineation of the subsurface into three to four geoelectric layers; the topsoil, the lateritic or weathered layer, the fractured basement and the resistive bedrock. In the topsoil, resistivity values range from 30 ohm-m – 301 ohm-m with the layer thickness varying from 1.3 m – 2.1 m. The second layer which is presumably the weathered zone, has resistivity in the range of 21 – 648 ohm –m with the thickness ranging from 0.3 m to 36.6 m. The fractured bedrock has resistivity in the range 36 ohm- m – 796 ohm – m. Geoelectric layers with relatively low resistivity values are considered zone of saturation which are the potential target for groundwater resources.

Assessment of the vulnerability potential of the aquifer especially the topmost aquifer was based on the geo-electric parameter evaluated from the resistivity data. Aquifer overlain by topmost layer with low resistivity (< 100 ohm-m) has been interpreted to imply clayey formations with good protective capability and less vulnerable. This occupies most of the central part and the southwestern part and constitutes about 65% of the study area. Aquifers within the zones overlain by topmost geoelectrically pervious materials (resistivity of 101 to 300 ohm – m) interpreted to be sand which occupy the northern part and some portions of the southern part of the study area represent about 35%. This is considered vulnerable to infiltrating surface-source contaminants.

The study has made possible the characterization of the vulnerability potential of the aquifer in the study area. Large part of the area is covered by topmost layer materials of weak to poor protective capacity which makes groundwater resources in the area vulnerable to pollution. It is therefore recommended that general awareness campaign is embarked upon in the area on the precautionary principles required to protect groundwater resources and health hazards accompanying indiscriminate disposal of wastes.

THE TWOFOLD EXPLOIT OF DRAINAGE CHARACTERISTICS IN GROUNDWATER POTENTIAL MODELLING USING REMOTE SENSING AND GIS: AN EXAMPLE FROM DENGI AREA, NORTHCENTRAL NIGERIA

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Keywords: Remote Sensing, Geographical Information System, Groundwater Potential Model

The need for refining of the skills employed in groundwater exploration and management is being emphasized as population surges and the importance of water to meet these growing demands increases. Remote Sensing and Geographical Information Systems (GIS) have routinely been used in targeting favourable zones for groundwater exploration thus necessitating the attempt to improve the reliability of this approach. While other factors like geology, elevation, slope, lineament density, contact proximity and soil remain constant (within the framework of the model), this work incorporates both drainage density and drainage proximity thematic layers into a single groundwater potential model by separating first order streams from second and third order streams, respectively. The groundwater potential model obtained via this dual application yields more reliable results in comparison to field conditions than the model produced by using either drainage density or drainage proximity alone. Consequently, this integrated application approach has proven extra usual and is thus encouraged.

THE VULNERABILITY TO POLLUTION OF THE MAIN GROUNDWATER RESERVOIR (MGR) No 417 - KIELCE

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Keywords: natural vulnerability, SE Poland, the Holy Cross Mountains, the Main Groundwater Reservoir No 417 Kielce, water quality

The article presents the results of studies regarding the identification of the natural vulnerability of the Main Groundwater Reservoir - Kielce, which were performed within the framework of the tasks of Polish Hydrogeological Survey: *"Appendix to the hydrogeological documentation of the Kielce exploitation area in order to establish the protection areas of the Main Groundwater Reservoir No 417 Kielce"*.

The reservoir is located within the Middle and Upper Devonian limestones, which form the Holy Cross Mountains. The MGR plays a very important role in water supply for the city of Kielce, because the Kielce-Białogon intake, which supplies 70% of communal water demand is situated here. Therefore, identification of the natural vulnerability of this reservoir is very important to protect the water quality.

The studies included the assessment of natural vulnerability that determines the vertical travel times of conservative contaminants through the vadose zone which depends mainly on the thickness and hydrogeological properties of the strata overlaying the aquifer. That allows to classify vulnerability according to classes of different timescale (<5, 5-25, 25-50, 50-100, >100 years).

In the southern part of this reservoir the degree of vulnerability is changing from moderate, to high, up to very high. This may indicate that the vertical migration time of the pollution (transported by the water infiltrating from the surface to the aquifer) have been ranging from less than 5 years (very high degree of vulnerability), through 5-25 years (high degree), to 25-50 years (moderate degree).

In the northern part of the MGR the degree of vulnerability is very differentiated from very high (<5 years) to very low (> 100 years), which may be caused by the structure of the vadose zone, composed mostly (in 50-90%) of poorly permeable clays. (Białecka, Kaczor, Kurzawa, 2015).

REFERENCE

Białecka K., Kaczor - Kurzawa D., 2015 - Appendix to the hydrogeological documentation of the Kielce exploitation area in order to establish the protection areas of the Main Groundwater Reservoir No 417 Kielce. PIG Warszawa.

RISK PERCEPTION AND COMMUNICATION OF ARSENIC CONTAMINATED GROUNDWATER: BALLIA, UTTAR PRADESH, INDIA

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Keywords: Risk, risk communication, risk perception, arsenic, groundwater contamination

Arsenic Toxicity in drinking groundwater is a global environmental risk and because of its geogenic origin, none can predict its occurrence from before. Long-time exposure to arsenic contaminated water leads to various health problems. It has a power to collapse the socio-economic backbone of the poor society. Higher degree of toxicity could cause arsenecosis, keratosis and melanosis.

Communicating an intertwined nature (geological)-human risk is not just a one-way transfer of information but a complex interaction between the sender and receiver. It needs a guidance to build their understanding and approach towards that risk. However the best way to assess the risk communication is to see how the message of risk is perceived by the receiver. In the case of arsenic contamination of groundwater in Ballia, Uttar Pradesh, India, the involved stakeholders are the 'sender' and affected community is the 'receiver'.

Various studies have showed the overabundance presence of arsenic in groundwater around the Gangetic plains mainly in West Bengal (> 50 µg /L) followed by Bihar and Uttar Pradesh. However, in recent times a few districts situated in eastern UP have been in focus of such occurrence of high arsenic in groundwater. This paper highlights on the functioning of both the sides of the communication channel in one of the affected district of Eastern UP named Ballia. The study encompasses on how the affected community reacts and cope with when receives the message of under threat or being vulnerable of arsenic toxicity. It pulls out various social and societal factors from the affected people, that helps them evaluating and judging the transmitted message by the receiver which further builds their perception on arsenic contamination. Secondly, it looks into the mechanism of the involved stakeholders (local-national-global) on how they are assessing the contaminated groundwater vulnerability transmitting the message of groundwater vulnerability and coping strategies.

The study revolves around interviews and narratives by both, hence it gives a much more qualitative approach to assess the vulnerability through perception building.

MEANDER EFFECT ON RIVER-AQUIFER INTERACTIONS

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Keywords: River-aquifer interactions, meandering rivers, meander curvatures, numerical groundwater model.

River-aquifer interaction is one of the most important reason of contamination of groundwater. As the interaction flowrate increases, contaminant transport between the two water bodies also increase. Therefore, the parameters, which affect the interactions, should be examined in detail to control the groundwater contamination due to interactions. These parameters can be classified as hydrostatic and hydrodynamic drivers. River planform is an important parameter because it directly affects the behaviour of these drivers. In a meandering type of stream, both hydrostatic and hydrodynamic effects become more dominant because meanders cause more momentum transfer, more turbulence and sudden head changes. This study focuses on the determination of interaction rates in different meandering streams. Models are developed by considering the curvature radius of the meander as the main parameter. Meander shapes are defined by using sinusoidal functions which are close representations of the natural conditions of the meander type of rivers. Curvatures of meanders are defined in a wide range changing from a straight river to sharp curved river in an aquifer. Numerical analyses are conducted to determine the interaction flow rate by using finite difference method. The effect of river curvature on groundwater flow distribution is observed. Interaction flow rates are obtained and it is concluded that as the meander curvature increases, interaction flow rate also increases. Moreover, flow paths are presented to see the effective contaminant transport zones in the aquifer due to the interactions.

SIMULATION OF RIVER-AQUIFER INTERACTIONS VIA EXPERIMENTAL METHODS

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Keywords: River-aquifer interactions, groundwater flow experiment, stream-aquifer simulation, groundwater tests.

The importance of the protection of the groundwater resources becomes more pronounced because of the population increase and land use effects. For a sustainable groundwater management, both groundwater quantity and quality should be determined via hydrological models and should be protected against the existing and future risks. Groundwater is under threat in urban and agricultural areas due to the contamination. The pollutants can also be routed to far-off regions by river flow. This study focuses on groundwater vulnerability from a different point of view: We investigate the effect of pollutants in rivers on groundwater contamination. River-groundwater interactions play a crucial role in the contaminant transport between river and aquifer. In order to examine this physical phenomenon, first, the interactions between a river and an aquifer need to be investigated and the effects of these interactions on groundwater head distribution should be determined. For this purpose, a new experimental setup is designed to simulate the river-aquifer interactions. An aluminum box with dimensions of 1.5 (m)x1.5 (m) x0.20 (m) is used to simulate the aquifer region. Two different shapes of stream are set along the two opposite sides of the aquifer. The first one simulates a straight stream and the second one simulates a meandering stream. With these channels, different types of boundaries such as constant, raising or sloped water surface can be simulated. The maximum volume of the aquifer part is 0.3 m³ and the maximum thickness of the aquifer is 20 cm. Moreover, sloped aquifer tests can be conducted with this equipment by using a sloped aquifer table which is adjustable to a slope up to 15 %. Moreover, the equipment allows for simulation of the contaminant transport models in stream-aquifer region. 17 wells are placed in the aquifer to control the groundwater depth and to take samples when needed. A valve is placed at the end of the stream to simulate the rising or falling flows. Within the scope of this study, the experiments for meandering and straight streams are conducted using this experimental setup; and preliminary results for groundwater level distribution are obtained.

PLACING A RESERVE DRINKING WATER SOURCE IN AN URBAN AREA - CRAZY IDEA OR NECESSITY?

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Keywords: reserve drinking water source, spatial planning, drinking water source protection, Ljubljana field aquifer

In accordance with legislation, Decree on drinking water supply (National gazette N° 88/12), the public water supply service has to have the reserve drinking water source to increase reliability and safety of public water supply. In Ljubljana the public water supply has tradition for almost 130 years. Water well fields that were in the past quite far away from urbanised area are today in inside. The distribution pipeline is spreading all over the Ljubljana field porous aquifer so the most suitable and efficient location of reserve drinking water source is one near the existing pipeline system.

The first investigations for reserve drinking water source for Ljubljana drinking water supply were in 2004-2006. On the basis of previous geological and hydrogeological research, three suitable locations for reserve water well fields on Ljubljana field aquifer were selected. One of them is Dravlje valley, which was also selected for pilot action in Interreg Central Europe project PROLINE-CE, aiming to harmonize land use practices and drinking water source protection and management.

The pilot action area is settled area, crossing by highway and with large open spaces adjacent to a Natural Park of hilly area. Because of its location in the suburbs of Ljubljana, there is also a high pressure on land use. Dravlje valley is also a flood area with no properly regulated surface waters drainage coming from hinterland. Despite favourable hydrogeological conditions, there is influence of existing land use on groundwater vulnerability, especially when considering also climate change. The main goal is to assess impact of agriculture, urbanization (sewage system, cesspits), industry, and forestry, transportation (highway) for elaboration of improved protection measures for potential drinking water source, based on modelling results and stakeholder meetings and workshops.

Acknowledgement

Research work within PROLINE-CE project is supported by means of the European Regional Development Fund (Interreg programme Central Europe).

COMPLEXITY VS FEASIBILITY IN AQUIFER VULNERABILITY MAPPING – CHALLENGES AND POTENTIALS

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Keywords: vulnerability mapping, soil science, validation, Germany

Vulnerability maps are a meaningful tool in the environmental decision-making process, supporting resource allocation, evaluation of alternative policies and increasing awareness. However, available methods often suffer of scarce data availability, particularly with respect to spatially inclusive and comprehensive information on water table depth and overburden thickness. This study features the combination of procedures applied in soil science and hydrogeology for the assessment of vulnerability to pollution of the soil and aquifer, respectively. The soil filter capacity retrieved from the German Soil Mapping Guideline (Bodenkundliche Kartieranleitung – KA5) is combined with the travel time of infiltrating water through the unsaturated zone, retrieved from the DIN standard 19732 (dislocation potential of non-absorbable substances). While the soil filter capacity is derived from the soil porosity and the cation exchange capacity, the travel time through the unsaturated zone is determined by the lithology and the thickness of the unsaturated zone and by the amount of groundwater recharge. Furthermore, the traditional approaches DRASTIC, SINTACS and AVI were applied and compared with the newly combined method. All methods were carried out on the territory of the federal state Mecklenburg-Western Pomerania, northern Germany, at a map scale of 1: 200.000 using GIS. Besides a discussion on the shortcomings related to data availability and the consequences for model applicability, the study also encompasses potential verification tools and data for validation and approval of the tested methods.

ACVM (AQUIFER COMPREHENSIVE VULNERABILITY MAPPING) - A NEW WIDE CONCEPT OF AQUIFER VULNERABILITY

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Keywords: Coastal aquifer vulnerability concept, Sea water intrusion vulnerability map, sea level rise and its impact on groundwater, groundwater quality defence, coastal aquifer management tools

Vulnerability mapping is a tool that can be used to illustrate how the intrinsic physical properties of an aquifer protects it from an external threat that can potentially decrease groundwater quality.

Coastal aquifer quality is treated by the infiltration of pollutants from surface and by sea water intrusion phenomena. Moreover, a modest increase in sea levels, due climate change, can result in significant salt water intrusion and subsequently a decrease in groundwater quality in the long term.

The ACVM (Aquifer Comprehensive Vulnerability Mapping) method represents a new wide concept of aquifer vulnerability. In fact, it can describe simultaneously many aspects of aquifer vulnerability using only one parameter. This new method is easy to use and can be applied with inexpensive data.

ACVM was conceived, developed and applied in the area of Ghar El Melh in Tunisia in the context of the Global Environment Facility (GEF)/UN Environment Programme (UNEP)/Mediterranean Action Plan (MAP) Strategic Partnership for the Mediterranean Sea Large Marine Ecosystem (MedPartnership Project, 2009 - 2015). UNESCO's International Hydrological Programme (IHP) was responsible for the execution of MedPartnership Subcomponent 1.1 on 'Management of Coastal Aquifers and Groundwater', which provided the framework for this activity.

Vulnerability maps prepared with the ACVM method show the distribution of the intrinsic physical properties that can protect an aquifer against all the considered external threats to its groundwater quality, over the short and long terms. Moreover, it is possible to translate this parameter into management recommendations that decision makers can use to help them understand how activities can impact the sustainability of coastal aquifers and their related habitats.

The ACVM method establishes a new conceptual approach to evaluate aquifer vulnerability in coastal aquifer and could be replicated on other test sites during the new phase of "Mediterranean Sea Programme (MedProgramme)" to demonstrate its potential for a widespread use.

VULNERABILITY OF WATER RESOURCES TO CLIMATE CHANGE IN SOUTH-EAST EUROPE

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Keywords: water resources vulnerability, climate change, South-East Europe

Land use and climate change pose increasing pressure on water resources quality and quantity. Climate changes indicate an increase of mean annual temperature combined with decreasing and/or increasing precipitation. Furthermore, associated with economic changes in South-east Europe region the land use pattern is expected to change, too. This topic was the main objective of the EU transnational project CC-WARE (program South-East Europe) aiming to develop an integrated transnational strategy for water resources protection and mitigating water resources vulnerability. Vulnerability is an integrated indicator which considers the physical and chemical state of water resources, the ecosystem capacity to ensure long term water provision and the adaptive capacity of the society to ensure water supply. To assess climate impacts a grid based water balance model has been established to estimate local water availability. Furthermore, the local water exploitation index (WEI) was calculated by comparing water demand with water availability considering also seasonal variability. For water quality vulnerability land use is a major driver, therefore land use load coefficients were applied to Corine land cover units. As adaptive capacity, socio-economic indicators (population density, GDP) and natural indicators (ecosystem services) were considered. Vulnerability maps were produced and designed for two periods covering the time periods from 1991 till 2020 (recent period) and from 2021 till 2050 (indicating a near future situation). For both periods water quantity and quality vulnerability maps were produced, from which we could identify regions with high or low sensitivity to climate change.

Acknowledgement

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APPLICATION OF THE “PRK PLUS” APPROACH TO EVALUATE THE SENSITIVITY OF THE COASTAL AQUIFER OF GHISS - NEKKOUR AGAINST POLLUTION

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Keywords: Coastal aquifer, multicriteria approach, water contamination, sensitivity, source of pollution.

In the North East of the Moroccan Mediterranean coast, 15 km south east of the Al Hoceima city, the coastal aquifer of Ghiss - Nekkour occupies an area of 100 km². Its exploitation constitutes a priority economic imperative for the city of Al Hoceima and its hinterland, due to the tourist character of the city and the agricultural orientation of the region. In the surface of this study area, alternate rural-type habitats with autonomous sanitation systems, agricultural plots, uncultivated land, a few small industrial units, a local road network consisting of two main roads: a coastal road linking Al Hoceima to Nador and another connecting the same city to Taza, in addition to the International Airport Charif El Idrissi. These are various potential sources of local anthropogenic groundwater contamination. Their intensity may grow with the socio-economic development that knows the region as a whole.

In this work, the authors present a new multicriteria approach of acronym "PRK Plus" to assess the sensitivity of the coastal aquifer Ghiss - Nekkour to anthropogenic pollution. The results obtained from this application show that despite the aggressiveness of the Ghiss - Nekkour groundwater pollution sources, 98% of the total surface area of the water table is "Very Little Sensitive" to anthropogenic contamination.

THE KOZŁOWA GÓRA DRINKING WATER RESERVOIR'S CATCHMENT AS A PILOT AREA IN A MULTI ASPECT SURVEY IN ORDER TO ASSESS THE IMPACT OF LAND USE MANAGEMENT AND CLIMATE CHANGE ON GROUNDWATER RESOURCES

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Keywords: land use, isotopes, climate changes, Triassic aquifer, drinking water reservoir, PROLINE-CE

The Kozłowa Góra drinking water reservoir is one of the pilot areas in a transnational project PROLINE-CE, whose main aim is to improve protection of drinking water resources as well as protection against floods/droughts in an integrated land use management approach. One of the objectives is to minimize conflicts between protection of water resources and land use management as well as results of climate change.

To meet the assumptions of the project a multi aspect water resources monitoring study was set up. Within the studies a groundwater research, in both quantitative and qualitative aspects, was conducted. The research took into account the reaction of the water table of the first aquifer in relation to the groundwater recharge fluctuations caused by precipitation variable in time. The aquifer is recharged directly from precipitation. Water table responses strongly to changes in meteorological and hydrological conditions.

One of the monitoring object was also identification of groundwater quality and potential sources of pollution. Field study concerning identifying of chemical status, potential sources of pollution as well as laboratory analyzes of isotopic composition of sulphates in groundwater were carried out. The results show that groundwater in the study area is characterized by varying degrees of anthropogenic pollution, but generally these are waters of poor chemical status. The obtained results of isotopic composition of sulphur and oxygen in sulphates were compared to the typical values of $\delta^{34}\text{S}$ and $\delta^{18}\text{O}$, characteristic for sulphate sources in water resources. Isotopic composition results analysis indicates three groups of the origin of the sulphates in water: (1) atmospheric precipitation or dry deposition, (2) municipal sewage and (3) mixed origin.

Acknowledgement

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NITRATES MIGRATION IN REGIONAL GROUNDWATER RECHARGE ZONE (LWÓWEK REGION, POLAND)

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Keywords: groundwater contamination, river bank filtration, drainage well

The regional groundwater recharge zones are sensitive for contamination because high downward gradients enable contaminants to migrate downward to a deep parts of the flow system. In the regional recharge zones of Quaternary aquifers located in central Wielkopolska (Lwówek region, Poland) relative high nitrates concentration ($>15 \text{ mgNO}_3/\text{l}$) was detected at a great depth ($>80\text{m}$). It is a region dominated by agriculture where sands and gravels in the whole geological profiles occur locally. These conditions facilitates contamination of groundwater by nitrates. The research performed in the net of multilevel piezometers shows that in shallow part of the aquifer the concentration of nitrates exceed $30 \text{ mgNO}_3/\text{l}$. In the deep part of the flow system relative high nitrates concentrations were documented in the regions of groundwater extraction ($>15 \text{ mgNO}_3/\text{l}$). Under natural conditions (where the water extraction is not performed) this contamination is not yet observed in deep part of the flow system and the concentration of nitrate is low. In this condition in deep part of the aquifer typical stagnation zone exists (as defined by Toth, 1963), what is manifested by completely different groundwater chemistry than in shallow part of the aquifer. The presented research is a great example how chemical data can support investigation of groundwater flow conditions and formulation of the conceptual model of groundwater circulation.

Acknowledgement

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THE MIGRATION OF PESTICIDE RESIDUES IN GROUNDWATER IN CASE OF BANK FILTRATION SITE (MOSINA-KRAJKOWO WELL SCHEME, POLAND)

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Keywords: agricultural contamination, pesticides migration in groundwater, vulnerability of bank filtration sites to pesticides contamination

The river bank filtration is widely used system for water supply purposes. During relative short water movement between the river bottom and abstraction wells the decrease of concentration of some water components is observed. This is important especially in case of specific micropollutants that appear seasonally in river water.

In the article the migration of pesticides is analysed in case of Mosina-Krajkowo well scheme where different methods of water abstraction are used. The water is extracted by two well galleries (one located at the distance of 70-80m from the Warta river and second one located more than 400 m from the river) and also by collector horizontal well with radial drains located 5m bellow river bottom. This situation allow to analyze the rate of pesticide residues removal in wells located at different distance to the river channel.

The results of the two sampling series performed in autumn 2017 show presence of 4 pesticide compounds in Warta river (sum of concentration 0,071 µg/l). The pesticides were also present in horizontal well (4 compounds, sum of concentration 0,060 µg/l). While in wells located at distance 70-80 m from the river only two compounds were found (concentration 0,035 µg/l). In the well located at the distance of 250 m from the river only one pesticide constituent was detected (at the concentration on the level of detection limit), while in well located 400 m from the river the concentration of pesticide residues is below detection limits (<LOQ).

The research performed show good effectiveness of pesticides removal during river bank filtration.

The work was completed by analysis supported by the AquaNES project. This project has received funding from the European Union's Horizon 2020 Research and Innovation Program under grant agreement no. 689450.

GROUNDWATER VULNERABILITY MAPS BASED ON A MODIFIED AVI MODEL: CASE STUDIES IN SOUTHERN ITALY

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Keywords: aquifer vulnerability, AVI, GIS, WFD

Many methods for “Aquifer Vulnerability to Pollution” have been developed in the past four decades, especially using GIS. However, if aquifer vulnerability concept is well defined and the methods have been constantly tested and compared, the problem of the choice of the best method, also suitable for the requirements of the Water Framework Directive 2000/60/EC, remains.

The WFD, with the aim of protecting groundwater and surface water, is devoted to the achievement of environmental objectives. To meet these objectives, the aquifer vulnerability maps are of crucial importance.

The choice of the method depends on a series of factors, including the scale of the problem, the hydrogeological characteristics of the area and data availability.

Among the methods, the AVI method has been widely tested and it presents the advantage of use only two physical parameters. The AVI Index represents the hydraulic resistance of an aquifer to the vertical flow, as ratio between the thickness of each sedimentary unit above the uppermost aquifer (D , length) and the estimated hydraulic conductivity (K , length/time) of each of these layers. The AVI index has a time dimension and it is divided into five classes in terms of years. In this study for avoiding a widespread and often found presence of the higher vulnerability classes, especially in shallow aquifers, the AVI classification has been modified, also using statistical methods.

Moreover, the study reports applications of the modified AVI method for groundwater pollution vulnerability, to two different areas in southern Italy, highlighting the limitations of the method and the differences among different methods.

The final aim of the study is the standardization of the methods, also in order to the WFD application, to permit a worldwide application, not only by researchers but also by environmental technicians.

ASSESSING COASTAL AQUIFER VULNERABILITY TO SEAWATER INTRUSION USING GALDIT METHOD: APPLICATION TO THE SIDI MOUSSA COASTAL AQUIFER, SAHEL DOUKKALA, MOROCCO

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Keywords: Sahel Doukkala, Sidi Moussa, vulnerability, seawater intrusion, GALDIT, GIS

The Sidi Moussa Coastal Aquifer is part of Sahel Doukkala System Aquifer, is one of the main groundwater coastal aquifers in Morocco. It covers about 1000 km² and has a significant role in satisfying water needs for agriculture and potable water supply in the region. Over years, the need for agricultural water has increased, overexploitation of groundwater resources can put their quality under stress. It could be based on rapid disturbance in groundwater level leading to saltwater intrusion in this coastal aquifer.

To evaluate extent of the threat of the seawater intrusion. The present study is an attempt to map the vulnerability of the groundwater in Sidi Moussa Coastal Aquifer of against this intrusion by means of modeling coupled with GIS. The methodology used in the study consists of assessment of vulnerability using GALDIT method, is based on the most important factors controlling seawater intrusion, that is, four intrinsic hydrogeological parameters, one spatial parameter and one boundary parameter including Groundwater occurrence (aquifer type), Aquifer hydraulic conductivity, depth to groundwater Level above the sea (hydraulic head), Distance from the shore, Impact of seawater intrusion and aquifer's Thickness.

Assigning each map an appropriate weightages and ratings, and the overlaid of the six thematic maps has allowed to produce vulnerability map. The result of the study indicates a high vulnerability to seawater intrusion due to excessive groundwater withdrawals, especially in the Oulja coastal zone. This vulnerability is more witnessed in the South near the Oualidia Lagoon than in the North of the studied area. The outcomes of this study provide useful insights on effective groundwater management for the Sidi Moussa Coastal Aquifer.

**INTEGRATION OF GEOGRAPHICAL INFORMATION SYSTEM,
REMOTE SENSING AND WATERSHED MODELING TO BEST
EVALUATE RAINWATER HARVESTING POTENTIALITY IN WADI
DAHAB, SOUTH SINAI**

*Authors did not agree to publishing the abstract online
Abstract is available in printed copy of a book*

GROUNDWATER RECHARGE VULNERABILITY CONNECTED TO METEOROLOGICAL AND HYDROLOGICAL DROUGHT

*Authors did not agree to publishing the abstract online
Abstract is available in printed copy of a book*

LABORATORY AND NUMERICAL INVESTIGATIONS OF BIODEGRADATION POTENTIAL DURING COMBINED TREATED WASTEWATER AND RAINWATER INFILTRATION TO MINIMIZE POLLUTION RISK

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Keywords: pollution risk, wastewater infiltration, numerical modelling, water quality, leakage

In rural areas, the decentralized treatment of wastewater and its infiltration may have economic and ecological advantages. In order to reduce pollution risk of groundwater resources, sufficient degradation of organic substances within the unsaturated zone is required. These processes depend on retention times of treated wastewater (TWW) and oxygen availability. Latter is achieved, among others, by avoiding saturated conditions along the vertical infiltration path. However, due to e.g. economic reasons or land requirements, technical solutions for aquifer recharge may focus on a combined infiltration of both rainwater and TWW. However, the interplay of appropriate TWW residence times, the necessary rainwater retention space as well as the intermixture of these waters within the unsaturated zone define a complex system.

To study the vulnerability of groundwater potentially being contaminated, laboratory-scale tests have been carried out with support by numerical simulations using the software codes HYDRUS and PCSiWaPro. Modification of the PCSiWaPro time step control has been tested for selected modelling scenarios in order to improve the computational performance when highly variable infiltration is simulated.

The laboratory tests include four 1D columns ($D = 0.15$ m, $L = 1.5$ m) as well as a 2D experimental tank (2.5 m x 1 m x 1.5 m) representing a combined aquifer recharge system. Among others, the water content of the unsaturated soil is detected during infiltration at different spatial locations to provide a base for numerical evaluation. The degradation of relevant organic substances is monitored at sampling ports along the vertical infiltration path.

The experimental results have been used for verifying the model-based assessment of combined infiltration. First results highlight that combined systems are feasible for specific set-ups where strong intermixture can be avoided.

TRACKING OF GEOLOGICAL STRUCTURES AND DETECTION OF THERMAL INTRUSION BY GEOELECTRICAL METHODS IN THE HIGHLANDS OF BOLIVIA

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Keywords: electrical resistivity tomography, thermal intrusion, highland, Bolivia

One of the largest cities in the Bolivian flat highlands, called Oruro, depends exclusively on groundwater to supply domestic consumption and irrigation. The porous aquifer that is exploited with those purposes has been scarcely investigated and is not fully understood in terms of its geometry, settings and interaction with other aquifers in the region. The current extraction rate is depleting the piezometric levels, creating a depression cone around a well-field, which in the future might reach contaminant sources like thermal waters in a site called Kapachos. In addition, previous studies detected geological structures beneath the porous aquifer, which might be part of a fractured aquifer in contact with thermal sources. The present study aims to fill the gap between those structures and the well-known fault system at the foot of the mountains by using geoelectrical methods like Electrical Resistivity Tomography and Transient Electromagnetic Soundings. Thirteen tomographic lines, placed transversely to the direction of three main faults, were intended to track those structures by following changes in resistivity and typical low values influenced by the presence of saline water from the thermal intrusion. Two of those studied faults seem directly connected to the thermal source, although there is no indication of horizontal flows between them and the closest volcanic outcrop, considering the depth of investigation of the present study. The refined hydrogeological model propose that the thermal waters mainly flow upwards, although there are structures which act as sinks of the saline water coming from the hot springs. The present study brings up new data and interpretations helping to understand the structures and flow interactions, in a site that might become vulnerable to future problems of contamination due to overexploitation.

Acknowledgement

The study was funded by the Swedish International Development Cooperation Agency (SIDA) and the Society of Exploration Geophysicists (SEG) through the Geoscientists Without Borders (GWB) programme. Likewise, the fieldwork was supported by Lund University (LU) in Sweden, Aarhus University (AU) in Denmark, Universidad Mayor de San Andrés (UMSA) and Universidad Técnica de Oruro (UTO) in Bolivia. Data acquisition was done in collaboration with Emil Svensson (LU), Viktor Broman (LU) and Kamran Ahmad (GWB).

EDIT: A NOVEL GEOELECTRICAL AND GEOMORPHOLOGICAL BASED METHOD FOR GROUNDWATER VULNERABILITY IN ALLUVIAL FANS

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Keywords: vulnerability mapping, geophysical methods, semiarid regions, Bolivia

In developing countries such as Bolivia it is common to find poorly gauged and monitored watersheds, where the access to hydrogeological variables, parameters and general information is limited. Furthermore, socioeconomic activities such as urbanization, industry and extensive agriculture are threatening the local aquifers. Therefore, protection plans of aquifers are needed, however most of the methods for assessing groundwater vulnerability need several hydrogeological parameters as an input. Therefore, the EDIT method is proposed for assessing groundwater vulnerability. The EDIT method is based on geoelectrical and geomorphological information, hence, gathering this information might be less demanding and time-consuming. The Punata alluvial fan in Bolivia was used as a case study. The results of the EDIT method were compared to those from DRASTIC method. In general, the EDIT results showed a good agreement with DRASTIC results, having a better spatial resolution and highlighting critical areas such as the groundwater recharge zones. The EDIT method can be of particular interest for planning groundwater protection plans in areas where there is limited hydrogeological information.

Acknowledgement

The present study was supported by the Swedish International Development Agency (SIDA) in collaboration with Society of Exploration Geophysicist- Geoscientists Without Borders (SEG-GWB), Lund University (Sweden), and Universidad Mayor de San Simón (Bolivia).

GROUNDWATER VULNERABILITY TO POLLUTION. CLIMATE CHANGE SCENARIOS IN YUCATAN, MEXICO

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Abstract is available in printed copy of a book*

INITIAL ESTIMATION OF AQUIFER VULNERABILITY BASED ON ARTIFICIAL TRACER EXPERIMENT (BRDA OUTWASH PLAIN, POMERANIAN REGION, NORTHERN POLAND)

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Keywords: groundwater vulnerability, groundwater recharge, tracer experiment, vadose zone, shallow aquifer

Estimating the actual amount of recharge is important in water management for the sake of protecting the quantity and quality of resources. Groundwater recharge plays significant role in contamination transport because it determines directions of groundwater flow in shallow aquifers. Therefore evaluation of infiltration rate is necessary for analysis of pollution migration, assessment of aquifer vulnerability to contamination, nutrient cycling, and detailed flow path calculations. Most of the methods applied to determination of well's protection zones is based on a time of vertical seepage. It is also important in waste disposal in order to landfills location outside of groundwater recharge zones to avoid contamination of water and soil with leakage.

There is a number of methods applied to recharge rate identification however the artificial tracer technique is commonly used to small-scale, one point, short-term recharge estimations. Presented work shows results of two tracer experiments performed during summer and winter seasons. The conservative tracer (chlorides) was applied as a pulse at the ground surface and its vertical flow in unsaturated zone was observed through electrical conductivity measurements. The investigations have an effect of vertical flux distinguished for summer and winter months which was a foundation to the aquifer vulnerability assessment.

Acknowledgements

This work has been supported by National Science Centre, Poland, in the framework of the project 2015/17/B/ST10/03233 "Groundwater recharge on outwash plain".

GROUNDWATER VULNERABILITY MAPS FOR POLICY SUPPORT ON PESTICIDES

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Keywords: pesticides, source water protection, GeoPEARL, MODFLOW, MODPATH

Groundwater vulnerability maps can be used for different purposes. Depending on the intended application different mapping techniques may be used. We discuss two applications of groundwater vulnerability maps for pesticides: (1) regional-scale maps supporting the development of groundwater monitoring plans e.g. in the context of the evaluation of pesticide registrations, and (2) more local-scale assessments of the vulnerability of specific receptors (well sites, river segments, ...) e.g. in the context of source water assessments. The aim of the first type of analysis is to map the spatial variation in the vulnerability of the entire phreatic groundwater layer for a specific pesticide. Many methods for regional-scale vulnerability mapping focus on leaching processes in the unsaturated zone, assessing the leaching potential either in a conceptual way or with process-based models. An example based on application of the process-based model 'GeoPEARL' in Flanders is presented. Possibilities for including saturated zone processes in these regional vulnerability maps are discussed and illustrated. The second type of application involves the vulnerability assessment of one or a limited number of specific receptors. In that case, an additional aim is usually to map the spatial variation in the contribution of the land area to the vulnerability of the receptor(s). This is illustrated with a case-study for a well field in Flanders. The potential sources of pesticide contamination of the wells are mapped using a combination of unsaturated (SWAP and GeoPEARL) and saturated (MODFLOW and F-LEACH) zone modelling. The results can be used to delineate protection zones and develop a source water protection plan.

MetQ: A METHOD FOR DETERMINING THE AQUIFER CONTAMINATION RISK APPLIED IN THE METROPOLITAN REGION OF SÃO PAULO (BRAZIL)

*Authors did not agree to publishing the abstract online
Abstract is available in printed copy of a book*

GROUNDWATER RECESSION CURVE ANALYSIS AND RECHARGE ESTIMATION FOR THE MOUNTAINOUS FRACTURED ROCK ENVIRONMENT: A CASE STUDY IN THE MID- AND UPPER-JHUOSHUEI RIVER BASIN IN CENTRAL TAIWAN

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Keywords: fractured rock aquifer、rock permeability、recession rate、groundwater recharge

Presently, studies on groundwater vulnerability assessment in Taiwan are focused on the plain region, but the same research for the mountainous fractured rock environment is drawn little attention. Existing methods of groundwater vulnerability assessment are unable to explain the inherent complexities of fractured rock aquifers, nor to recognize their susceptibility to contamination. As a matter of fact, aquifer vulnerability and groundwater recharge are nearly associated because both are concerned with the rainfall infiltration down through the unsaturated zone to the water table. Groundwater recharge amount or intensity is therefore one of dominant factors that is usually taken into account for delineating groundwater vulnerability. This study preliminarily focuses on dealing with recharge estimation in fractured rock aquifers to provide an essential information in vulnerability assessment.

Groundwater monitoring data reveal response of hydrological cycle, rainfall-recharge processes, and hydrogeologic characteristics of groundwater aquifers. Prior to quantitatively estimating groundwater recharge, groundwater recession behavior and correlations between recession rates varying with depths and aquifer hydraulic properties must be understood. This is beneficial to developing a more realistic estimation model for groundwater recharge, which is particular important in study areas where recharge occurs in fractured rock media. Since groundwater recharge to fractured rock aquifers dominates by lithology and fracture properties, this may affect the duration and amount of recharge.

Thus, the main point of this research is to conduct correlation studies between fractured rock properties and recession rates. Meanwhile, the above study outcome incorporated into a rock mass permeability index system is capable of developing an empirical model for estimating recession rates, which can help speed up groundwater recharge calculation and obtain actual recession behaviors in response to intrinsic properties of fractured rock aquifers. The research results indicated that a linear relationship exists between the recession rate and permeability index. The derived empirical linear equation can be used to predict the recession rate, and thereby the potential groundwater recharge can be estimated.

AQUIFER VULNERABILITY ASSESSMENT TO NITRATE CONTAMINATION USING GIS-BASED DRASTIC AND SOLUTE TRANSPORT MODEL

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THE EFFECT OF DROUGHT ON THE PABDEH KARSTIC AQUIFER, SOUTHWEST IRAN

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Keywords: Karst, spring, groundwater, drought, wet, index, Bibitalkhone

The Pabdeh karstic anticline is placed in the Zagros Mountain Range in the northeast of Khuzestan province, southwest Iran. The Pabdeh anticline which bears a significant karstic aquifer is a double plunging asymmetrical anticline trends corresponding to general pattern of the Zagros Structural Belt. The Pabdeh anticline has transversely bisected by the Taluk tectonic vally which created by Balaroud sinistral strike slip fault. The Bibitalkhone karst spring emerges in the left bank of this valley with an average annual discharge of 2 m³/s and this is the only source for different usage of inhabitants in the area. Drought is a part of climatic condition in the area and occurs as a result of the lack of precipitation. In recent years, the lack of local precipitation and the incidence of consecutive droughts in the study area has raised concerns about the sustainability of the quality and quantity of groundwater resources. This study carried out to investigate the relationship between precipitation and potential quantity and quality of groundwater resource in the study area during the period 2004-2014. To achieve this purpose, indexes such as standard precipitation index(SPI), stream flow drought index (SDI) and groundwater drought index(GRI), were determined and 2005-2006 water year as the wet period, 2011-2012 water year as drought and water year 2013-2014 as normal year were considered. The spring hydrograph was used to determine monthly and yearly water table drawdown and recession coefficient (α) and this coefficient was taken into account to calculate dynamic storage volume of the aquifer. The results show that the discharge of the Bibi Talkhone springs, is affected by indexes (SPI), (SDI) and (GRI), without interrupt time and hydrochemical data such as EC and Cl ion as well as the diagrams indicate qualitative impact of the spring from the wet and dry events.

GROUNDWATER POLLUTION ASSESSMENT IN URBAN AREAS OF QOM CITY IRAN

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Keywords: groundwater, aquifer pollution, WHO standard, water wells, Qom City

Nowadays it's vital to pay attention more seriously to the urban environmental risks because of its effects on citizens' lives. One of these problems is groundwater pollution which threatens much valuable water resources. Drinking water in Qom city is provided from different resources, such as watersheds and water wells which are located within the city. Although there is a shortage of water supply, according to the extreme water demand, these wells are used to provide city drinking water.

Unfortunately, Sewage collection network in this city has not been completed yet and only a small amount of municipal wastewater is collected by the sewer network. As a result the city aquifer has been contaminated by the wastewater infiltration through the septic tanks scattered across the city. In order to assess the amount of contamination in water wells in urban areas of Qom City, sampling and testing of 24 deep wells which are scattered in the city was performed on December 2013.

The measured qualitative parameters consist of color, Temperature, Turbidity, TSS, pH, EC, TDS, DO, BOD₅, COD, Total Alkalinity, CO₃, HCO₃, Total Hardness, Ca, Mg, SO₄, Cl, Na, K, NH₄, NO₂, NO₃, PO₄, Br, I, TC, FC, FS, HPC, Fe, Hg, Pb, Co, Cd, Ni, As, Zn, B, Cu, Mn, Sn, Ba, and Sr.

In this study, the drinking water physical, chemical and microbiological specifications guidelines of Iranian Standards and Industrial Research (ISIRI) and the World Health Organization standards (WHO2011) were used to evaluate the amount of the aquifer pollution. The results indicate that the aquifer in Qom is polluted widely by B, NO₃, TC, FC and HPC.

SIMULATION OF REACTIVE TRANSPORT IN FRACTURED GEOLOGIC MEDIA USING RANDOM WALK PARTICLE TRACKING

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ASSESSMENT OF CONTAMINATED SHALLOW DRINKING GROUNDWATER IN AN AGRICULTURAL AREA OF SOUTH KOREA

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Keywords: shallow groundwater, agricultural area, hydrogeochemistry, nitrate, trend analysis

The identification of sources and behaviors of contaminants in a shallow and/or unconfined groundwater aquifer is important to manage the groundwater quality in an agricultural area. In this study, hydrogeochemical characteristics of major contaminants in the shallow drinking groundwater were investigated and the possibility of improving the groundwater quality by controlling the contaminant sources was evaluated. The shallow groundwater wells (n=30) that already have been used for the drinking purpose and the monitoring wells (n=18) that were installed after this study started have been monitored from June 2015 in the study area. Hydrogeochemistry of the shallow groundwater belongs to Ca-Cl (NO₃) type with significant concentrations of NO₃-N. The linear positive relationships between concentrations of NO₃-N and Cl, NO₃-N and SO₄ indicate that these compounds are mostly originated from anthropogenic sources. These anthropogenic compounds gradually increased along from the upgradient to downgradient area in the study area. This spatial pattern indicates the anthropogenic contamination of groundwater mainly can be caused by agricultural activities on paddy and dry fields. The $\delta^{15}\text{N}$ and $\delta^{18}\text{O}$ of nitrate in groundwater were measured to identify NO₃ sources. The dual isotopic compositions were plotted within or near the general ranges of NO₃ formed in manure and sewage or nitrification of soil organic-N. The result suggests that the deterioration of shallow groundwater is affected by the organic fertilizer. The total amount of organic fertilizer used in 2016 was reduced to the half in 2015. High NO₃-N concentrations (>20 mg/L) in wells have slightly decreased over time. The additional monitoring will be performed for the trend analysis.

PRACTICAL ESTIMATING METHOD OF GROUNDWATER LEVEL VARIATION FOR URBAN FOUNDATION STRUCTURES NEAR THE FLUVIAL AREA

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Keywords: urban area; groundwater level; river stage; prediction model; geotechnical engineering

Groundwater level (GWL) fluctuation can be affected by the change in climate and hydrological components causing change in stress state within subsoil. This change, directly and indirectly, induces several geotechnical issues such as the reduction of bearing capacity of foundations, land subsidence, and earthquake-induced liquefaction. However, in many cases, groundwater level is considered as a fixed property obtained from the geotechnical site investigation. In this study, an estimation model of GWL is presented for foundation structures near fluvial urban area. The model was developed using the results from the finite element analysis based on Darcy's flow rule and various river stage scenario. Using the model, even without previous GWL data, it is possible to estimate the GWL variation near the fluvial area by utilizing the accessible properties for geotechnical engineers. The correlation model is validated by comparing with the observed GWL data of Seoul-Magok (Korea). In addition, the feasibility of the model is evaluated by comparing with the results from artificial intelligence (AI) method, which are based on the correlation data learning process.

INTERPRETATION OF GROUNDWATER LEVEL FLUCTUATIONS IN TERMS OF VULNERABILITY

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Keywords: groundwater level, groundwater level fluctuations, seasonal variability, groundwater vulnerability, groundwater vulnerability assessment

Groundwater vulnerability analysis is often performed in areas for which groundwater level monitoring is carried out. However, so far these data are not used within the framework of vulnerability assessments. This paper presents an idea of how information about seasonal variations of water level in unconfined, porous aquifers could be used in certain conditions to strengthen groundwater vulnerability assessments.

Seasonal groundwater level fluctuations depend on meteorological and hydrogeological conditions of an area. Similarly to vulnerability, groundwater levels fluctuate according to the lithology and permeability of rocks, the depth of the aquifer, the thickness of the aeration zone and the terrain morphology. Konoplaczev and Siemionov (1979) have shown that in porous aquifers the amplitude of seasonal groundwater fluctuation caused by meteorological factors decreases with an increase of thickness of aeration zone. Thus, increasing the thickness of an aquifer's overburden causes a gradual decrease in the amplitude of annual fluctuations - especially from depths at which the effect of evaporation disappears. In case of phreatic water level in recharge zones, where vertical inflow is dominant in shaping the water table, the relative annual amplitude can reflect intensity of potential impact impulses, which can reach an aquifer from a terrain surface. It may be treated as an indirect information about aquifer's vulnerability. The stronger it is, the higher groundwater vulnerability of an area. However, the use of groundwater level fluctuations for vulnerability assessment is only possible under a number of conditions. The most important of these are similarities in: lithology and permeability of aquifers and aeration zone between comparable monitoring points or areas; climate, geomorphology, hydrography and river regime; degree of drainage; and hydrodynamic zone. Apart from groundwater level monitoring data, a good understanding of hydrogeological conditions is necessary prior to applying this approach. Hence the use of groundwater level fluctuations is proposed as an aid, not a basic element in vulnerability assessment that can be applied only in specific cases. The major advantage of this approach stems from the fact that it sums up an influence of many factors, which reflect in vulnerability and is a value measured in the field, not estimated. However, the limitation of this method is a relatively small areal application, which can impact on its practicality.

AN ASSESSMENT OF THE OPEN LOOP HEAT PUMP OPERATION BY THE TOUGH2 MODELLING SOFTWARE

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Keywords: numerical modelling, heat transport, groundwater, heat pump technology, temperature influence

There has been increasing recent use of heat pump technology to heat and cool buildings in Bratislava and its surrounds. Groundwater is the heat source most often used in this technology and important aquifer hydraulic and thermal parameters must be known for effective use of this source. Thermal parameters is not possible to measure directly in the field, so monitoring of temperature is inevitable to evaluate them by calibration. Combined data from numerical groundwater flow modelling and aquifer heat transfer enables prediction of the temporal development of the pumped groundwater temperature. The calculation results allow optimisation of the following well technology; the number of wells, their spatial distribution and pumped and recharge quantities. With the modelling we can also protect aquifer from the heat pollution. The TOUGH2 program was used here to model temperature development in pumped and recharge water in the town Ivanka pri Dunaji. Numerical modelling identified the physical processes required for the appropriate calculations, so that the numerical simulation results are sufficiently accurate to approximate the actual observed situation. The use of the TOUGH2 model also has some disadvantages. The program solves very complicated equations, but this can lead to problems in creating a modelling grid and calculating periods. If the model has too many calculation points or periods, the calculation time increases significantly, and problems with calculation convergence can easily occur. Therefore, it is extremely important to make the best choice for discrete division of space and time to ensure correct entry of the individual parameters. However, the advantages outweigh disadvantages and this program has proven a most valuable tool for calculating study area changes in groundwater temperature resulting from heat pump operation.

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ASSESSING VULNERABILITY OF GROUNDWATER TO CONTAMINATION IN RESPONSE TO GROUNDWATER DEPTH VARIABILITY

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A PRELIMINARY ASSESSMENT OF THE GEOLOGICAL FACTORS AFFECTING GROUNDWATER QUALITY AROUND TOSHAM, A PART OF MALANI IGNEOUS SUITE, INDIA

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AQUIFER VULNERABILITY AND RISK ASSESSMENT IN THE PANNONIAN PART OF CROATIA

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Keywords: aquifer vulnerability, risk assessment, SINTACS, WFD

Aquifer intrinsic vulnerability and risk assessment is important part of groundwater quality issues analysis as a prerequisite for a successful management of water resources in a frame of sustainable development, which itself is the basis of the EU Water Framework Directive (WFD). For the purpose of groundwater bodies status and risk assessment in the scope of WFD implementation, the results of aquifer vulnerability assessment in the Pannonian part of Croatia were particularly convenient for the estimation of risk of groundwater bodies without comprehensive monitoring of groundwater quality. This was obtained by linking results of vulnerability assessment with existing point and non-point pressures on groundwater. There are different types of aquifers in Pannonian basin, ranging from unconfined alluvial aquifer, semi-confined and confined aquifers of intergranular porosity up to fissured and karstic aquifers. In order to take into account this variability of hydrogeological setting, SINTACS method was chosen for vulnerability assessment mainly due to its flexibility. It involves 7 system parameters and provides several strings to adapt to different hydrogeological settings and land use. Given the size of the investigated area (29133 km²) and resolution of input data for vulnerability and risk assessment, the size of the raster's grid cells was 500 m x 500 m. All preparatory work and analyses were performed in GIS environment. As a result, all categories of vulnerability, from very low to very high, were identified. The results of risk assessment were in line with groundwater quality data for groundwater bodies with adequate monitoring network and thus justified methodological approach. Out of 15 groundwater bodies in the Pannonian part of Croatia, only two are found to be in a state of risk based on groundwater quality indicators and performed risk analysis. Furthermore, one groundwater body was added in a category of potential risk solely on the basis of performed risk assessment.

USE OF KARST SPRINGS' MASTER RECESSION CURVES IN VULNERABILITY ASSESSMENT AND ITS VALIDATION BY TRANSFER OF PRECIPITATION $\delta^{18}\text{O}$ SIGNAL

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Keywords: recession curve analysis, spring hydrograph, vulnerability, mean transit time, signal transfer function

Hydrograph recession curve analysis was performed on 22 gauged karstic springs encompassing Muránska planina karstic plateau (Central Slovakia). Discharge depletion was used to create recessional equations, and for each individual spring, depletion hydrograph equations were classified into different categories according to recessional parameters quantitatively describing individual groundwater flow components. Parameters of recessional equations mathematically describing the shape of master recession curves can therefore be used for qualitative assessment aquifer vulnerability within the spring's recharge area, as the nature of processes between water infiltration and its outflow in the spring is somehow reflected in their values. Based on assumption that differences in character of individual karstic spring's depletion hydrographs enable the assessment of the anticipated extent of absorption, attenuation and self-purification processes during the groundwater penetration through the rock environment, parameters of recessional equations were linked to vulnerability degree, a qualitative scale ranging from 1 to 10. Master recession curves were derived by the use of hybrid genetic algorithms from springs' discharges measured on daily or weekly basis. In the meantime, systematic sampling of Muránska planina springs for $\delta^{18}\text{O}$ (295 individual springs sampled within 10 days) revealed significant differences in $\delta^{18}\text{O}$, between -10.90‰ and -7.32‰. These were possibly caused by different $\delta^{18}\text{O}$ signal transfer of heavy rainfall events 111 mm and 102 mm which happened 52 and 32 days before sampling, with $\delta^{18}\text{O}$ values of -5.3‰ and -8.9‰. Simplified estimation of precipitation $\delta^{18}\text{O}$ signal transfer function was used as groundwater vulnerability indicator to estimate the indicative value of the mean transit time for the same set of springs. Differences found in $\delta^{18}\text{O}$ seem to correspond with aquifer properties advised by recession curve analysis in aquifer sensitivity degree to potential contamination. Karst springs' vulnerability assessment based on recession curve parameters can be considered as validated by $\delta^{18}\text{O}$ signal transfer, at least in the case of the Muránska planina karstic plateau.

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activities, and the outputs of the project should also serve to reduce the risk of environmental impairment fragile ecosystems, depending on the quantity and quality groundwater. In the KRASCAVE project, the State Geological Institute of Dionýz Štúr Bratislava was acting as coordinating beneficiary and civic association Envi Slovakia Bratislava as associated beneficiaries. In addition to the European Commission, also the Ministry of Environment of Slovak Republic participated in the project co-financing.

ORIGIN OF NITRATE IN CHALK GROUNDWATER FROM NITRATE N AND O STABLE ISOTOPIC SIGNATURES

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Keywords: nitrate, chalk, dual stable isotope analysis, fertilisers, rainfall

Groundwater has suffered a decrease in quality as a result of human activities. Nitrate is of concern as heavy use of artificial fertilisers in previous decades has led to increased concentrations in many aquifers. Here we report a study aimed at understanding nitrate sources and associated processes within groundwater in the Northern Province Cretaceous Chalk aquifer, Yorkshire UK, which contains elements present elsewhere in lithified aquifers, including dual porosity response from interplay between conductive fractures and less permeable elements. Chalk aquifers occur across Northern Europe and represent a major water resource.

An acetone dissolution method has been adapted for nitrate extraction from high-carbonate groundwater. Dual stable isotope analysis of extracted nitrate enabling isotopic fingerprinting for source apportionment and determination of the extent of attenuation processes is ongoing, using samples from the Kilham subcatchment in Yorkshire, UK.

To assess impact of agricultural practices, the extent to which rainwater nitrate contributes to the overall groundwater nitrate burden needs establishing. Previous rainfall data show nitrate concentrations to be low (0.015-8.86 mg/l) compared to those in groundwaters; hence to obtain sufficient mass of nitrate for stable isotope analysis and avoid sample biodegradation, rainfall nitrate is collected using field-deployed ion-exchange columns.

Initial findings are indicative of two discreet sources of nitrate contamination that differ in signature from rainfall background. A minor signal potentially represents nitrate from manure or sewage (9-11‰ $\delta^{15}\text{N}$, 4-8‰ $\delta^{18}\text{O}$). The most significant source (3-6‰ $\delta^{15}\text{N}$, 4-8‰ $\delta^{18}\text{O}$) has a less clear origin although likely represents nitrate derived from mineral fertilisers. Some denitrification signatures have been identified, but the importance of this process in the wider aquifer is subject to ongoing work.

HYDRAULIC CHARACTERIZATION AND MODELLING CONTAMINANT TRANSPORT IN A PERMIAN DOLOMITIC LIMESTONE, THE SPEN FARM STUDY CASE (NE ENGLAND, UK)

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Keywords: Fractures, Modelling, Contaminants, Hydraulic conductivity, Scale.

A range of contaminants (e.g., nitrate, phosphate) migrate downwards through the vadose zone to reach the saturated zone of fractured carbonate aquifers in areas of arable and livestock farming activity. Once in the saturated zone such contaminants are transported at relatively high rates via fractures. Here, we report a hydro-geophysical characterization of the Permian Magnesian Limestone in Yorkshire (NE England) at an experimental farm site (Spen Farm), coupled with catchment-scale groundwater flow and solute transport modelling, in order to assess the risk posed by the farm activities to abstractions and groundwater-fed rivers. Three boreholes were geophysically logged, in an area away from faults within the arable part of the experimental farm site. Optical televiwer logs show vertical dissolution pipes in the vadose zone of the Magnesian Limestone aquifer, which represent likely pathways for contaminants being rapidly vertically transported to the water table located at 9 – 25 mBGL. Within the saturated zone, optical and acoustic televiwer images, fluid temperature and conductivity logs show how the principal flow pathways are represented by sub-horizontal bedding plane fractures (sub-vertical joints occasionally represent pathways and allow vertical connectivity between bedding plane fractures).

Falling head tests undertaken in the multi-level piezometer nests show rapidly reducing of permeability with depth below the water table (9-40 m BGL). Hydraulic conductivities from slug tests ($K_{\text{median}} = 0.54$ m/day) are one order of magnitude lower with respect to those seen in single-borehole pumping tests ($K_{\text{median}} = 2.95$ m/day) previously undertaken in the area. Thus, the degree of hydraulic connectivity of the fractures progressively increases from the scale of a few meters seen in falling head tests up to tens of meters seen in pumping tests, i.e. due to activation of progressively larger geological structures. Groundwater flow modelling defines the kilometre-scale permeability arising from hydraulic interaction of bedding planes, vertical joints and extensional faults; favourable flow pathways for contaminants.

APPLICATION OF NEURAL NETWORKS FOR THE DEVELOPMENT OF AN INTEGRATED KARST AQUIFER VULNERABILITY MODEL (IKAV).

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VULNERABILITY ASSESSMENT AND HYDRODYNAMIC ANALYSIS FOR AREAS WITH SCARCE INPUT DATA - CASE STUDY OF KARST AQUIFER "GRAPA" IN SE SERBIA

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CONSIDERATIONS FOR GROUNDWATER FLOW CONSERVATION METHODS IN UNDERGROUND CONSTRUCTION WORKS

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Keywords: groundwater flow conservation, underground construction, ground consolidation

Japan, as an earthquake-prone country in one of the world's most active seismic areas, faces severe damages on its infrastructure every year. The necessity to reconstruct old and build new railroads and motorways is emerging. Limited space for new constructions led to a stronger focus on underground tunnels, particularly in densely populated areas. While underground tunnels free cities from traffic above ground, they inhibit natural water flow and can have negative effects on surrounding structures and the environment, especially in shallow and soft grounds. Without adequate measures for groundwater flow conservation, rising groundwater levels upstream of the underground tunnel increase buoyancy forces on the underground structure, the risk of liquefaction of sandy soils during earthquakes, as well as leakage flow into the structure. The quality of the stagnating groundwater deteriorates and root zone saturation adversely affects plant growth. On the other hand, falling water levels downstream potentially lead to ground subsidence and building lean, as well as the depletion of ponds, small streams, paddy fields, and the root zone in general. Moreover, soil's redox conditions change from anoxic to oxic conditions deteriorating groundwater quality due to mobilization of ions, or heavy metals in polluted areas. Further, in coastal areas, also salt water intrusion has to be considered.

Measures to preserve the natural groundwater flow come with challenges in design and application. Design and installation of collection and recharge wells have to consider not only the correct distance between the wells. Especially practicable methods for long-term diagnostics and maintenance of the wells have to be established in order to prevent and treat deterioration and clogging.

GROUNDWATER RISK ASSESSMENT BY LWPI DUE TO LANDFILL LEACHATE IMPACT

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Keywords: groundwater risk assessment, Landfill leachate pollution, LWPI, Tabriz Landfill

The majority of municipal solid waste landfills in Iran are operated as dump sites without control of landfill leachate. The purpose of the present paper is to assess the groundwater contamination by leachate originating from the Tabriz waste dump site using the landfill water quality index (LWPI).

Certain physicochemical parameters such as pH, electrical conductivity (EC), total organic carbon (TOC), polycyclic aromatic hydrocarbon (PAH), Cd, Pb, Zn, Cu, Cr, and Hg were analyzed over the 4 groundwater samples. The monitoring and laboratory tests results were referred to the WHO (World Health Organization) standards of the groundwater quality. The LWPI range in the groundwater samples were 0.9 to 30. It is noted that a LWPI value below 1 proves that analyzed water is not affected by the landfill, $1 < LWPI < 2$ moderately polluted water due to a small landfill impact, $2 < LWPI < 5$ poor water with high visible landfill impact, and $LWPI > 5$ strongly polluted water under an evidently very high landfill impact. The results of this risk assessment using LWPI demonstrated that the quality of the groundwater around the landfill is under a strong landfill effect. Also, results have shown that newly developed LWPI is an efficient method for assessing the information on the water quality near Tabriz landfill while reduced number of physicochemical parameters are included in this indices. This study approved the need to build a sanitary landfill as well as closure of current landfill and remediation arrangements based on environmental regulations to decrease negative environmental impacts.

WATERPROTECT – INNOVATIVE TOOLS ENABLING DRINKING WATER PROTECTION IN RURAL AND URBAN ENVIRONMENTS

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Keywords: groundwater, nitrates, groundwater quality, groundwater contamination

Data from the European Commission show that more than 50% of European water bodies and lakes and about 25% of groundwater bodies are characterized by poor chemical status. In the case of surface waters, nitrogen and phosphorus compounds (NO_3 and PO_4) have been the main problem for years, contributing to the eutrophication of rivers and lakes, which are often associated with intensification of agricultural activities and disorderly municipal management. Action programs to reduce nitrate pollution from these sources, which were introduced over the years 1992-2012, resulted in a reduction in the average concentration of nitrates in rivers in the European Union from 2.7 to 2.1 mg NO_3 / l and average nitrate concentrations in waters. They are significantly lower than the current threshold values of 50 mg NO_3 / l. Unfortunately, in spite of the actions taken, areas heavily contaminated with nitrogen compounds still exist, and their elimination requires systemic solutions.

The WATERPROTECT project has been designed to develop an integrated model for the management of intensive agricultural use in areas where nitrogen pollution has been identified. The basic assumption of the built-in management model is the cooperation between many different users of the catchment area. The overriding objective of the project is to develop a strategy that includes an action program to improve water quality in the catchment area where all its users, including farmers, their advisers, representatives of water and sewage companies, food producers, environmental inspectors, representatives of municipalities and residents will have both purpose, benefit and participation. The project will evaluate the effectiveness of the actions taken so far to protect the quality of water by various entities and through various formal and legal solutions. A review and integration of local and regional water monitoring systems will be made, as well as evaluation and verification of agricultural practices. An important element of the project is an effective communication between the users of the catchment area and economic analysis of both existing and proposed solutions. In addition, an information technology tool for decision support, including visualization of spatial information, on catchment characteristics, farm practices, monitoring results and numerical modeling will be developed.

The project is implemented in the area of 7 pilot basins located in EU countries - Denmark, Ireland, Spain, Romania, Italy, Belgium and Poland. Based on the results of the studies and analyzes carried out in the differentiated catchment areas, management models for the different catchment types will be developed that will be applicable to other similar areas. The project is financed by European funds under Horizon 2020 (RUR-04-2016).

EVALUATION OF THE COMPARISON OF FOUR GROUNDWATER VULNERABILITY METHODOLOGIES: A CASE STUDY OF DAHOMEY BASIN SHALLOW AQUIFERS

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Keywords: RTt, AVI, DRASTIC, PI, Validation

Four groundwater vulnerability assessment methods were evaluated, compared and applied to assess the aquifer risk of the Dahomey Basin shallow groundwater. The methods include the DRASTIC, PI, RTt and AVI. These methods are grouped into the travel time, physically based approach (AVI and RTt method) and the index based method (DRASTIC and PI). The results show the best correlation among the four assessment methods between the DRASTIC and AVI method with 73%, DRASTIC and RTt method with 62% while the lowest correlation was recorded between PI and DRASTIC with 14%. Comparison of the four vulnerability parameters indicate the PI with the most assessment parameters and AVI the least assessment parameters. The AVI assessment method presents the largest areas (73%) of the basin as having high vulnerability risk and the PI assessment method classified 66% of the basin as low vulnerability areas. The comparison of the four vulnerability assessment methods has shown that the AVI is the strictest which means an over estimation of the perceived risk to contamination while the PI method is mildest of the four methods.

ADSORPTION AND DESORPTION PARAMETERS OF ERYTHROMYCIN MIGRATION IN SATURATED POROUS MEDIA BASED ON COLUMN TESTS

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Keywords: groundwater, erythromycin, sorption, leaching, optimization

The occurrence of pharmaceuticals in surface waters and groundwater is widely discussed in the literature. Erythromycin, a macrolide antibiotic used in veterinary practice and in human health care, is one of many pharmaceuticals that can be found in water. It may cause many adverse effects, especially after high doses and in patients with liver or kidney failure. It may also interact with other drugs, lessening their effectiveness or increasing their toxicity.

Erythromycin enters the water cycle through sewage water and washouts of solid waste. Examining the fate of erythromycin in different water-bearing media and in different conditions is an important task. The aim of the presented research was to 1) determine the mathematical model of erythromycin migration and 2) estimate adsorption and desorption parameters based on breakthrough curves registered for two different porous media.

The research was conducted in laboratory conditions where column tests were performed. One column was filled with glass granules, 600–800 μm in diameter, and the second column was filled with a natural sediment – sandur sand. The tested media were fully saturated with water. During each experiment, erythromycin (ERY) was injected after injecting a sodium chloride solution (CTR). Continuous injection was applied during these experiments, which resulted in obtaining an increasing and a decreasing breakthrough curves characterizing the transport of the tracers through the investigated media.

Conductivity was measured at the output of the columns in order to determine tracer concentrations based on calibration curves. An interpretation of the experiment results was conducted in the MATLAB environment using numerical optimization procedures. This included estimating transport parameters based on CTRbreakthrough curves, determining the mathematical model and estimating ERY migration parameters. Differential equations of ERY migration for both – simple and hybrid (two-site) – models were solved numerically. The convergence between theoretical and experimental breakthrough curves was analyzed qualitatively by calculating the RMSE and correlation coefficient r .

The paper presents the ERY adsorption and desorption curves for both porous media. It was proved that the migration of erythromycin in both cases is best described by a hybrid model that assumes the coexistence of equilibrium and nonequilibrium sorption. The obtained values of transport and sorption parameters are presented.

Acknowledgements

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SCALE EFFECTS IN STATISTICAL BASED GROUNDWATER VULNERABILITY MODELS? A CASE STUDY ON CONTINENTAL-SCALE OF AFRICA

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Keywords: Groundwater vulnerability, DRASTIC model, Statistical modelling, Scale issue, pan-African scale

Groundwater is a crucial natural resource supporting the development of the African continent, but it is subjected to many pressures. Therefore, to support Africa policy in groundwater management in such context, it is important to identify which aquifer systems/groundwater resources and settings are most vulnerable to degradation and factors which contributes to nitrate pollution. We developed methods for assessing groundwater pollution risk at the pan-African scale. To do so, we compiled the best available continental-scale dataset on soil, land use, geology, hydrogeology and climate in a Geographical Information System (GIS) at the resolution of 15 kmx15 km and the 1:60,000,000 scale. We first produced a vulnerability map by using the generic DRASTIC vulnerability indicator (Ouedraogo et al. 2016). Subsequently, we refined the vulnerability assessment using statistical models. For this we integrated monitoring data into the vulnerability mapping. Given the availability of data, we used observed nitrate contamination of groundwater as a proxy for groundwater vulnerability. Therefore, nitrate contamination data were compiled from a meta-analysis and used to calibrate as well linear and nonlinear (random forest, RF) statistical models; the latter performing much better as compared to simple linear statistical models (Ouedraogo and Vanclooster, 2016). Finally, we validated the continental-scale model of groundwater contamination by using a nitrate measurement dataset from three African countries. The modelling procedure in the random forest (RF) format exhibited very good success using the continental-scale dataset inferred from a meta-analysis (e.g. $R^2 = 0.97$). However, the continental-scale model could not be used without recalibration to predict nitrate pollution at the country scale using observed regional data (Ouedraogo et al.2017). In addition, when recalibrating the model using country-scale datasets, the order of model exploratory factors changes. This suggests that the structure and the parameters of a statistical spatially distributed groundwater degradation model for the African continent exhibits strong scale effects.

Findings in this study can improve knowledge about the continental scale degradation of groundwater and help decision makers develop best management strategies and policies that advance groundwater sustainability to achieve the SDG 6 in Africa.

REFERENCES:

Ouedraogo, I., Defourny, P., Vanclooster, M. (2016). Mapping the groundwater Vulnerability for pollution at the pan-African scale. *Science of the Total Environment*, Vol. 544, p. 939-953. DOI: 10.1016/j.scitotenv.2015.11.135.

- Ouedraogo, I., and Vanclooster, M. (2016). A meta-analysis and statistical modelling of nitrates in groundwater at the African scale. In: *Hydrology and Earth System Sciences*, Vol. 20, no.6, p. 2353-2381. DOI: 10.5194/hess-20-2353-2016.
- Ouedraogo, I., Defourny, P., & Vanclooster, M. (2017). Validating a continental-scale groundwater diffuse pollution model using regional datasets. *Environmental Science and Pollution Research*, 1-15. <https://doi.org/10.1007/s11356-017-0899-9>.

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ASSESSING GROUNDWATER VULNERABILITY FOR NITRATE POLLUTION IN THE BRUSSEL'S CAPITAL REGION (BELGIUM) USING STATISTICAL MODELLING APPROACHES

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Keywords: groundwater nitrate pollution, urban groundwater, DRASTIC, data mining

In this study, we assess the groundwater vulnerability for nitrate pollution of the Brusselean groundwater body in the Brussels Capital Region using statistical and conceptual modelling approaches. The land use in this region is very heterogeneous, with important forest areas, in the South South-East part of the region, and intensive urbanisation in the remaining part. Groundwater nitrate concentration data were determined at 48 measurement stations distributed over the region, from 2006 till 2017. In addition, oxygen and nitrogen isotope concentration of the nitrates were determined. The data show that the groundwater body is degraded, in particularly in the urbanised part of the region. A statistical trend analysis shows that the contamination with nitrates at degraded stations is slightly decreasing, while the opposite is true for the nitrate contamination at the less degraded stations. We modelled the contamination and trends of nitrate contamination using linear and non-linear statistical modelling techniques. In total, we defined 23 spatially distributed ancillary variables that could contribute to the explanation of nitrate contamination in the groundwater body. The variables included variables related to the natural environmental conditions, and anthropogenic pressures at the surface. These ancillary variables were defined at the grid size of 50 m, and averaged over the influence zone of each measurement stations. These latter influence zones were identified using a simplified particle tracking algorithm from the groundwater piezometric map and showed to be consistent with results obtained from a detailed numerical groundwater flow and transport model. Stepwise regression allows explaining 56 % of the observed variability of nitrate contaminations with 5 dominant ancillary variables, while non-linear artificial neural network model allows explaining nearly 70 % of the variability. The dominant ancillary variables are the percentage of impermeable surface, the percentage of the sewage system that is in a degradation state, the number of urban infrastructure construction permits with a high pollution risk, the size of the influence zone, and the depth of the groundwater sampling. These results illustrate the important role of urban infrastructure in groundwater degradation. These results are also consistent with the isotopic signature of nitrates determined on the sampling stations. The overlay of the nitrate contamination data with the DRASTIC vulnerability model shows that this latter conceptual model only partially captures the spatial signature of the observed contamination.

POTENTIAL CHANGES IN VULNERABILITY OF FRACTURED CARBONATE AQUIFERS IN CENTRAL ITALY AFTER THE 2016-17 SEISMIC SEQUENCE

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Keywords: earthquake hydrology, groundwater resources, seismic precursor, monitoring, hydrochemistry

The seismic sequence started on August 24th 2016 and closed on January 18th 2017, which included 9 earthquakes having $M_w > 5$, directly involved the fractured and karstified aquifers of Central Italy, which show significant changes in groundwater flow, discharge and chemical parameters after the main seismic events.

Groundwater monitoring was active in the area with different purposes, including drinking water supply, environmental protection, thermal SPA surveillance and namely for investigating relationships between groundwater and seismic activities. Springs, rivers and wells have been monitored since 2014 in different aquifers indicating changes in groundwater flow and geochemistry attributed to the seismic events.

The fractured nature of the aquifers enhanced the effect of seismic waves, leading to clear post-earthquakes effects, as: water table rise, increased discharge of springs and rivers (baseflow), appearance of some metal ions in relevant concentrations respect with pre-seismic periods. Conversely, minor springs located in recharge areas and/or at higher elevation, suddenly disappeared.

An evident signal of the effect on groundwater flow was turbidity increase, linked to fracture cleaning due to pore pressure propagation during the earthquakes. As secondary effect, the fracture cleaning caused an increase of bulk hydraulic conductivity of the strucked aquifers.

In addition to the main post-seismic effects, the groundwater flowpath evidenced short-term changes, with very high sustained discharge (more than doubling the natural discharge in the Nera River Upper Valley), and consequent water table rise (up to 15 m of increase in the Norcia Plain). As mid-term effect, during the following exhaustion period, the main springs and river show a different recession curve. This condition can affect the aquifer characteristics as a potential long-term effect. In this scenario, possible changes in natural vulnerability of the aquifers has to be evaluated for correct future management of the groundwater resource of the study area.

GROUNDWATER VULNERABILITY MAPPING APPROACH AT SPRING / WELL CATCHMENT SCALE AS A TOOL TO BETTER FORECAST THE IMPACT OF CONTAMINATION IN POROUS MEDIA

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Keywords: porous media, water catchment area, recharge conditions, transit time, water quality forecasting

The method presented aims at providing a tool to determine groundwater vulnerability and predicting contamination propagation at the scale of a water catchment area in porous media. It is meant to bring a complementary insight to existing groundwater protection approaches, mainly by estimating the storage function of the unsaturated zone and assessing the short and long-term effects of contamination related to various hazards on exploited groundwater resources.

It considers the detailed hydrogeological functioning of the aquifer as well as recharge distribution, and allows evaluating semi-quantitatively the transit time of water, or a conservative pollutant respectively, in the unsaturated zone. It additionally takes into account local water flow at the surface prior to infiltration (e.g. sinking streams) and allows estimating the transit time in the saturated zone in order to forecast the contaminant pathway between soil surface and spring or well of interest.

Transit time in the unsaturated zone is deduced from a) the storage capacity within the sequence between soil surface and groundwater table b) the recharge. The total storage capacity is estimated based on the thickness and volumetric water content / field capacity of each unsaturated layer. The indicative transit time is then calculated by dividing the total storage capacity by the mean annual recharge based on local meteorological data ("piston flow" approximation).

Zones where infiltration rates exceed significantly mean diffuse meteoric recharge (e.g. stream infiltration) or are notably below this value (low permeability layer at the surface or subsurface) are taken into account as they can strongly affect, i.e. decrease or increase the protective function of the unsaturated zone. Such effects can also be produced by artificial recharge related to specific hazards.

Final vulnerability maps are linked to indicative transit time and therefore can be used as a tool to better forecast the impact of various contamination scenarios not only in terms of transit time, but also in terms of persistence and possible concentration level of degradable contaminants at the groundwater resource of interest.

KARST AQUIFER CRITERIA TO DEFINE CONTAMINANT ATTENUATION POTENTIAL AND GROUNDWATER VULNERABILITY

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Keywords: karst aquifer, storage capacity, recharge scenario, tracer recovery, protection zoning

Karst aquifer protection is challenging due to locally high groundwater velocity along preferential paths and generally poor filtration capacity. Substantial storage capacity linked to densely fractured rock (epikarst) or thick protective cover can still provide a significant attenuation in case of surface contamination.

Unlike in porous media where thickness and properties of unsaturated geological layers (granulometry, porosity, hydraulic conductivity) can be considered as relevant and sufficient criterion for defining the degree of protection and inversely the vulnerability of groundwater, the specificities of karst hydrology require other parameters and investigation methods to be taken into account.

The approach presented is focused on groundwater protection zone delineation. It already considers a significant protection effect for partial contaminant attenuation and relatively short residence time in karst system. Unlike most groundwater vulnerability methods, which integrate mean annual meteorological data to define aquifer recharge for more general purposes, it implies the consideration of short-term events as reference recharge scenario.

Vulnerability / natural protection assessment is based on evaluation of the field storage capacity / attenuation potential along groundwater flowpaths for a given recharge scenario and adequate observation period. The protective function of each subsystem / parameter considered (epikarst, protective cover, infiltration condition, karstic network) has been evaluated by conducting multiple tracer experiments on selected point of contrasting vulnerability under similar injection scenarios.

By interpreting quantitatively tracer breakthrough at the discharge area, it was possible to propose a classification and rating for each parameter based on semi-quantitative criterion, essentially on predicted mass restitution. This implements some principles of the so-called European approach for karst groundwater protection and goes beyond conventional vulnerability mapping methods.

INITIAL ASSESSMENT OF GROUNDWATER POLLUTION IN THE PUCK MUNICIPALITY AREA

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Keywords: groundwater vulnerability, groundwater quality, agricultural contamination, young glacial area, Puck Municipality

Transport of contaminants in the groundwater can cause a serious water supply and environmental problems. Puck Municipality, situated in the northern part of Poland, is an example of a hydrogeological diversified region where various groundwater vulnerability to pollution is observed. The Municipality of Puck is an agriculture area with dynamically growing tourism and agro-tourism sector. Agricultural type of land use can be a potential spatial source of a contaminated groundwater, therefore groundwater quality studies are necessary.

Presented study shows initial risk assessment of groundwater contamination in the Puck Municipality area. Groundwater quality identification was based on an archival data and field investigations. The purpose of this research was to analyze groundwater quality in reference to occurrence of groundwater and type of land use structures using GIS methods. The concentrations and distribution of a selected groundwater pollution indicators over the past few years have been also analyzed. Results of the investigations allow to extract preliminary areas of a different groundwater vulnerability to contamination.

The conducted research is a part of a project which main goal is a development of groundwater contaminant transport model and detailed identification of a potential agriculture pollutant sources in the selected watershed of the Puck Bay.

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OCCURRENCE OF URANIUM IN GROUNDWATER IN CRYSTALLINE BASEMENT AQUIFERS OF AMBAJI REGION, NORTH GUJARAT, INDIA

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NITRATE VULNERABILITY ASSESSMENTS ON LOCAL SCALE FOR HALF A COUNTRY

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GROUNDWATER MANAGEMENT WITH DEEP SEALING WALLS

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Keywords: mining areas, groundwater, simulation, slurry wall, sealing wall

Active opencast mines require groundwater management. In order to minimize the impact of groundwater depression and, therefore, make the mine more efficient and environmentally friendly, underground sealing walls are established in the Lusatia lignite mining area. Limiting the extent of the depression can have significant impact on the ecology of the area and its vulnerability to pollution and overexploitation. In order to build such underground flow barriers, a clay suspension is filled in a deep trench. Subsequently, the suspension penetrates into the surrounding soil resulting in colmation and forming a so-called filter cake. The hydraulic conductivity of this clay layer with several centimeters' thickness is about 1×10^{-11} ms⁻¹ and effectively reduces the resulting horizontal hydraulic conductivity. Consequently, groundwater inflow in the active open pit is significantly reduced. Currently sealing walls are produced with depths exceeding 100 meters and lengths of several kilometers.

Sealing walls represent hydraulic discontinuities that give rise to demanding questions. Over very small distances, the effective hydraulic conductivities between the sealing wall and the surrounding loose rock varies by several orders of magnitude. A very strong hydraulic gradient, more than 60 meters' pressure difference per meter, were recorded. Existing analytic solutions, based on the DUPUIT assumptions, are not suitable to describe the 3D hydraulics around the flow barrier.

This paper provides an overview of the current state of sealing wall technology in the Lusatian mining district and shows which numerical methods could be used to calculate hydraulics in the vicinity of a sealing wall. The software tools for flow simulation, MODFLOW, a finite-volume model, and PCSiWaPro, a finite-element model, were modified and evaluated. Hydraulics were investigated for various scenarios, e.g. resulting velocities in the flow and underflow of the sealing wall. In conclusion, 3D numerical methods are necessary to accurately reproduce this particular hydraulic situation.

SPECIFIC GROUNDWATER VULNERABILITY TO ACID MINE DRAINAGE AT A REGIONAL SCALE: CASE STUDY OF WITBANK COALFIELD, SOUTH AFRICA

*Authors did not agree to publishing the abstract online
Abstract is available in printed copy of a book*

DESIGN AND MAINTENANCE OF A RECHARGE WELL TO PREVENT CLOGGING

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Keywords: recharge, well, clogging, filter, construction site

Background:

Groundwater recharge is effective to prevent groundwater source reduction and ground subsidence by drawdown. The recharge facility has wells and ponds. However, in any facilities, clogging occurs and the recharge rate is often decreased. Therefore, it is difficult to recharge for a long time. As a cause of clogging, injection water quality and rearrangement of soil particles in the ground have been reported. The purpose of this study is to examine injection flow rate, injection water quality, well washing, and filter structure of a well in order to recharge for a long time.

Methodology:

First, numerical analysis and in-situ step recharge test were conducted to determine the injection flow rate to prevent rearrangement of the soil particles in the ground. Next, numerical analysis and in-situ well washing test by pumping were conducted to decide the maintenance method of a well. Furthermore, the laboratory test was conducted to examine the filter structure of a well to prevent clogging due to injection water quality. Based on the results, recharge wells were set up in the construction site and operated for 6 months.

Results:

This study presents the schematic design and maintenance of a recharge well to prevent clogging, and the findings after 6 months of continuous operation. In the step recharge test, the injection flow rate was determined in the one-step 1 hour test. In the well washing test, the pumping rate and the pumping interval were confirmed to increase the extraction rate of fine grains from the well. In the filter structure test, it was confirmed the materials of the multilayered filter for a high performance. By the measurements at the construction site, we found the effect of preventing clogging on the filter structure of a well and the filtration treatment of injection water.

COUPLING INTRINSIC VULNERABILITY WITH BACTERIA-SPECIFIC CONCEPTS

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Keywords: specific attenuation, residence time, karst groundwater, global vulnerability

Protection against bacterial contamination is a key objective of the groundwater vulnerability concept, especially when focusing on karst environments. However, it is only integrated in an indirect manner so far, without taking explicitly into account the specific attenuation of fecal bacteria allowing for better assessing the risk of contamination. This is particularly challenging in karst aquifers with bacteria inactivation to be considered during fast transport and transient storage. Such an approach needs a more sophisticated vulnerability definition coupling residence times with the cumulative effect of potential mass loss.

Field experiments and sampling at both local and catchment scales provided deepened insight into the relevant processes, i.e. input, interaction and inactivation. This includes, besides fecal contamination, the natural bacterial load in groundwater resources, which has shown to be significantly higher for karst aquifers than for other aquifer types. This is assumed the result of a higher degree of recently infiltrated water components, which makes bacterial cell density a reliable additional parameter for aquifer characterization, and levels of global vulnerability, respectively. Bacteria originating from fecal contamination represent only around 1/100'000 of the total bacterial load.

Global vulnerability can be defined as part of the intrinsic vulnerability concept reflecting the overall response of aquifer systems at catchment scale. For karst systems, bacteria cell density correlates with global vulnerability, both for karst springs and related sub-systems. High vulnerability is thereby characterised by increased cell densities, and vice versa, according to the bacteria-specific behaviour in the subsurface. Findings indicate that knowledge about the origin and fate of both natural and fecal microorganisms is crucial for predicting microbial contamination as well as for establishing adequate protection, i.e. vulnerability, concepts.

ASSESSING IRRIGATION IMPACT ON SOUSS-MASSA GROUNDWATER VULNERABILITY USING DRASTIC METHOD

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Keywords: Souss-Massa Aquifer, vulnerability index, irrigation system, nitrate contents, DRASTIC model.

Extensions of irrigation areas in Souss-Massa plain, southwestern Morocco, have negatively impacted groundwater quality and exacerbated its vulnerability to pollution. Thus, the objective of this study was to assess Souss-Massa aquifer vulnerability under natural and irrigation conditions using a GIS-based DRASTIC model. Seven layers (Depth to water, net Recharge, Aquifer media, Soil media, Topography, Impact of vadose zone, and hydraulic Conductivity) were created from available data and overlaid in a GIS environment.

Under natural conditions, the output vulnerability map shows a low vulnerability index (< 104) prevailing in the whole region but in few localized areas situated in mountain piedmonts, along Souss and Massa rivers and near the coastal area where vulnerability index is moderate (104 to 145) to high (145 to 160). This indicates that groundwater resources are naturally protected from any potential source of contamination.

However, under irrigation conditions, the integration of irrigation components in the recharge layer has tremendously changed the vulnerability setting in the area. Several areas with low to moderate vulnerability index under natural conditions, have become of high (145 to 185) to very high (> 185) vulnerability index under irrigation conditions.

In order to validate this vulnerability assessment, a total of 298 groundwater samples were collected from different vulnerability zones of the study area and analyzed for nitrate contents. Besides to this, a mapping of the irrigation system used (rain-fed agriculture, flood-furrow irrigation, sprinkling irrigation, and trickling irrigation) was made.

Results indicate that high vulnerability zones are characterized by high nitrate contents (> 100mg/L) and coincide with sectors where flooding and sprinkling irrigation are practiced; whereas low vulnerability zones match with sectors where trickling irrigation and rain-fed agriculture are used within which nitrate contents are low (<50 mg/L).

GROUNDWATER RECHARGE ESTIMATION AND IRRIGATION WATER MANAGEMENT USING SOIL MOISTURE INDEX ACROSS VARIABLE SATURATED ZONE

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Keywords: groundwater recharge, irrigation, soil moisture dynamic

Temporal-spatial soil moisture status in a variable-saturated zone plays a vital role in agricultural water management, groundwater recharge and solute transport. It is fundamentally regulated by plant growth and its water extraction rate along with soil properties and weather conditions. The soil moisture distribution pattern at soil element scale is regulated by Richard's equation integrated with a term representing water uptake rate by plants. A Richards equation-based model coupled with the water uptake term is numerically solved using the finite difference method to obtain the soil moisture dynamics across the root zone. The model has been tested for simplified cases for a wheat cropped site in the Patna region of Bihar, India with the pedotransfer functions obtained from soil sample analysis. Simulation for a period of 120 days shows that, out of 24 cm irrigation applied, plus 10.61 cm rainfall, 47.0% was lost as evapotranspiration, 28.9 % of water was stored in the soil column as soil moisture and 23.9 % of water was recharged to groundwater. Based on this result, an irrigation schedule is recommended for an optimal utilization of both rainwater and irrigation water for better management of the available water resources.

ASSESSING O₂ REDUCTION RATES TO EVALUATE NITRATE VULNERABILITY OF A POROUS AQUIFER

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Keywords: denitrification, O₂ reduction rate, $\delta^{15}\text{N}$, mean transit time

Nitrate contamination is one of the main sources of degraded groundwater quality in Europe, the US and elsewhere. Groundwater vulnerability towards nitrate contamination is dependent on the self-purification potential and redox conditions of an aquifer. We used aqueous geochemistry data and stable isotope compositions of $\delta^{15}\text{N}_{\text{nitrate}}$ and $\delta^{18}\text{O}_{\text{nitrate}}$ to determine that anthropogenic nitrate contamination in the porous aquifer in Lower Bavaria, Germany, was caused by excess use of manure and synthetic fertilizer and that denitrification was not a dominant process. Using environmental isotopes ($\delta^2\text{H}$ & $\delta^{18}\text{O}$, $^3\text{H}/^3\text{He}$, ^{14}C) and a lumped parameter model, we assessed apparent mean transit times (MTT) of groundwater of < 5 yrs to >100 yrs. Moreover, we determined low O₂ reduction rates of 2.2 $\mu\text{mol L}^{-1} \text{yr}^{-1}$ for zero-order kinetics and 0.015 yr^{-1} for first-order kinetics. Denitrification lag times (time prior the commencement of denitrification) of 94 to 109 years were calculated by extrapolating the O₂ reduction rates. Our results indicate that assessing O₂ reduction rates and groundwater mean transit times are key factors in determining the time frame required to achieve improvement in the level of nitrate contamination in aquifers. The determination of oxygen reduction rates in future groundwater studies, however, would allow assessing the fate of redox-sensitive contaminants, and consequently, the vulnerability of aquifers posed by dissolved nitrate and its persistence to drinking water resources.

OVERVIEW OF APPLICATION OF SOIL AND ITS PROPERTIES FOR GROUNDWATER VULNERABILITY ASSESSMENT

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Keywords: vulnerability, methods, protective function of soil

The soil, its thickness and properties play a crucial role in groundwater vulnerability and pollution risk assessment. The soil plays an especially important role in karst areas, where it is often the only protective layer in relation to groundwater. The article provides an overview of the different methods of groundwater vulnerability assessment in which the protective function and protective effect of soil was taken into account. In classical methods such as: DRASTIC, SINTACS, GOD, AVI and their various modified forms, the intrinsic vulnerability assessment for types of soils have been applied, using available soil maps (at various scales from 1:200000, 1:500000 for the entire country and more detailed maps for small areas of special interest 1:5000, 1:10000, up to 1:50000). In some places results of field investigation of soil and existing soil profiles have also been applied.

For karst areas, in addition to the soil maps, more detailed field and laboratory soil studies were used. Typically, for the assessment of intrinsic vulnerability, the type of soil cover and its thickness was characterized (e.g. EPIC, RISKE, COP, DRISTPI, PaPRIKA and others). In some cases, the physical and chemical composition of soil (KARSTIC), grain size distribution, organic matter (REX), hydraulic conductivity (Time-Input method), effective capacity of soil (GLA, PI, VURRAS) were also applied.

Recently a lot of methods for groundwater vulnerability assessment have been used based on the time scale of water flow through the soil and unsaturated zone (MRT, Time-Input method). For this purpose a few different terms have been used: travel time, residence time, transit time, turn-over time, and the exchange time of water in the soil profile. These methods were mainly related to steady-state conditions and recently also applied to transient conditions (the transient time method).

For specific vulnerability, in addition to the basic soil parameters (type and thickness and also its texture, structure, organic matter content), research has included: water content and hydraulic conductivity, porosity, types of clay minerals, cation exchange capacity, adsorption of chemicals on soil particles and organic matter, the diffusion and dispersion coefficients, interaction between microorganisms and soil.

In groundwater vulnerability assessment mathematical modeling is being used more frequently. For modeling itself and model calibration and validation the results of field tests (e.g. lysimeters) and laboratory tests (batch and column tests) have been used. The term "hydrogeochemical vulnerability" is introduced as well as related detailed studies of the so-called geochemical signals in unsaturated zone. These type of investigations are very important for the complex assessment of the role of soils in limiting groundwater pollution (formation of different geochemical barriers).

IMPORTANCE OF GEOLOGICAL ASPECTS OF KARSTIC AQUIFER FOR VULNERABILITY ASSESSMENT: CASE STUDY OF UČJA VALLEY, NW SLOVENIA

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Keywords: karstic aquifer, groundwater vulnerability, geological mapping, structure, Učja Valley

Groundwater represents an important supply of drinking water and is very important for various other uses. Due to the increasing water consumption shortages are getting more and more frequent (main problem is drinking water supply) therefore the protection of this resources and sustainable management is crucial.

To ensure sufficient quantities of quality drinking water also in the future, it is necessary to define in advance the potentially suitable aquifers. In this contribution we present results of the first research phase of karst-fissured aquifer of the Učja Valley and plans for the following supplementary work.

Within the first research phase detail geological map (lithological and structural) was done to better understood basic geological conditions of groundwater reservoir and define the spatial distribution of the aquifer. The results pointed out that catchment area is not bound to the simple watershed conditions, but follows complex geological structure characterized by highly-variable lithologies displaced by prominent faults and fractured zones. This means that structure-dependent catchment area of karstic aquifers is often crucial for determination of their vulnerability. During this phase, a data on micro-location and discharge of particular water sources was collected. Besides, the detailed analysis of climate parameters and climate changes (rainfall and temperature) and land use conditions of the area were studied.

Based on the gathered data, subsequent studies were selected that include groundwater geochemical and isotopic analyses of selected sources and geochemical modelling. These results will additionally contribute to understanding of groundwater flow in aquifer and consequently its vulnerability.

LAGTIME OF RIVER SYSTEMS TO CHANGES IN CONTAMINATION LOAD ON CATCHMENTS: TIMESCALE-BASED VULNERABILITY CONCEPT

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Keywords: lagtime, Mean Residence Time, vulnerability map

Transport of conservative contaminants through groundwater systems (e.g. nitrate under oxidized conditions) is significantly delayed when compared to movement of those contaminants through surface water compartments. Characteristic time scales of groundwater movement may easily reach tens or hundreds of years. This results in large lagtimes of contaminant transport in the subsurface. These lagtimes are particularly important when response of river basins to measures aimed at recovery of good groundwater status is considered. Incorporating lagtime principles into water quality regulations may result in more realistic expectations when such policies are designed and implemented. Vulnerability assessments based on principle of timescales of water flow can be considered as the measure of lagtime.

The lagtime of contaminant transport in the subsurface with respect to transport through surface and near-surface (drainage) runoff can be separated into two components: (i) the delay associated with travel time of water and contaminants through the unsaturated zone, and (ii) the delay linked to timescales of groundwater flow, from the recharge area down to the discharge zone (river).

The concept of lagtime assessment is presented for the Kocinka catchment – the case area in BONUS-Soils2Sea project (www.soils2sea.eu). The transported contaminant is nitrate. The lagtime of nitrate in the unsaturated zone was assessed on the basis of MRT (Mean Residence Time) of water in this zone. The MRT was calculated using methodology adopted from the existing Groundwater Vulnerability Map of Poland (GVMP) (Witczak et al., 2011). The lagtime of nitrate in the saturated zone (T_{sat}) was approximated by travel time of water flowing along the local hydraulic gradient to the closest river. The resulting lagtime of Kocinka river system is a sum of the travel time of water through the unsaturated zone (MRT) and the travel time associated with movement of water between the recharge and discharge areas. The median value of the total lagtime of nitrate for the Kocinka catchment is in the order of 40 years.

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III. AUTOR INDEX

Abd-Elmegeed M.A.	36	Fisch S.	64
Achheb A. El.	22	Fľaková R.	40
Abdulhamid A.	5,6	Fourie F.	65
Adeyeye O. A.	8	Gómez E.	26
Ahmed M. S.	5,6	Gomo M.	65
Akinsunmade A.	7	Gonzales Amaya A.	27
Albornoz Euán B.S.	28	González Herera R.	28
Alejos-Moo E.	48	Gorczevska-Langner W.	29
Arabi A. S.	8	Górski J.	20
Aureli A.	15	Grabala D.	18
Badamasi M. M.	5,6	Graeber P.-W.	25,64
Banwart S.	47	Gumuła-Kawęcka A.	29,61
Banzato F.	58	Guo J.	64
Barberio D.	48	Gupta P. K.	33
Barmen G.	26	Haendel F.	25
Berbieri M.	58	Hassan A.E.	36
Bertolo R.	31	Heuvelmans G.	30
Biaľecka K.	9	Hirata R.	31
Biswal T.K.	62	Hodasová K.	40
Biswas C.	10	Hsaissoune M.	68
Blankenburg R.	25	Hsissou Y.	68
Blaskovicova L.	24	Hsu S.-M.	32
Bogaert P.	57	Hwang J.Y.	37
Bottrell S.	46	Ikpokonte A. E.	8
Bouchaou L.	68	Jahangeer	33
Boutaleb S.	68	Jakóbczyk-Karpierz S.	18
Boyraz U.	11,12	Jaworska-Szulc B.	29,61
Bracic Zeleznik B.	13	Jo H.J.	37
Brkić Ž.	43	Joris I.	30
Broda S.	14	Kaczkowska E.	18
Carrubba S.	15	Kaczor-Kurzawa D.	9
Casares Salazar R.	28	Kalantari N.	34,35
Cencur Curk B.	13,16	Kalantari F.	34,35
Cherkaoui Dekkaki H	17	Kazezyilmaz-Alhan C.M.	11,12
Choi W.	38	Khafagy M.M.	36
Coetz H.	65	Kim G.	38
Conicelli B.	31	Kim H.K.	37
Czekaj J.,	18	Kim I.	38
Dahlin T.	26	Kim J.	38
Dams J.	30	Kim M.S.	37
Dąbrowska D.	51	Kochhar N.	42
Dragon K.	19,20	Kouz T.	17
Drożdżyński D.	20	Kowalczyk A.	39
Ducci D.	21	Kovács T.	40
Echelfi Y.	22	Krčmář D.	40
Einsiedl F.	70	Krmpotić M.	49
El Achheb A.	22	Krogulec E.	41
Elewa H.H	23	Kuczyńska A.	52
El Nahry A.H	23	Kuke C.	25
El Maliki S.	22	Kumar N.	42
Engelmann C.	25	Kumari S.	42
Fendek M.	24	Labudova L.	24
Fendekova M.	24	Lacchini A.	58
Fichtner T.	25	Lagod M.	15
		Larva O.	43

Lee J.	38	Rózkowski J.	71
Lee J.F.	32	Rubin H.	18
Lee M.	37	Rubin K.	18
Lgourna Z.	68	Sakala E.	65
Liebhold M.	14	Sánchez y Pinto I.	28
Liedl R.	25,48,64	Sbarbati C.	58
Lietaer A.	57	Sellerino M.	21
Maertner B.	25	Shimizu T.	66
Malík P.	44	Shin I.	37
Mansel H.	25	Simonato M.	31
Mansour S.	17	Singh V.	69
Marinelli V.	58	Sinreich M.	59,60,67
Marković T.	43	Sitek S.	18
Mayer B.	70	Siwek P.	18
McSherry J.	46	Skrzypczak M.	18
Medici G.	47	Slivova V.	24
Milinović M.	49	Sołtysiak M.	51
Monsour S.	17	Stefan C.	48
Moreno-Gómez M.	48	Svensson E.	26
Mourabit T.	17	Szymkiewicz A.	29,61
Moustadraf J.	68	Ślósarczyk K.	18
Nadri A.	34	Šoškić A.	49
Nešković D.	49	Tadić D.	49
Nishigaki M.	50	Tagma T.	68
Nosair A.M.	23	Tanko A.I.	5,6
Nourani V.	51	Thomas A.	33,69
Nowakowska M.	52	Tomecka-Suchoń S.	7
Oke S.A.	53	Vanclooster M.	55,57
Okońska M.	54	Van den Belt K.	30
Osorio Rodríguez H.	28	Vrablikova D.	24
Ouedraogo I.	55	Yadav B.K.	33,69
Park S.H.	37	West J.	46,47
Passaretti S.	58	Wild L.	70
Pavlović V.	49	Witczak S.	73
Petit S.	57	Witkowski A.J.	18,71
Petitta M.	58	Woźnicka M.	52
Pietrewicz K.	54	Zabłocki S.	41
Pinzinger R.	25	Zadrożna D.	41
Pochon A.	59,60,67	Zarei H.	34
Potrykus D.	61	Zwahlen F.	60
Pradhan R.M.	62	Ženišová Z.	40
Pruszkowska-Caceres M.	29,61	Žvab Rožič P.	72
Pytlich A.	63	Žurek A.J.	73
Rahimi M.H.	35		
Ramadan E.M.	23		
Reichling J.	14		
Reimann T.	64		
Rosberg J.E.	26		
Róžański K.	73		