# 2<sup>nd</sup> Atlas Georesources International Congress AGIC2019

### **APPLIED GEOSCIENCES FOR GROUNDWATER**

28-30 March 2019, Hammamet, Tunisia



Book of Abstracts April 2019





### Foreword

#### Dear esteemed participant and reader

The Laboratory of Georesources (LGR) at the Centre for Water Research and Technologies (CERTE, Tunisia) and the Tunisian Committee of Hydrogeology (TCH) at the Association Eau & Dévelopement (AED, Tunisia) were honoured to organize and host the second Atlas Georesources International Congress (AGIC2019) at the city of Hammamet from 28 to 30 March 2019.

This year **AGIC2019** focused on **Applied Geosciences for Groundwater.** This was an invitation to researchers, experts and policy makers to discuss and present recent advances in applied geosciences and their applications to address current issues and future challenges in groundwater. Over 100 participants coming from 15 countries (Algeria, Egypt, France, Germany, Italy, Lybia, Mauritania, Morocco, Palestine, Poland, Portugal, Saudi Arabia, Switzerland, Tunisia, and Zambia) have delivered more than 80 abstracts covering the four topics of the conference in a good atmosphere and fruitful discussions. This attests to the success and international dimension of the **AGIC2019**. Moreover, four plenary keynote lectures were given in the opening session of each topic by internationally distinguished researchers namely Prof. Ralf Ludwig (LMU, Germany), Prof. Ezio Crestaz (JRC, Italy), Prof. Hakim Gabtni (CERTE, Tunisia) and Prof. Wolfgang Kinzelbach (ETH Zurich, Switzerland), thus contributing to provide a deeper understanding of the conference's interest theme.

The scientific programme was organized by the conference committee chaired by Haykel Sellami & Faten Jarraya Horriche from the LGR (CERTE) and the TCH (AED) together with the topic chairs namely Sihem Benabdallah (LGR-CERTE/TCH-AED), Ammar Mlayah (LGR-CERTE), Hakim Gabtni (LGR-CERTE), Faten Jarraya Horriche (LGR-CERTE/TCH-AED), and Jose Joel Carrillo Rivera (UNAM, Univ. Mexico). Therefore, we would like to take the opportunity here to thank them. The scientific committee of the **AGIC2019** is made of an international panel of scientists and experts who reviewed more than 140 contributions in a double-blind evaluation. This book of abstracts is the compilation of the latter papers retained by the scientific committee and presented at the conference. In addition, each single oral and poster contribution was evaluated by a scientific jury during the conference who decided to confer the awards of best oral and poster presentation to **Janja Vrzel et al**. (Ludwig-Maximilians-Universitaet München, Germany) and **Yassin Kadri et al**. (LGR-CERTE, Tunisia), respectively. Congratulations to the winners!!! Furthermore, a short list of the presented papers will be selected to be submitted into Special Issue in *Hydrological Sciences Journal*.

Preparation of the **AGIC2019** and this book of abstracts would not be possible without the assistance of many people. We would like to express our thanks, first of all, to all the members of the organizing committee from the LGR (CERTE) and the TCH (AED) whose work and dedication made possible the successful organization of this conference. Next, we would like to thank all the scientific committee members for reviewing the papers and helping us



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with their expertise and time. We would also like to thank the committee program and the chairs of the topics who made it possible to put together a program that we believe was very exciting and of high scientific quality. We would also like to thank the invited keynote speakers for their invaluable contribution and for sharing their vision in their outstanding talks. Special thanks to our sponsors and exhibitors for their financial and technical support.

We wish you enjoyed the conference and had an unforgettable stay in Hammamet, Tunisia. We hope to meet you again for the next edition of **AGIC**. Finally, we invite you to visit the conference website <u>https://lgr-certe.com.tn/</u> for more details and news.

Dr. Haykel Sellami & Dr. Faten Jarraya Horriche



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### **Topics**

#### **Topic 1: Global Change and Groundwater**



## Chair: Dr. Sihem Benabdallah, Laboratory of Georesources (CERTE) & Tunisian Committee of Hydrogeology (AED)

This topic welcomes contributions that focus on the impacts of global change on groundwater resources including surface waters and groundwater interactions, climate change impact on groundwater, groundwater system modelling under uncertainty, population growth, urbanization and land use changes impact on groundwater, groundwater over-exploitation and marine intrusion, agricultural

practices and associated impacts on groundwater, and groundwater management and adaptive measures.

### **Topic 2: Groundwater Quality and Pollution**



#### Chair: Dr. Ammar Mlayah, Laboratory of Georesources (CERTE)

This topic emphasizes the need to protect, manage, repair and sustain groundwater quality in growing urbanized and rural environments. Participants can expect to have a socially and technically stimulating experience that brings scientists, practitioners and decision makers up-to-date on the latest issues related to groundwater quality, including new approaches for

measuring, modelling, and managing water quality, and groundwater pollution assessment.

### **Topic 3: Groundwater Exploration & Monitoring**



#### Chair: Prof. Hakim Gabtni, Laboratory of Georesources (CERTE)

New challenges in freshwater resources exploration and deep brackish/geothermal Groundwater require advanced approaches such as geophysical investigations, satellite imagery analysis, GIS methods, isotopic study, hydrogeological exploration, monitoring observations, Modeling, etc. This Topic gives the possibility to discuss and disseminate recent research and latest advances in

the Groundwater Exploration and Monitoring field.

#### **Topic 4: Groundwater Modelling & Risk Management**



#### Chair: Dr. Faten Jarraya Horriche, Laboratory of Georesources (CERTE) & Tunisian Committee of Hydrogeology (AED)

The session welcomes contributions related to challenges, developments and applications of modelling tools in groundwater including hydrogeological and hydrogeochemical modelling, stochastic modelling, surface and subsurface water flows modelling, solute transport modelling and interactions, groundwater modeling in porous

and karstic Medias, vulnerability and risk assessment, and decisional support system.

#### Special Session in Topic 4: Regional Groundwater Flow Systems



### Chair: Prof. Jose Joel Carrillo Rivera (UNAM, Univ. México & RGFC-IAH)

The session anticipates to analyse issues connected to groundwater management and related environmental protection defining physiscal and chemical degradation in the context of groundwater flow system functioning. Contributions related to alternative methods of defining groundwater flow components and their

application in establishing, regulating and mitigating negative environmental impacts to and from groundwater are also encouraged to be submitted.

**Book of Abstracts** 

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- Faten Jarraya Horriche : Georesources Laboratory & Tunisian Committee of Hydrogeology
- Haykel Sellami : Georesources Laboratory & Tunisian Committee of Hydrogeology

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- Topic 1 : Sihem Benabdallah, Georesources Laboratory & Tunisian Committee of Hydrogeology
- Topic 2 : Ammar Mlayeh, Georesources Laboratory
- Topic 3 : Hakim Gabtni, Georesources Laboratory
- Topic 4 : Faten Jarraya Horriche, Georesources Laboratory & Tunisian Committee of Hydrogeology

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- Samia Khadhar : Georesources Laboratory
- Fairouz Slama : National School of Engineers of Tunis & Tunisian Committee of Hydrogeology
- Sameh Chargui : Georesources Laboratory
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- Rachid Khanfir: Association Eau et Développement & Tunisian Committee of Hydrogeology
- Haykel Mosrati : Association Eau et Développement

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- María Luisa Calvache (Univ. Granada, Spain)
- Abdallah Ben Mammou (FST, Tunisia)

### Organizers



### **Oral Programme**

		Thursday, 28 March			
12h00	15h00	Participant registration			
15h00	16h00	Opening Ceremony			
		Topic 1: Global Change & Groundwater			
16h00	16h45	Keynote Prof. Ralf LUDWIG "Assessing global change impacts on surface water and			
		groundwater resources in Mediterranean basins"			
17h00	17h15	MOSBAHI Manel "Impact Of Land Management Scenarios On Groundwater Recharge Modelling In A Semi-Arid Catchment"			
16h45	17h00	Coffee-break			
17h15	17h30	OUESLATI Ines "Impact Of Climatic And Anthropogenic Scenarios On The Groundwater Management Of Meguellil Watershed Using The Weap Model"			
17h30	17h45	El GHOUL Imen "Hydrological Modelling Of The Siliana Catchment: Application Of Swat, Sensitivity And Uncertainty Analysis"			
17h45	18h00	RIBEIRO Luis "Puquios And Foggaras – Dialogues Between Two Historical Water Cultures"			
18h00	18h15	CAMARA Yelli "Dynamic Of A Coastal Aquifer Under The Oceanic Tidal Influence : Case Of Nouakchott (Mauritania)"			
18h15	18h30	MANSIR Imane "Study Of Water Resources Vulnerability In The Souss Massa Region At Cerle Level"			
		Friday, 29 March			
		Topic4: Groundwater Modelling & Risk Management			
08h30	09h15	Keynote Prof. Wolfgang KINZELBACH "Role of groundwater models in sustainable			
		groundwater management"			
09h15	09h30	GRODZKA-ŁUKASZEWSKA Maria "Modelling The Water Flow Through The Hyporheic Zone – Example Of A Small European Lowland River"			
09h30	09h45	LACHAAL Fethi "How To Safeguard Groundwater Resources In Jerba Island In The Scenario Of A Sea Level Rise Using 3D- Feflow Salinity Transport Model?"			
09h45	10h00	HUWAYSH Abdelraheem "Development And Calibration Of Transient Groundwater Flow Model For Al Kufrah Region, Southeast Libya"			
10h00	10h15	SAIDI Chayma "Multilayer Groundwater Modelling For A Coastal Aquifer In North-Eastern Tunisia"			
10h15	10h30	BOGACKI Wolfgang "Seawater Intrusion Modelling In The Mornag Aquifer, Tunisia"			
10h30	10h45	Coffee-break			
10h45	11h00	SLAMA Fairouz "Impact Of Different Irrigation Regimes With Saline Water On Solute Return Fluxes To Groundwater"			
11h00	11h15	VRZEL Janja "A Modelling Framework For Simulating Groundwater And Surface Water Dynamics And Their Interactions"			
11015	11030	Solifi Adii Novel Havel Time Based Approaches For Groundwater Modelling Education And Management			
11h30	11h45	Areas: A Case Study Of Nadhour-Sisseb-El Alem Basin, Tunisia"			
11h45	13h30	Poster Session T1 & T2			
13h30	14h30	Lunch			
		Topic 3: Groundwater Exploration & Monitoring			
14h30	15h15	Keynote Prof. Hakim GABTNI "Spatialization of Geophysical Information for Groundwater"			
15h15	15h30	BEDIR Mourad "New Hydro-Geophysical Investigations, Tectonic And Lithostratigraphic Control Of Hydrogeologic Deep			
		Aquifers Reservoirs Systems in Eastern Tunisian (North Africa)" TRARELSI Rim "Identification Of Recharge Conditions And He Sources In The Dioffare Aquifer System (Southeastern			
15h30	15h45	Tunisia)"			
15h45	16h00	KHALIL Yara Abdelaziz "Mapping Renewable Groundwater Potentiality By Remote Sensing And Geophysical Techniques At Al-Shiyhana Region, Ksa"			

16h00	16h15	OUHICHI Nejmeddine "Hydrogeophysical Characterization Of Groundwater Recharge By The Leakage Of The Lebna Dam			
		(Cap-Bon, North Of Tunisia)"			
16h15 16h30	SDIRI Souha "Application Of Gis Based Data Driven Frequency Ratio And Evidential Belief Function Models For				
	10030	Groundwater Potential Mapping In Ghardimaou Aquifer, Medjerda Basin"			
16h45	17h00	Coffee-break			
17h00	17h15	MEKEBRET Imane "Isotopic And Hydrochemical Features Of Geothermal Water From Northwestern Algeria "			
17h15	17h30	TRABELSI Rim "The Use Of Environmental Isotopes And Krypton-81 To Describe And To Date Continental Intercalaire			
		Paleogroundwater (Southern Tunisia)"			
15h15	16h15	BANDA Kawawa "Estimation Of Groundwater Reserve In The Zambezi River Basin"			

Saturday, 30 March

08h30	09h155	Topic 2: Groundwater Quality & Pollution Keynote Dr. Ezio CRESTAZ "Geospatial technology advancements towards effective groundwater data and knowledge management"			
09h15	09h30	GHOUILI Nesrine "Assessment Of Groundwater Vulnerability In The Takelsa Aquifer (Northeastern Tunisia) Using The Susceptibility Index Method"			
09h30	09h45	GAMMOUDI Safa "Groundwater Quality Assessment In Urban Environment: Case Of Study Sidi Bouzid City"			
09h45	10h00	BEN MASSOUAD Rania "Impacts Of Domestic Treated Wastewater On The Shallow Aquifer Of The Kairouan Plain (Central Tunisia)"			
10h00	10h15	SUISSI ZINA "Investigation Of Sidi Elheni'S Aquifer Salinization (Central East Of Tunisia) Using Geophysical Methods And Geochemical Tracers"			
10h15	10h30	AOUITI Soumaya "Vulnerability Assessment Using Combined Remote Sensing And Gis. Case Study Of The Quaternary Aquifer Of Hajeb Layoun-Jelma Basin (Central Tunisia)"			
10h30	10h45	Coffee-break			
10h45	11h00	Topic 4-1: Special Session on Regional Groundwater Flow Systems			
11h00	11h15	DHAOUI Oussama "Insights into the Groundwater Salinization Processes in Menzel Habib Shallow Aquifer, South- eastern Tunisia"			
11h15	11h30	DJAAFRI Ibtissem "Tóthian Flow Systems Contribution To The Hydro-Structural Study Of The Thermo-Mineral Waters Of Guelma Region (East Algeria)"			
11h30	11h45	HADDAJI Boulbaba "Hydrogeological Characterization Of The Regional Groundwater Flow In El Hamma Thermal Aquifer System, Southeastern Tunisia"			
11h45	13h30	Poster Session T3 & T4			
13h30	14h30	Lunch			
14h30	15h15	Closing Ceremony			

### **Poster Programme**

Friday, 29 March 2019 12h:00-13h30	
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	Topic 1 : Global Change & Groundwater			
111	BENABDALLAH	Sihem	Monitoring Soil Plant Interaction In An Orange Orchard Using Electrical Resistivity Tomography	
141	CHARGUI	Sameh	Assessing The Coevolution Of Climate And Groundwater Resources In A Semi-Arid Region (Grombalia	
			Catchment, Tunisia)	
154	SAYEDI	Mariem	Source Rocks Geochemical Characterization And 1-D Burial And Maturity Modeling In The Marine	
			Chebba Block, Offshore Northeastern Tunisia	
155	SOUSSI	Salma	Characterization Of The Upper Albian Oceanic Anoxic Event (Oae1D) Of The Lower Fahdene Mouelha	
4.65			Member In The Fkirine Area (El Djehaf Anticline)	
165	MARZOUGUI	Abir	Preliminary Results Of Geotechnical And Geophysical Investigations For Infiltration And Seepage	
202	DEN	14/-£-	Detection Of El Kebir Dam The Detection Of Ford Forward Neural Network For Accessing Underlaging Underlaging Underlaging	
203	BEN	wata	The Potential Of Feed Forward Neural Network For Assessing Hydrological impacts Of Climate	
	MAHMOOD			
			Topic 2 : Groundwater Quality & Pollution	
31	LAHNAFI	Adnane	Wastewater Treatment By Biological Contractors Coupled To Local Clay Membranes For Reuse In	
62		Tojosino	Agriculture	
112		Taissire	Study Off Defluoridation Of Water Osing Natural Wilferal Clay	
113	IVIEJKI	Sabrine	Stable Isotopes Of S. N. O. And H.	
158	ARAR	Amani	Hydrogeochemical Study Of The Groundwater Flow System Of Chebba-Ghedbabba Central East Of	
150		Amam	Tunisia	
166	ΔΟΙΙΤΙ	Soumava	Pollution Potential Assessment Using Gis-Based Drastic Model In The Shallow Aquifer Of Hajeb	
100		eeuna ju	Layoun-Jelma Basin (Central Tunisia)	
175	GASMI	Omeyma	Groundwater Vulnerability Assessment To Pollution Using Drastic Method A Case Study On Mornag	
		-	Plain, Tunisia.	
186	ALLOUS	Dalia	Elaboration Of Alginate-Starch Filled Graphene Oxide Beads And Its Evaluation In Adsorption Of	
			Congo Red Dye	
187	TROUDI	Nizar	Hydrogeological And Hydrochemical Characterization Of Groundwater In A Semi-Arid Region	
			(Northeast Of Tunisia)	
196	ALLOUS	Dalia	Response Surface Methodology Approach On The Removal Of Methylene Blue By Green	
		_	Carboxymethyl Cellulose Based Gel Beads	
213	FAKHFAKH	Emna	Methylene Blue Removal By Adsorption And Fenton-Like Process	
292	TALBI	Rachida	Valorization And Optimization Of A Bio-Flocculant Coagulant Extracted From Opuntia Ficus-Indica	
200		Khaqula	Application of Coochamical And Icatonic Techniques In The Study Of Croundwater In Sidi Merzaug	
299	KHIVIILA	Kildoula	Application of Geochemical And isotopic rechniques in the study of Groundwater in sid Merzoug-	
300	BRAHMIA	Rim	Geochemical And Isotonic Investigation Of The Aquifer Systems Of Maiel Rel Abhes Basin (Central	
500	Divinini		Tunisia)	
353	FKIH	Dalila	Adsorption And Thermodynamic Studies On The Removal Of Methyl Red From Aqueous Solutions	
	ROMDHANE		Using Clays Of Seinane	
354	NASRAOUI	Rawya	Assessing The Risk Of Pb, Zn And Cd In Jebel Ressas Mining Environment	
371	SALHI	Rania	Characterization Of Heavy Metals Of The Mining Disharges : Case Of The Former Jbel Ressas Mine	
			(Ne Of Tunisia)	
374	GHAZOUANI	Nermine	Role Of Saltwater Intrusion In Increasing Salinity Of The Mahdia-Ksour Essef Water Table	
400	ACHOUR	Dhouha	Spatial Distribution Of Organic Pollutants In Surface Sediments From El Bey River Northeast Of	
			Tunisia	

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Topic 3 : Groundwater Exploration & Monitoring			
69	ARBI	Roza	Hydrogeophysics Study Of Oligocene Reservoirs In The Kairouan-Souassi Basin (Tunisian Sahel)
92	SDIRI	Souha	Groundwater Potential Mapping Using Frequency Ratio Probabilistic Model In The High Valley Of
			Medjerda Basin, Tunisia
110	ALOUI	Dorsaf	A Primary Study Of Aquifer Storage And Recovery (Asr) Feasibility In Chegarnia – Sidi Abiche Aquifer,
			Ne Of Sousse Prefecture, Tunisia
114	AZOUZI	Rim	Balance, Trend And Hydro-Dynamism Of The Salinization, Of The Artificial Refill Korba Site (Tunisian
			Oriental Coast)
132	SEEBER	Kristin	Improved Integrated Water Resource Management (Irwm) In The Mornag Area- Engineering
			Component - Artificial Aquifer Recharge
147	CHABAANE	Achref	Delineation Of Groundwater Contamination Plumes Using Electrical Resistivity Tomography:
			Maâmoura, Jebel Ressas And Borj Chakir Cases Study
188	BEN FRAJ	Amina	Geophysical Contribution For The Characterization Of Deep Aquifers And Conceptualization Of A
			Hydrogeological Operating Model: Moghrane- Zaghouan - Bouficha Area
190	DHAOUI	Mohamed	Gravity Analysis For Geometric Insights In Mornag Plaine
192	SEBAI	Amal	The Sebkha Kelbia In Central Tunisia: Is It The Main Outlet Of The Large Plio-Quaternary Aquifer Of
			The Kairouan Plain?
193	LAMOUCHI	Ichraf	Geophysical Mapping Of Hidden Geological Features Under Gaafour-El Aroussa-Bouarada:
			Hydrogeological Implication
194	MESSAOUDI	Souhir	Characterization Of The Cherita Water Table (Mahdia / Tunisia) Using Geochemistry And Geophysics
250	AZAIEZ	Hajer	Deep Groundwater Investigation Using Combined Gravity And Seismic Reflection Methods: Case
			Study Of Ain El Beidha Basin, Central Tunisia
343	MEZNI	Imen	A Comprehensive Study Of The Groundwater Regionalization In Jeffara Basin Using Gis Tools,
			Multivariate Analysis And Geostatistics
Topic 4: Groundwater Modelling & Risk Management			
83	KADRI	Yassin	Hydrodynamic And Hydrochemical Study And Numerical Simulation Of Seawater Intrusion In The
			Mornag Aquifer (Tunisia)
115	M'NASSRI	Soumaia	Identifying Key Controls On The Behaviour Of Soluble Salts In The Sidi El Hani Aquifer Using Reactive
			Transport Modeling
156	CHAIRI	Raja	Impact Of Anthropogenic Activities On Surface Sediment Wadis In The Gulf Of Tunis
163	AMEUR	Meriem	Groundwater Management And Hydrogeological Modeling Of The Sminja-Oued Rmel Aquifer System
			In The Zaghouan District (North-Eastern Tunisia)
241	ZGHIBI	Adel	Assessment Of Seawater Intrusion For Sustainable Groundwater Management: Case Study Of
1	1		Tunisian Coastal Aquifer

#### Saturday, 30 March 2019, 12h:15-13h30

### Keynote Prof. Ralf LUDWIG

Ludwig-Maximilians-Universitaet Muenchen (LMU) Department of Geography



Prof. Ralf Ludwig is Dean of the Faculty of Geosciences and Professor in Applied Physical Geography and Environmental Modelling at LMU's Department of Geography. His research is focused on process-based and spatially distributed hydrological modelling at the catchment scale, data assimilation and model integration for water resources, land use and climate change impact assessment from Mediterranean to subarctic environments. He co-ordinated the FP7-project CLIMB and manages the CLIWASEC cluster of FP7-

projects on Climate Change, Water and Security in the Mediterranean. He leads the WP-SCENARIOS in the FP7-project GLOBAQUA, is chair of the Collaborative Program "Changes in the Hydrological Cycle" of the European Climate Research Alliance (ECRA) and Spokesperson of the Albertan-Bavarian Energy-Environment research network ABBY-Net.

# Assessing global change impacts on surface water and groundwater resources in Mediterranean basins

#### Ralf Ludwig Ludwig-Maximilians-Universitaet Muenchen (LMU)

Water and water-related services are major components of the human wellbeing, and as such are major factors of socio-economic development; yet freshwater systems are under threat by a variety of stressors, including climate and land use change. Water scarcity is one of the most important drivers of change in the Mediterranean region and is commonly associated with inappropriate water management and resulting river flow reductions. The conjoint occurrence of multiple stressors under water scarcity will produce novel synergies and most likely very pronounced effects on freshwater ecosystems.

In this context, land use and land cover as well as climatological conditions can be seen as two main stressors for the quality and quantity of surface and subsurface water. These factors considerably affect the use and availability of water, especially in regions which already experience water scarcity. To assess future conditions, spatially distributed, integrated scenarios to drive various impact models are inevitable. These simulations then assess future conditions of aquatic ecosystems, both in water quality and quantity, and provide decision support.

The presentation summarizes some lessons learned from recent EU-FP7-projects, especially from CLIMB (GA: 244151) and GLOBAQUA (GA: 603629), which focus on climate and land use induced changes for the hydrological conditions and water resources management in the Mediterranean. It will emphasize on a) the interactions of land cover and land use change with water resources management under climate and socioeconomic change and b) their impacts on the hydrology of selected river basins and aquifers, including the flow

regime, water quality trends and surface-subsurface interactions on groundwater behaviour. For all shown cases, projections of future climate conditions originate from the simulations provided through large climate model ensembles. After a thorough investigation of available simulations and an estimation of the uncertainty envelope, a small subset of models was downscaled to represent the regional conditions and provide the climate forcing for the selected case studies.

a) A modeling framework is set up to develop integrated scenarios of changes in climate, land use and water management. These scenarios are based on storylines around various Representative Concentration Pathways (RCPs) and Shared Socio-economic Pathways (SSPs), which are downscaled to the basin scale. The impacts of the SSPs are represented in spatially distributed land use maps developed through the land use change model iCLUE (Conversion of Land Use and its Effects). Changes in land use distribution and water management are taken into account to produce maps of future water demand and availability, highlighting regions in which water scarcity is likely pronounced or critical in the future.

b) The presented case studies embody a variety of hydrological models with different spatiotemporal concepts and complexities. They are applied concurrently to provide benchmarks for uncertainty estimates in hydrological modeling of mid- to far-future periods. The hydrological modelling framework was applied to simulate future hydrological conditions, seeking to identify hot spots of water scarcity in surface and subsurface hydrology. Model intercomparison studies reveal that a) selected hydrological indicators show large uncertainties which propagate into ecological assessments, b) flow ecological assessment are hampered by the lack of reliable reference flow regimes and, c) the simulation of anthropogenic alterations in hydrological models must be improved.

The presentation closes with a critical reflection on the usefulness, applicability and regional transferability of the presented modeling frameworks. It discusses the implications on regional water resources management under water scarcity and climate change, and reflects upon the potential and limitations of such data and methods to support policy on regional and decision making on local levels.

**KEYWORDS**: GLOBAQUA; CLIMB; integrated scenarios; water scarcity; climate change; land use change; flow-regime; water quality; groundwater; water resources management

#### Acknowledgements

The funding for this research through the FP7-projects GLOBAQUA (GA: 603629) and CLIMB (GA: 244151) by the European Commission is gratefully acknowledged.

### **Keynote Prof. Ezio CRESTAZ**

#### Joint Research Centre, European Commission



Dr. Ezio Crestaz is a geologist (Turin Un.), with masters in GIScience and Computer Science (Manchester Metropolitan and Hertfordshire Un., UK). He worked as geophysicist, groundwater modeler and geo-spatial analyst at various brands of ENI (Oil Italian company), since 1986. Operating in the geothermal, mining, water management, environmental protection and remediation fields, he contributed to both local and regional scale corporate and internationally funded (OLADE, UNDP, EC, World Bank) projects, in Italy and abroad. He is currently working as Contract Agent at the JRC (Joint Research Centre) of the European Commission, mainly focusing on WEFE (Water-Energy-Agriculture-Ecosystems) nexus assessment in sub-saharian Africa (ACEWATER2 project). He has been contract professor in groundwater hydrology (Camerino Un., 2006-2007) and GIS

(Urbino Un., 2016), and guest lecturer in GISc (Birkbeck College/UCL, London, 2010-2013). He (co)authored various scientific contributions in groundwater modeling, spatial analysis, spatial databases and applications design and development.

### Geospatial technology advancements towards effective groundwater data and knowledge management

#### Ezio Crestaz Joint Research Centre, European Commission

The talk addresses the challenges and benefits of most recent advancements in geospatial technology to support the design and development of effective groundwater information systems.

Groundwater hydrology characterization, modeling, and management demand for a wide range of expertise, tools, data collection and continuous monitoring. Such a complexity is briefly captured through few groundwater flow and transport modeling case studies addressing water supply, salt water intrusion, and groundwater protection/remediation at regional and local scale.

During the last decades, increasing efforts focused on the design of flexible and effective groundwater spatial systems, aimed at integrating data and tools in a unique framework to facilitate reporting, geo-visualization, analysis, and modeling.

As for data management, the adoption of relational database technology and centralized infrastructures partly overcame the widespread use of proprietary text and binary formats on single-user platforms, improving control over data integrity.

In 1999, the new ESRI geodatabase framework became the leading solution in managing spatial information. Specialized geodatabase models were designed, including the (surface) water centered Hydro and Groundwater ones.

Still, geodatabases revealed major limitations due to their proprietary nature, high licensing and maintenance costs, somehow limiting their widespread adoption. The codification of

spatial information in proprietary binary formats, whether in personal, file or enterprise geodatabases, emerged as a major barrier against integration. Only recently this was overcome through the support of database native spatial data types.

The emergence of advanced OS (Open Source) applications and new native spatial databases represented a major step ahead towards a wider accessibility of geospatial information to all the potential stakeholders (practitioners, users, beneficiaries). Native spatial databases provide their own spatial data types, indexing, advanced SQL, and spatial data uploading facilities. Traditional relational database platforms, as Oracle and PostgreSQL, have been integrated with rich geospatial facilities, turning them to powerful geospatial analysis engines.

The continuous collection of groundwater relevant data through monitoring networks, sampling, and laboratory chemical analyses definitely pose other challenges, as data homogenization, cleaning, tidying and validation, far before data could be loaded to a homogeneous database. All these topics are addressed by the emerging electronic data transfer concepts and their practical implementation, as the EPA (US Environmental Protection Agency) EDD (Electronic Data Deliverables) and EDP (EDD files Processing) tools.

A web R application embedding a PostgreSQL/PostGIS spatial database, designed after the Hydro Data Model, will be used to discuss the concepts above.

Native spatial databases are seamlessly integrated in most OS GIS tools, as QGIS, and easily accessible through advanced statistical and visualization tools (i.e. R through the RPostgreSQL library), while the access using proprietary platforms as ArcGIS still witnesses some relevant limitations.

On the other hand, such an integration is not yet available in most of the advanced groundwater modelling environments, as is the case for GMS and Visual Modflow, embedding OS USGS codes, and DHI-WASY Feflow, tight coupling a GUI with its finite element numerical engine

Still, the presentation of the new built-in Feflow integration with Oracle/PostgreSQL-PostGIS native spatial databases provides the opportunity to better illustrate the benefits arising from the direct access to monitoring data.

Based on this overview, best practice guidelines towards the design and implementation of flexible and effective groundwater information systems are presented.

### Keynote Prof. Hakim GABTNI

Georesources Laboratory, Centre for Water Research and Technologies, Technopole Borj Cedria, Tunisia



Prof. Hakim Gabtni is senior geophysicist scientist, Professor and Georesources Laboratory Head at Water Research and Technologies Center (CERTE), Tunisia. He earned a B.S. degree in Natural Sciences (Geology option) in 2000, master's degree in 2002 (Geology of Sedimentary Basins), Ph.D. in 2006 (Geology/Geophysics), and HDR in 2012 in Geology/Geophysics from Tunis El Manar University. His interests include gravity and aeromagnetic investigations of sedimentary basins, integrated Geoelectrical techniques (DC Resistivity, Electrical Resistivity Tomography & Time-domain Electromagnetic) to

investigate geothermal plumes, karst systems and complex alluvial aquifers and also near surface geophysics applications (microgravity, seismic refraction, MASW, etc.). Hakim GABTNI teaches also Geophysical methods courses and field geophysical prospection sessions for Master degree students at the Faculty of Sciences of Tunis, University Tunis El Manar, Tunisia. He is the author of several papers in international refereed journals.

### Spatialization of Geophysical Information at different Scales for the Knowledge of Deep Groundwater/Geothermal Reservoirs

#### Hakim GABTNI

Co-authors (Alphabetical authorship): Achref Chabaane, Belgacem Redhaounia, Chrifa Meftahi, Dhekra Khazri, Hajer Azaiez, Ibtissem Mechergui, Ichraf Lamouchi, Marwa Djebbi, Meryem Ben Farhat, Mohamed Dhaoui, Mourad Bedir, Oussama Kortas, Sana Ayari

The knowledge of the spatial configuration and heterogeneity of Subsurface Groundwater/Geothermal Reservoirs is a crucial information for a sustainable management of resources. To obtain this information, potential field geophysics methods can help and be useful at the scale of a sedimentary basin. Gravity & Magnetic surveys can explore large areas in Tunisia above ground quickly and inexpensively to highlight structuring, geometry and continuity of deep groundwater / geothermal reservoirs (or example to investigate the geothermal gradient in the context of low enthalpy by using the determination of the Curie Point Depth). The conversion of the geophysical information into physical properties via advanced data processing and analysis remain a fundamental challenge.

We propose also different approaches and study cases of Geoelectrical and seismic applications to understand the Fine-scale structure (alluvional reservoirs distribution, Geothermal plumes along fault suture, Karst hidden features etc.).

**Key Words:** Spatialization, Geophysical, Information, Scales, Knowledge, Groundwater, Geothermal, Reservoirs

### Keynote Prof. Wolfgang KINZELBACH

ETH Zurich, Switzerland



Prof. Kinzelbach was born in 1949 in Germersheim, Germany. He studied physics at the Universities of Mainz and Munich. In 1972, Stanford University, he switched at to environmental engineering, in which field he earned his doctorate from the University of Karlsruhe in 1978. His professional activities have taken him to Maiduguri, Nigeria, the Nuclear Research Center in Karlsruhe, and the Environmental Research Institute of the Academia Sinica in Beijing. In 1988 he was appointed full professor of Technical Hydraulics and Hydrology at the University of Kassel, in

1993 full professor of Environmental Physics at the University of Heidelberg, and in 1996 full Professor of Hydromechanics and Groundwater at ETH Zurich. Since 2014 he is retired but still heading a major project on groundwater management in China.

His research focused on flow and transport processes in the environment with practical applications in groundwater resources management, pollution control, aquifer remediation and nuclear waste isolation. He is a worldwide known expert on groundwater modelling. His current main interest is sustainable water resources management in arid and semi-arid regions, mainly in Africa and China. He was awarded the Ehrensenator Huber Prize by the University of Karlsruhe, the European Prize of the Koerber Foundation, the Software prize of the German Federal Minister of Research, the Henry Darcy medal of the European Geophysical Society, the Muelheim Water Award and the Saudi-Arabian Prince Sultan International Prize for Water. He is a fellow of the American Geophysical Union, distinguished affiliated professor of Munich University and scientific advisor of the Chinese Geological Survey.

#### Role of groundwater models in sustainable groundwater management

Wolfgang Kinzelbach<sup>a</sup>, Yu Li<sup>a</sup>, Beatrice Marti<sup>b</sup> <sup>a</sup>ETH Zurich, Switzerland, <sup>b</sup>Hydrosolutions, Zurich

With growing groundwater demand for irrigation, unsustainable practices of aquifer use are increasing worldwide. The most prominent among them is the overpumping of aquifers. Out of the global groundwater abstraction of 1000 km<sup>3</sup>/a, about one quarter is not replenished by recharge any more. While aquifer depletion gives a feeling of abundance of water and consequently boosts food production, negative consequences of declining groundwater levels include increased pumping cost and irreversible damage such as soil subsidence, seawater intrusion, and die-off of groundwater dependent ecosystems. This development has to be stopped by proper management. Not only low groundwater tables require

management. High groundwater tables are also undesirable as they lead to soil salinization under arid conditions.

To determine what is needed to return to sustainable use of an aquifer system, some methodology is required, which provides the capacity to project aquifer behavior under alternative management measures or lack thereof. Due to the inertia of groundwater bodies this methodology must be based on groundwater models. They present spatially resolved water balances including all recharge and discharge fluxes and allow to compute the resulting state of the piezometry and its temporal development. The sustainability of a management strategy can be tested by running the model under assumed future stresses to the long time limit. The long-term solution then has to be analyzed with respect to sustainability requirements. Given the fact that parameters and especially future drivers of the systems are uncertain, the results have to be subject to an uncertainty analysis. The goal of modelling is to propose robust management solutions for aquifers systems. This concept is illustrated by an application to the groundwater basin of the mid-reach river oasis of the Heihe River in Gansu, China.

The Heihe mid-reach basin is a highly productive agricultural area. As rainfall is only about 100 mm/a agricultural production relies completely on irrigation. Ever-increasing water withdrawal from the river for irrigation led to the drying up of the terminal lake of this inland river and the die-off of riverine forests of *populus euphratica* along its lower reach. In 2000, the state council decreed that about half of the river inflow has to be released to the downstream. To compensate for losses of surface water, farmers turned to groundwater, which led to the development of two large cones of depression. Initially, overpumping only reduces groundwater storage locally and is felt through increased pumping cost. But as a new system state is approached, the river flow is diminished in two ways: Groundwater, which initially drained to the river, now ends up in pumps, while pumping wells close to the river will abstract river water by induced bank infiltration. If the reduction of river water abstraction by irrigation canals is just compensated by pumping more groundwater, the criterion for ecological release will still be violated as long as the total water use is not decreased.

A groundwater model, containing a simplified river model, was constructed and calibrated with historical data and then used in determining an optimal strategy of conjunctively using the total available water resources in space to satisfy sustainability criteria. This optimization involves multiple objectives, which are partially opposed to each other. Therefore only a set of Pareto-optimal solutions can be proposed. The set can be evaluated with respect to the required decrease in total water use and robustness. One solution is further illustrated. A stochastic model assimilating past observation data shows the uncertainty in the development under the uncertainty of the development of climate.

While a model only proposes options, real management has to take decisions on technical and administrative levels to implement one of them. Practical results through strict management have already been achieved. In Luotuocheng irrigation district, the district located on the largest groundwater depression cone, smart water meters with real-time connection to a server, were introduced. At the same time water rights were distributed to farmers and a water price was set, effectively making a cubic meter of water twice as expensive as before, when only electricity cost of pumping had to be paid. Wells equipped with smart meters are operated with a swipe card, which contains the prepaid water quota. The surface water supply was strengthened and subsidized drip irrigation equipment has been distributed. All these measures combined have decreased the rate of groundwater table decline from 0.6 m/a to 0.2 m/a. This is an encouraging result. The model indicates that the neighboring irrigation district of Sunan has to follow up with similar efforts to reach the goal of stopping further water level decline in the depression cone area. The example also shows that the reduction of water use is a difficult task, as it is connected directly to the livelihood of farmers. It requires the farmers' cooperation. A stepwise process of enforcement quota, subsidies for good practice and modernization of irrigation showed to be effective. At the same time expansion of agricultural area had to be avoided under any circumstances to avoid a rebound effect.

## **ORAL SESSION**

# TOPIC1: Global Change & Groundwater

### Impact Of Land Management Scenarios On Groundwater Recharge Modelling In A Semi-Arid Catchment

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**Abstract:** The knowledge of groundwater resource potential is necessary for informed management decisions, in water-limited regions. Although recharge plays a key role in controlling groundwater system, much doubt subsists concerning the relationships between groundwater recharge and its governing factors. In fact, topography, land cover, soil textures, land management and hydro-meteorological conditions are among the main elements to be accounted for groundwater recharge.Therefore, in this study, we focus on assessing the impact of different land management practices scenarios on groundwater recharge for the Sarrath catchment North Western Tunisia. The Soil and Water Assessment Tool (SWAT) hydrological model is used to estimate this component.

The model calibration and validation were performed on a monthly time steps. Results indicated that SWAT model was efficient in simulating water flow in a complex semi-arid catchment showing a good level of accuracy given by a Nash coefficient (NSE), a determination coefficient (R2) and a percent bias (PBIAS) with the respective values of 0.80, 0.78 and -13.22 %.

Different best management scenarios were developed: contour farming, reforestation, parallel terraces and streambank stabilization. The proposed scenarios were represented by modifying the relevant parameters in the model and were simulated individually as well as in combination to reflect the impact of changing land management practices on groundwater recharge.

Results revealed that the implementation of individual scenarios reduced slightly runoff and as a result increased the aquifer recharge component. The most efficient scenarios are those using combined land management practices. A specific interest was given to sub-basins contributing to aquifer recharge.

**Keywords:** Groundwater recharge; land management scenarios; Sarrath catchment; SWAT model



### Impact Of Climatic And Anthropogenic Scenarios On The Groundwater Management Of Meguellil Watershed Using The Weap Model

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**Abstract:** Population growth, rapid urbanization and industrialization, expansion of agriculture and tourism, as well as climate change, are putting increasing pressure on water resources. Therefore, a sustainable management of all available water resources and meeting as much as possible all water demands, is crucial. The Merguellil watershed, situated in the center of Tunisia, represents exactly this state of fact where the agriculture is the main consumer with about 80% of the total water resources because of the continuous increase and intensification of irrigated area. The surface water can satisfy a very low portion of this demand; consequently, the groundwater is overexploited.

To analyze the actual and future water balance of the Merguellil watershed, and to identify critical trends and thresholds and effective solutions, a WEAP (Water Evaluation and Planning system) application has been developed. It utilizes a constrained optimization algorithm to allocate water among competing demands in a basin.

The period 2001 - 2013 is considered as the reference data base which represents the basic definition of the water system as it currently exists, and forms the foundation of all scenarios analysis. The impact of two climatic scenarios on the groundwater resources that represent the increase of temperature until 2050, were tested. Moreover, three anthropogenic scenarios were compared to the reference one. The first one tests the increase of irrigated area in the kairouan plain deduced from the land use maps obtained by multi dates remote sensing data. The second one describes the change of 70 % of the actual land use to arboriculture. The last one represents the progressive decrease of the water transfer to coastal zones (15% per yer to become equal to zero in 2030).

Merguellil WEAP model demonstrates how different management options can be evaluated and compared for future climate, land use change and technology development scenarios.

Keywords: Climate change, land use chnage, groundwater management



### Hydrological Modelling Of The Siliana Catchment: Application Of SWAT, Sensitivity And Uncertainty Analysis

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**Abstract:** Sustainable management of water resources in the Siliana catchment relies on comprehensive analysis of interactions between surface and groundwater resources. Indeed, both groundwater quality and quantity depend on surface water that recharges the groundwater system. Therefore, it is important to better understand the surface water processes first before undertaking the groundwater system of the catchment. Hydrological models are valuable tools to understand the hydrological processes of the Siliana catchment. We implemented the SWAT (Soil and Water Assessment Tool) hydrological model with available local data (e.g. climate, land use and soil) and calibrated its parameters against daily flow measurements while evaluating both SWAT performances and uncertainty. Based on 500 iterations with different sets of parameters generated using the Sequential Uncertainty Fitting program (SUFI-2), almost half of them were identified as acceptable with the Nash and Sutcliffe coefficient (NS) ranging between 0.5 and 0.86. These statistics suggest good model performance to simulate the hydrological regime of the Siliana catchment. The sensitivity analysis revealed that the CN2 (Curve Number) and soil parameters related to surface water component are the most sensitive. This suggests that the hydrological functioning of the watershed is dominated by surface runoff (90%) while only a very limited portion of the water balance is allocated to recharge.

Keywords: Siliana catchment; hydrological modelling; SWAT; SUFI-2; Uncertainty



#### Puquios And Foggaras – Dialogues Between Two Historical Water Cultures

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**Abstract:** Underground aqueducts have played a vital role in groundwater extraction since ancient times. Underground aqueducts run across the desert like the body's veins, bringing life and prosperity to the people who used to live off the water flowing down them. This technology is the focal point of the genesis of Civilization in some parts of the world. The harsh environment drove people to invent the technology of these structures and the knowhow revolving around it.

These structures, which are called in Peru puquios, have emerged in response to a long period of drought in the Nazca region around the year 560 A.D. In Algeria these galleries are called foggaras and are situated in agriculture zone in the Western Sahara and appeared to combat adverse climate change scenarios after the last Pluvial starting from the 20<sup>th</sup> century BC. These underground aqueducts have always enjoyed compatibility with nature as a practicable means for the rational abstraction of groundwater, proving that our forefathers guaranteed the sustainable balance of water resources through their wise policies.

Unfortunately, nowadays we disturbed this wise practice through excess mining of water using modern technology such as deep wells and electrical pumps which are a threat to groundwater resources in arid and semi-arid zones, and now we can clearly observe a fast decline in water tables throughout those regions. Therefore, underground aqueducts as the main means of sustainable utilization of these aquifers should be taken into consideration.

It is time for society to believe in the great potential our traditional know-how has. It is not wise to give up all modern technologies and revive and use only traditional methods, but it is quite wise to adopt the sustainable relationship which has always existed between the environment and elements of the traditional production system.

Keywords: Groundwater; Arid, Galleries; Natural bases solutions



### Dynamic Of A Coastal Aquifer Under The Oceanic Tidal Influence : Case Of Nouakchott (Mauritania)

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**Abstract:** Piezometric level variations of a coastal aquifer under tidal influence permit a hydrodynamic characterization on this aquifer. The present study was based, firstly on the observation and the analysis of the water level fluctuations in the Quaternary aquifer of Nouakchott (Mauritania), and, secondly, on comparing these variations with those of the Atlantic Ocean tide.

The recordings were made in two piezometers located at 230 m and 460 m from the coast. Data were collected during the period July 2017- July 2018 due to one measurement every two hours. Originality of this study consisted of the period recording duration (one year of measurements).

The results showed a tidal influence on the water level in the piezometers in daily and synodic periods. We observed that groundwater level variations followed the fluctuations of the ocean. Recordings showed a rise of 6 to 15 cm during the period attributed to the risen sea level. These results, combined with measurements on 13 other piezometers, also allowed us to determine the distance at which the tidal wave is damped.

The tidal influence contributes to the water table rise under the city of Nouakchott, already saturated by the water pipes losses, domestic discharges and rains.

Keywords: Nouakchott; Coastal aquifer; Tidal effect; Groundwater level



### Study Of Water Resources Vulnerability In The Souss Massa Region At Cerle Level

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Abstract: Morocco, a bioclimatic and ecological transition country, has fragile water resources, threatened with rapid degradation in the coming decades. The Souss-Massa region, located in the south-west of Morocco, is among the regions that suffer the most from water stress. The area undergoes a long periods of severe drought because of its arid climate with low and irregular rainfall in time and space. Moreover, the economy of the region is mainly based on agriculture which consumes more than 90% of the region's total water resources. As a result, surface and groundwater resources have become insufficient with regard to the demand. Faced with this situation, the agricultural sector has moved towards groundwater depletion, which plays an important role in the socio-economic development.Current water related challenges and water scarcity problems, caused by imbalances between supply and demand, high population growth, water pollution and inadequate funds for the exploitation of available resources, have rendered integrated water resources management a necessity. Treated wastewater has been proven to be a reliable alternative water resource that can play a vital role in integrated water resources management, addressing both: water demand and supply, wastewater disposal and environmental protection.

This work focuses on the study of the water resources vulnerability in the Souss-Massa region by developing a map which presents the vulnerability of water resources throughout the region. Thus, to identify the most vulnerable zones, the main indicators determining their vulnerability and taking into account the parameters of their exposure, their sensitivity and their ability to climate change adaptation.

**Keywords:** Vulnerability; Water resources; Cercle; Water Stress



## **ORAL SESSION**

# **TOPIC2: Groundwater Quality &**

## Pollution



### Assessment Of Groundwater Vulnerability In The Takelsa Aquifer (Northeastern Tunisia) Using The Susceptibility Index Method

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**Abstract:** Mapping the groundwater vulnerability is an important step especially when the groundwater is subject of a possible contamination. In fact, the coupling of the vulnerability map with the hydrogeologic properties can be used by managers and decision makers to identify the greatest contamination susceptibility areas and so to preserve the groundwater quality. For the Takelsa aquifer, subject of this research work, agricultural land and orchards are the major practices. Most of the time, these cultures require large amounts of water, fertilizers as well as pesticides to increase production. The use of these fertilizers and pesticides may induce the groundwater contamination, which can restrict the regional economic development. Under these conditions, we developed a pollution vulnerability map by using the GIS tools and the Susceptibility Index method. The SI method is a parametric vulnerability method designed to evaluate the specific vertical vulnerability to pollution caused especially by agricultural activities. It is based on five parameters: water depth, recharge, aquifer media, topography and land use. The results show that the vulnerability of the study area varies between low, to very high SI index, with 90% of the area characterized by moderate to very high pollution susceptibility. Areas with high pollution susceptibility are characterized by a low water table depth, flat slope, the presence of sandy soils, high recharge rate and a very developed agricultural activity (irrigated perimeter). This latter appears to be a major factor in assessing the vulnerability of the Takelsa aquifer. Low vulnerable areas, that represent 9% of the study area, are related to the forests and semi natural zones. The obtained vulnerability map was validated using salinity, chlorides and sodium concentration. In fact, a good correlation between the concentration of the chemical elements and the SI index was shown. A return of irrigation water can be responsible for these high values.

**Keywords:** Groundwater vulnerability; SI method; GIS; groundwater contamination; Takelsa aquifer



### Groundwater Quality Assessment In Urban Environment: Case Of Study Sidi Bouzid City

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Abstract: Urbanization has several adverse repercussions on the hydrological cycle due to great demands of land and water for housing, transport, health, agriculture, education etc. This study aims to investigate the impact of urbanisation on groundwater quality in the Sidi Bouzid city. A total of 32 groundwater samples were collected and analyzed . The spatial distribution of groundwater quality parameters were created using geographic information system (GIS). Interpretation of physicochemical data revealed that cations(Na<sup>+</sup>, K<sup>+</sup>, Ca<sup>2+,</sup> Mg<sup>2+</sup>) and anions (HCO3<sup>-</sup>, Cl<sup>-</sup>, SO4<sup>2-</sup>, NO3<sup>-</sup>) exceed the permissible limits of drinking water standards prescribed by the World Health Organisation (WHO) in all part of the city. The higher total dissolved solids (TDS) concentration was observed in the north-eastern part of the study area, downstream the city. The hydrogeochemical evaluation of the groundwater demonstrated with the Piper trilinear diagram indicates that Ca-Mg-SO4 is the dominant water type. The quality of groundwater has been assessed by two indices; the first one is the Water Quality Index (WQI) based on the weighted arithmetic mean, it indicates that more than 62 % of the water samples fall within the "poor" index, 25% within "very poor" and 9% within "unsuitable for drinking", and only 3% of water samples fall within "good water". The second one is the Groundwater Quality Index (GQI)based on GIS environment; it indicates the medium quality of water with values ranging between 58 and 62. This study highlighted that groundwater under the Sidi Bouzid city is unsuitable for drinking water and should be used with precautions for other purposes.

Keywords: Urbanization; Groundwater quality; Sidi Bouzid; WQI; GQI



### Impacts Of Domestic Treated Wastewater On The Shallow Aquifer Of The Kairouan Plain (Central Tunisia)

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**Abstract:** The Kairouan plain aquifer in Central Tunisia is a typical example of overexploited aquifers in semi-arid and arid regions. The main consequence is a general drop in the water table level (up to 1 m per year). In such a context of heavy water scarcity, the future of wastewater is an important issue. The city of Kairouan is by far the largest urban area of the region. Since 2008, its wastewater has been led to the treatment plant of Dhraa Tammar. The treated wastewater (TWW) is later mainly (89 %) released into the Sebkha Kelbia and also exploited for irrigation (11 %). During the last five years (2012-2016), the average volume of TWW was about 5.5 hm3 y<sup>-1</sup>. This study presents the first hydrogeological assessment of changes in groundwater recharge to the phreatic aquifer because of the release and reuse of the TWW. It exploits the piezometric and physicochemical survey in 15 wells complemented by the analysis of six TWW samples collected during 2 sampling campaigns conducted in February and April 2017. The shallow groundwater has a natural high salinization, higher than 20 g.L<sup>-1</sup> in most surface wells. The TWW had a high content in organic matter (BOD5 and COD), nutrient elements (NO2<sup>-</sup> and P), a high SAR and an important bacteriological load (coliforms and streptococci) in both field campaigns. Consequently, the TWW does not have the required physicochemical and microbiological quality fixed by the Tunisian standards for the release in the natural environment and for irrigation. The TWW infiltration has induced a local improvement in the groundwater mineralization (lower than 10 g.L-1), especially for wells located in the rejection site and the Dhraa Tammar irrigated scheme. Nevertheless, a high fecal contamination (250-450 germs per 100 ml) was detected in the aquifer mainly in these two areas. In parallel, the local hydrodynamics benefits from the TWW infiltration: the water table has risen by 1 to 1.5 m in the release area during the last three years (2014-2016).

**Keywords:** Overexploited aquifer; Artificial recharge; Treated wastewater reuse; Biological contamination; Piezometric level.



### Investigation Of Sidi Elheni'S Aquifer Salinization (Central East Of Tunisia) Using Geophysical Methods And Geochemical Tracers

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**Abstract:** The groundwater flow system of Sidi El Heni is located in the central eastern region of Tunisia, in the region of Mahdia. The aquifer is characterized by high salinities which limit its safe use in irrigation and drinking water purposes. The objective of this work is to delineate saline groundwater plumes and to understand the origin and mechanisms of salinization using a multi-disciplinary approach based on geophysical investigations and geochemical tracers. Seismic reflection profiles and gravimetric data were used to understand the different structure in the subsurface and Plio-Quaternary reservoir. They proved the existence of an overlapping tectonic node stuck between the complex structures and major accidents causing an effusion of Triassic salt in weakness areas. The path of salt effusion starting along faults can reach the groundwater flow system in Sidi Elheni region. The geochemical study confirmed that the waters at the NW and the center of this aquifer are highly saline and characterized by an intense mineralization (Ca<sup>2+</sup>, Na<sup>+</sup>, Mg<sup>2+</sup>, Cl<sup>-</sup>, SO4<sup>2-</sup>, HCO3<sup>-</sup>). The groundwater facies is calcium sulphate with sodium chloride. Furthermore, aquifer mineralization is mainly caused by rock-water interaction via the dissolution of halite and gypsum which are abundant in this area.

Keywords: Sidi Elheni aquifer; salinization; geophysics; geochemistry


### Vulnerability Assessment Using Combined Remote Sensing And Gis. Case Study Of The Quaternary Aquifer Of Hajeb Layoun-Jelma Basin (Central Tunisia)

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Abstract: Groundwater is a good source for human water requirement because its low susceptibility to pollution, but this resource can be also affected by different hazards, such as contamination and pollution. So the prevention and the protection of this resource to the contamination are prominent task in the groundwater management. The central Tunisia contains important aquifers with groundwater resources mainly used for agricultural and drinking purposes. Facing the increase of water demand and the economic development in the region, the preservation of groundwater resources is vital. The Hajeb El Ayoun-Jelma multilayer aquifer which is among the important aquifers in the central of Tunisia is exploited since the 70s. The overexploitation of this groundwater and the agriculture activities led to the degradation of the water quantity and quality. The multilayer aquifer system covering an area of about 1380 km<sup>2</sup> consisted of three aquifer layers: the Cretaceous, the Miocene, and the Mio-Plio-Quaternary aquifers which coincide with the following local formations (from the bottom to the top): Abiod, El Gueria, Ain Grab, Béglia, Segui, and Quaternary deposits. This work aimed to assess the vulnerability in 2017, of the shallow aquifer of Hajeb El Ayoun Jelma basin, to pollution, using the Susceptibility Index method, based on combined remote sensing and GIS. Mapping was done using Arc GIS software. The parameters used as input data are Depth to water table, net aquifer Recharge rates, Aquifer media, Topographic and the land use of the study area. The land use is derived from the satellites images acquired by two different satellites sensors of Landsat 8 including Landsat OLI and Landsat 8 TIRS. The vulnerability map shows three classes: highest (35%), high (19%), low (46%), the validity of this method to agricultural pollution was verified by comparing the distribution of salinity in the aquifer with the distribution of the vulnerability classes.

Keywords: Hajeb El Ayoun Jelma basin; vulnerability; salinity; SI method; Gis



# **ORAL SESSION**

# TOPIC3: Groundwater Exploration & Monitoring



### New Hydro-Geophysical Investigations, Tectonic And Lithostratigraphic Control Of Hydrogeologic Deep Aquifers Reservoirs Systems In Eastern Tunisian (North Africa)

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**Abstract:** Tunisia as southern Mediterranean semi-arid to arid country is facing a water deficiency. Water supply and storage do not respond to the demographic and economic growth and demand. In addition, only 5 109 m<sup>3</sup> of water from 35 109 m<sup>3</sup> per year renewable rain water supply are retained and remobilized as surface, dam and groundwater resources. A hydrogeologic research project has been launched since 2002 to investigate new deep aquifers water resources by new multidisciplinary approaches based on geophysics and hydrogeology.

Seismic reflection, gravity, electric tomography and geochemical field and laboratory studies undertaken for the purpose to investigate new deep carbonate and sandstone reservoir of unconfined and semi-confined aquifers known as proven hydrocarbon and reservoir aquifers elsewhere in Tunisia.

Eastern Tunisian margin of Kairouan and Sahel regions is structured in subsurface as a mosaic of kilometric Mesozoic folded Rift Horst platforms anticlines and Grabens synclines gutters, limited by deep-seated E-W, N-S, NE-SW and NW-SE strike slip flower faults.

Seismic reflection sections, hydraulic and petroleum wells as well as lithostratigraphic and hydrogeologic correlations have highlighted the identification and the tectonic structuring of Mesozoic fractured carbonate and multi-layered Cenozoic sandstone reservoirs horizons.

Reservoirs parameters of fractured carbonate and sandstone porosities range respectively from 8 to 15 % and from 20 to 40%, a permeability varies from 500 to 1100 md, a transmissivity from 0,1 to  $30*10^{-3}$  m<sup>2</sup>/s, a salinity from 0.5 to 5 g/l and the storage coefficient of confined aquifers from  $10^{-3}$  to  $10^{-4}$ .

Subsurface structuring of reservoir levels put in evidence for the first time the close relationship between the later and the hydraulic recharges and flows pathways. This had led to calculate and estimate geologic and water reserves as billions of cubic meters that should be a strategic reserves for actual and future in Tunisia.

**Keywords:** Tunisia; Hydro-geophysics; Reservoirs; Tectonics; Reserves



### Identification Of Recharge Conditions And He Sources In The Djeffara Aquifer System (Southeastern Tunisia)

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**Abstract:** The deep groundwater of the Djeffara aquifer constitutes the main water resource in southeastern Tunisia. This aquifer, logged in the sandstones deposits of the Miocene and the limestone formations of the Upper Cretaceous, has been extensively exploited for water supplying and agriculture irrigation since the 1970s. A proper estimation of groundwater residence time, recharge conditions and hydrodynamic would be very useful to calibrate existing groundwater flow models. In this investigation, environmental isotopes (2H, 18O, 13C, and 14C) combined with noble gas concentrations and 3He/4He ratios were used, as the first step for the assessment of dynamics and age of paleo-groundwater in southern Tunisia using long-lived radionuclides. Environmental stable and radioisotopes have provided useful information about the origin, the recharge mode and geochemical processes controlling groundwater quality. The 14C corrected age confirms that the studied groundwaters are confined and most of these resources was recharged during humid periods of Holocene and Late Pleistocene.

As conservative tracers, the dissolved atmospheric noble gases (He, Ne, Ar, Kr, and Xe) in groundwater water were used to investigate the origin and groundwater recharge conditions. Based on 4He concentrations and the corresponding 3He/4He and Ne/He ratio ratios, the dissolved helium in CT groundwater was identified to be a mixture of atmospheric with radiogenic helium. Helium-4 (4HeTerr) contents originating from terrigenic sources calculated the Closed Equilibrium (CE) model, are increasing with residence time and flow path, which can be explained entirely by accumulation of in situ produced radiogenic He. Ongoing investigation is focusing on the determination of the Djeffara groundwater residence time using 81Kr and 4He.

Keywords: Environmental isotopes; noble gases; paleoclimate; Helium-4; Tunisia



### Mapping Renewable Groundwater Potentiality By Remote Sensing And Geophysical Techniques At Al-Shiyhana Region, Ksa

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**Abstract:** Water security is one major challenge that face KSA. However it has the highest level of water consumption which mainly relies on groundwater resources. This work aims at mapping groundwater probabilities using an integrated model based on remote sensing and geophysical data, the latter was employed to validate the model results. The remote sensing data used to generate several physiographical layers, as semi-quantitative variables that contribute to groundwater recharge and accumulation. The Shuttle Radar Topography Mission used to extract topography, slope, curvature, Topographic Witness Index, and drainage density layers. The Landsat-8 image utilized to create the lineament density Land Use/Land Cover, and near-surface thermal anomaly variables; while the Tropical Rainfall Measuring Mission employed to construct the accumulated precipitation layer. Each layer of these variables was converted to weighted layer based on their contributions in groundwater recharge through infiltration and percolation processes. A GIS overlay analysis based on the Simple Additive Weight (SAW) method was applied for generating a Groundwater Potential (GWP) map. The GWP has classified the study area into five classes ranging from very high to very low groundwater potentiality zones. These zones were investigated using geophysical tools, including Magnetotelluric (MT) method to validate the remote sensing results. MT data are recorded in the time-domain, with the electric fields measured using dipoles 50-200 m in length that are connected to the ground with nonpolarizing electrodes. MT time data are processed to yield frequency-domain estimates of apparent resistivity and phase. In conclusion, the integration between remote sensing data and geophysical tools can provide a powerful tool to explorer renewable groundwater resources in arid lands, especially in the Arab World.

Keywords: Remote sensing; GIS; Groundwater; Magnetoteeluric; Al Muzahaimiah



### Hydrogeophysical Characterization Of Groundwater Recharge By The Leakage Of The Lebna Dam (Cap-Bon, North Of Tunisia)

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**Abstract:** In semiarid countries, dams serve to regulate water flows, to trap sediments, and to control aquifers recharge. Recharge is frequently an undesired process discovered after construction. Since its construction in 1986, Lebna Dam, for instance, has illustrated a decrease in its lake reservoir and, at the same time, witnessed a discharge by groundwater flows to the neighboring aquifer. Little work has been done on processes and the quantification of these flows and their effects on aquifers. This paper suggests new modellings for the processes of concentrated leakage and the dam/aquifer relation. Our approach combines hydrological lake balance computation, geological field observations, and geophysical resistivity investigation.

The analysis of the evolution of reservoir water levels, from 1990 to 2017, highlights many stocking and destocking periods. Infiltration flows estimates are based on calculations during dry seasons when no inflows take place and decreasing reservoirs levels are linked to evaporative fluxes. The calculation of the hydrological balance over the last 27 years shows that an estimated volume of  $3.7 \text{Mm}^3 \text{ y}^{-1}$  has been infiltrated from the Lebna Dam reservoir to the groundwater downstream. The geological outcrop mapping of Lebna Dam shows that permeable layers of sand and sandstone on the lake southern banks are distributed from 16m to 18.04m altitudes. Seepage quality is related to the permeability of the geological material that the water reaches on the banks.

A geophysical survey based on 11 electrical resistivity soundings in southern bank reservoirs was performed in order to follow the lateral continuity of the leakage zones. The interpretation of these geophysical data and the available logging and piezometric data are used to characterize the leakage geometry of the reservoir lake towards the coastal aquifer. Evidence collected allow to conclude that the concentrated leakage occurs in downstream part and especially on the right bank of the dam.

Keywords: Concentrated leakage; resistivity; Hydrological balance; Dam; Characterization



### Application of GIS based data driven Frequency Ratio and Evidential belief function models for groundwater potential mapping in Ghardimaou aquifer, Medjerda basin

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**Abstract:** Resolving the potential groundwater yield zonation occurring at depths of several hundred meters has been an important and challenging objective of the hydrogeological research in Medjerda basin. The purpose of this study is to investigate the application of the Geographical Information System -based probabilistic models of Frequency Ratio (FR) and Evidential belief function (EBF) in groundwater potential mapping of Ghardimaou aquifer located in the high valley of Medjerda basin. Moreover, this study includes the analysis of the spatial relationships between Transmissivity (T) and various hydrological and morphometric conditioning factors derived from various data sources such as satellite imagery, topographic and geological maps, and associated database. About 86 transmissivity data were collected from drilling wells pumping tests. Further, these selected data were randomly divided into a dataset 70% (60 wells) for training and the remaining 30% (26 wells) was applied for validation purposes. A total of thirty groundwater conditioning factors that affect the storage of groundwater occurrences were used such as elevation, slope, curvature, stream power index (SPI), topographic wetness index (TWI), drainage density, lithology, lineament density, land use, soil, rainfall... Subsequently, groundwater potential maps were produced using FR, and EBF models and classified into five zones as very high, high, moderate, low, and very low.

Finally, the receiver operating characteristic (ROC) curves for both the groundwater potential models were constructed and the areas under the curves (AUC) were computed. From the analysis, it is seen that the FR model (AUC= 82.5 %) performs better than EBF model (AUC=65.08 %). The results of groundwater potential maps can be helpful for future planning in groundwater resource management and land use planning.

**Keywords:** Groundwater potential map; Frequency Ratio; Evidential belief function; Ghardimaou aquifer; Medjerda



### Isotopic And Hydrochemical Features Of Geothermal Water From Northwestern Algeria

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**Abstract:** In northwestern Algeria, numerous geothermal reservoirs are located in fractured carbonate rocks (Jurassic limestone and dolomite). The region, which belongs to the Alpine-Magrebide belt, is bordered by the Mediterranean Sea and characterized by some volcanic activity during Miocene and Plio-Quaternary.

Thermo-mineral waters in this part of Algeria show wide ranges of salinity (up to 68g/l) and temperature (up to 69°C), associated, in some areas, with CO2 outgassing and strong H2S smell.

An environmental isotope and hydrochemical study was carried out to better understand the parameters that control the functioning of the hydrothermal systems: water-feeding conditions, possible mixings, acquisition processes and origin of mineralization, and deep reservoir temperature using geothermometry. For that purpose, 25 thermal-water samples and 12 cold-water samples were collected from springs and boreholes, for chemical and isotopic ( $\delta$ 180 and  $\delta$ 2H of water) analyses.

The results show that cold spring waters are of Ca.Mg-HCO3.(Cl). type, whereas thermal waters are mainly of Na-SO4.Cl and Ca.Mg-.HCO3 types. Most of the high-salinity spring waters probably acquired their characteristics by leaching evaporite minerals from Triassic (or locally Messinian) formations. For few coastal springs, a limited contamination by seawater could contribute to this salinity.

The water stable isotope contents indicate that both thermal and cold groundwaters are essentially of meteoric origin, with limited effects of evaporation.

**Keywords:** Thermal water; Salinity; Hydrochemistry; Water stable isotopes; Northwestern Algeria



### The Use Of Environmental Isotopes And Krypton-81 To Describe And To Date Continental Intercalaire Paleogroundwater (Southern Tunisia)

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**Abstract:** In the south of Tunisia, located in arid climate region, socio-economic development is mainly liable with deep groundwater resources and particularly the Continental Intercalaire (CI) aquifer system, which constitutes one of the most important aquifer in the North Western Sahara Aquifer System (NWSAS) in Africa; covering more than one million of km2. This aquifer system is mainly confined, poorly recharged but intensely abstracted. Efficient management of this paleogroundwater relies on accurate data such as recharge/discharge rate, water flow dynamics and mean residence times for the assessment of the reliability and potential of deep aquifers as a major source of water supply in medium and long-terms groundwater dynamics.

In this investigation, environmental isotopes (2H, 18O, 13C, and 14C) were combined with long time lived radionuclide (81Kr), present in very old groundwater and considered as an excellent tool, in order to give greater constraint on the groundwater residence time in the CI aquifer system.

The results of the environmental isotopes demonstrate that most of the water in the CI, and particularly in southern Tunisia, is non-renewable and recharge occurred under climate conditions that prevailed thousands of years ago. This result is intensely supported by 14C measurements where the most of analyzed samples are below the detection limit, indicating that carbon-14 correction models residence times are greater than 35 ka. The range of estimated ages using 81Kr contents is from 150 kyr to 600 kyr, and is evidently much older than the 14C ages, confirming that this method is not appropriate for dating CI groundwater.

Keywords: Krypton 81 (81Kr); carbon-14; noble gas; paleogroundwater; CI Tunisia



#### Estimation Of Groundwater Reserve In The Zambezi River Basin

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Abstract: Groundwater plays an important role as a source of water for various socioeconomic uses and environmental requirements in the Zambezi river basin. Hence it is important to know its availability and adequacy in space to inform decision making for sustainable water management practices. This study evaluates the groundwater reserve in the basin and the threats that exist. Several datasets were used for this evaluation that included aquifer type, production, yield and geology (national and regional). The Zambezi basin is composed of nine aquifers of which two are intergranular, one is Karst and six are fractured covering 42%, 10% and 48% of the basin respectively. Groundwater reserve estimated taking storage coefficient, average saturated thickness and aquifer geometry in a GIS environment. Results showed that total groundwater reserve in the Zambezi basin is estimated at over 28 billion cubic meters (BCM) with the Quaternary Alluvial Aquifer accounting for over 68% of the total reserve. However this scarce resource is threatened by human activities among which agriculture and mining are the main sources of pollution. The results from this study will aid in effective water resources management of the Zambezi River Basin, addressing the challenges of the WEFE (Water-Energy-Food-Ecosystems) nexus assessment The analysis was implemented in the framework of the ACEWATER2 project, funded by DEVCO (EC Directorate-General for International Cooperation and Development) and under implementation by JRC, through the NEPAD African Network of Centres of Excellence in Water Sciences and Technology (CoE) in support to water sector in Africa.

**Keywords:** Groundwater Reserve; Karst; GIS; Water Resources Management; Zambezi Basin



# **ORAL SESSION**

# **TOPIC4: Groundwater Modelling &**

### **Risk Management**



### Modelling The Water Flow Through The Hyporheic Zone – Example Of A Small European Lowland River

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**Abstract:** Presented issue will touch the problem of modelling the groundwater-surface water interaction - one of the applications of modelling tool in modern hydrogeology will be shown.

In line with Shelton's observations (2011), two general categories of water resources – surface and groundwaters – were historically considered as two separate sources of water. The first references focused on the need to integrate these two types of water resources date back to 1952 (Glover, 1952) and 1959 (Hantush, 1959). In the 1960', the researchers became interested in a conceptual connection of these two resources. Creating the groundwater flow model is it essential to consider the accurate flux between surface water and groundwater.

The presented model is focused on water flow calculations in hyporheic zone. The model covers the 4 km stretch of the Upper Biebrza River (NE Poland, Central Europe). This area remains one of the biggest coherent wetland areas of the European Union. The section of the river is characterized by its undisturbed river bed due to the ban on mowing and dredging since 1992. Unique habitats and species of the site are protected as Biebrza National Park and Natura 2000. The 3D model (based on finite element method) was developed using the commercial software FEFLOW (DHI). The automatic measurements of groundwater head in piezometers located in four transects was used in model calibration process. The result - detailed 3D velocity field and groundwater flow system in hyporheic zone will be presented.

**Keywords:** flow modelling, hyporheic zone, FEFLOW



### How To Safeguard Groundwater Resources In Jerba Island In The Scenario Of A Sea Level Rise Using 3D-Feflow Salinity Transport Model?

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**Abstract:** The groundwater resources in Jerba Island are especially sensitive to sea level rise (SLR) because the island's relief is very moderate and the altitude of the piezometric surface is close to zero. Sea water intrusion is widespread but varies from one area to another, depending on groundwater abstraction rate and economic activities. The freshwater lens is probably sustained in the eastern part of the island through the infiltration of some wastewater. To meet the expected demand growth, integrated management of all water resources will be paramount (including irrigation quotas, infiltration of treated wastewater and desalination of brackish water).

In this study, we numerically investigate the impact of SLR by the implement of a 3D-FEFLOW salinity transport model for the costal aquifer in Jerba Island. The model was calibrated and validated with datasets during the 1992–2018 period.

The water table and salt intrusion evolutions were estimated according multiple scenarios of climate change (RCP8.5 and RCP4.5). The groundwater recharge, extraction, discharge into the aquifer, rainfall, and water need were projected according to the same scenarios. For each scenario, the piezometric and salinity maps were simulated for the years 2030, 2050, and 2100.

The model simulations show that the Jerba aquifer exhibits a highest sensibility to SRL and intensive extraction. The model is an essential tool for organizing a sustainable groundwater management, with the aim of preserving the agricultural and tourist activities that form the basis of the island's economy. It can be regarded as a useful tool for analyzing the water resources management and sea water intrusion for groundwater in arid and semi-arid regions.

**Keywords:** climate change; sea level rise; sea water intrusion; modelling; integrated water resources management



### Development And Calibration Of Transient Groundwater Flow Model For Al Kufrah Region, Southeast Libya

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**Abstract:** Al Kufrah Basin, which is a part of the huge trans-boundary Nubian sandstone Aquifer system (NSAS) shared by Libya, Egypt, Sudan and Chad, is a major water resource in North Africa. The NSAS consists of a number of aquifers laterally and/or vertically interconnected, extending over more than 2X10<sup>6</sup> km<sup>2</sup>. In recent years, the demand in some areas has resulted in withdrawals that substantially exceed replenishment of the aquifers.

A 3-D groundwater flow model was constructed and calibrated to simulate the sub-regional groundwater flow during the pre- and post-development periods in response to stresses within Al Kufrah Region.The developed model utilized PMWIN® Software, a fully integrated modeling platform that uses the USGS Modular MODFLOW2000®. The entire simulated thickness of 300 m was modeled as three hydraulically connected horizontal layers; each layer consists of 181 rows and 181 columns with grid spacing of 500 m by 500 m to cover a total area of 8190 km<sup>2</sup>. General Head Boundaries (GHB) were assigned to the southern and eastern nodes to simulate the groundwater inflow and outflow. Evapotranspiration was assigned to the upper model layer, with a maximum rate of 2750 mm/yr and an extinction depth of 2 m below the ground surface.

Groundwater flow parameters (principally hydraulic conductivities, boundary conditions and recharge) were set during the steady state calibration process. Calibration proceeded by varying these input parameters until the model results most closely matched field measurements. In addition, the simulated hydraulic heads were consistent within the model domain with the actual field measurements.

Five stress periods - transient state flow model, was constructed and calibrated using all available data from 1968 to 2010. Specific storage values range from 10<sup>-5</sup> to 10<sup>-2</sup> for the middle and the lower layers and specific yield range between 2x10<sup>-3</sup> and 2x10<sup>-1</sup> for the upper layer were initially assigned based on the previous hydrogeological studies of Al Kufrah Basin, these values were repeatedly adjusted for the three layers during the calibration of the first period until satisfactorily calibrated hydraulic heads were reached. A value of about 10% of the total applied water was assigned to layer 1 as a surface recharge. Analysis of the residual statistics and spatial distribution of residuals as well as the visual comparison between simulated and observed hydrographs and potentiometric surfaces were used to analyze the ability of the calibrated model to simulate aquifer conditions within acceptable error. The root of mean square errors range from 0.8 m to 2.34 m for the 33 observation wells. Calibrated model output includes a 43-years estimate of the water budget by the end of each stress period at the shallow and deep layers. The historical calibration of this transient state model indicated a very close matching between the calculated and the observed drawdown values that have exceeded 40 m during some periods.

Keywords: Nubian Aquifer System, Al Kufrah region, Transient state flow model, Stress Periods



### Multilayer Groundwater Modelling For A Coastal Aquifer In North-Eastern Tunisia

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**Abstract:** The eastern coast of the Cap-Bon in Tunisia is characterized by important groundwater and surface water resources systems. The shallow aquifer is often linked to the hydrographic network so that the idea to couple a hydrological model and a hydrogeological model is of interest. Several studies have been done on the area. The multilayer groundwater and its functioning within the watershed was not yet modelled. In this study, the plio-quaternary layer and the deep aquifer are modelled by application of MODFLOW-NWT. Use is made of graphical interface of Model Muse which allows to resolve the problems of drying and wetting nonlinearities of the unconfined groundwater. As a first step, a conceptual model is developed in a first step based on the digital elevation model DEM (50m x 50m), the watershed delineation generated by SWAT2012, the aquifer delineation, the groundwater recharge zoning, the hydraulic conductivity, a set of boundary conditions and the available hydrogeological data. In the second step, we calibrated the groundwater flow model in steady state, by referring to the year 1972. The objective is to reproduce the flow conditions in each layer referring to the observed hydraulic head and the global water budget. The first simulations, based on sensitivity tests of boundary conditions, and a set of input parameters, made it possible to quantify the components of the water budget and to generate maps for hydraulic heads, evapotranspiration, drainage area, vertical flow and outlet to the Sea. The RMSE is about 8 m for the simulated versus the observed hydraulic heads and the correlation coefficient is equal to 0.95.

**Keywords:** MODFLOW-NWT, groundwater modelling



#### Seawater Intrusion Modelling In The Mornag Aquifer, Tunisia

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**Abstract:** The Mornag coastal aquifer, located in the north of Tunisia, has experienced an over-exploitation during the last decades due to the increasing groundwater abstraction mainly for irrigation purposes. As a consequence, in recent years the drawdown of groundwater levels has reached more than 10 m in some areas. Moreover, groundwater levels below sea level have been recorded indicating the danger of a seawater intrusion. The regional groundwater modelling of the Mornag aquifer, using FEFLOW, confirms the alarming situation and predicts a further substantial drawdown of the groundwater table if extraction stays at the present level. This would inevitably lead to a progressing seawater intrusion, which ultimately will destroy the Mornag aquifer as a valuable freshwater resource causing severe socio-economic problems. To prevent seawater intrusion entering into the areas of today's groundwater extraction, a hydraulic barrier by artificial groundwater recharge is planned, recharge water will be obtained from the Channel of Medjerdah-Cap Bon. The effect of the hydraulic barrier and in particular the minimal amount of artificial recharge needed is investigated by FEFLOW finite element software. Vertical cross-sections are used to simulate the density dependent saline water movement from the sea to the interior area of the aquifer. The hydraulic boundary and initial conditions for these local solute transport models are deduced from the previous calibrated regional flow model. Aquifer layers are refined according to recent geological investigations and an inter-annual simulation time-step is introduced to take into account the seasonal hydrologic variability of natural recharge as well as of the pumping rates. By a sensitivity analysis, the influence of stratigraphy and hydro-geological parameters on the propagation of the seawater interface is demonstrated and compared with recent field investigations. In addition, FEFLOW model simulation results with the planned hydraulic barrier are presented.

Keywords: Seawater intrusion; FEFLOW; Artificial recharge; Mornag aquifer



### Impact Of Different Irrigation Regimes With Saline Water On Solute Return Fluxes To Groundwater

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Abstract: Experiments on Drip irrigation associated with Deficit Irrigation (DI) have been performed to assess their potential as water saving techniques and climate change adaptation measures. Yet, before general implementation their environmental impacts on soil and groundwater have to be investigated more deeply especially when using saline irrigation water. Solute recycling is considered a major threat for the sustainability of irrigated systems. In many irrigated areas, wells are the main sources of irrigation water, especially in the dry season, which leads to the extraction of solutes from these wells and their re-distribution on lands. Soil water content and salinity were monitored in a fully drip irrigated potato plot using brackish water (4.25 dS/m) in semiarid Tunisia. The HYDRUS-1D model was used to investigate the effects of different irrigation regimes (Deficit irrigation (T1R, 70% ETc), full irrigation (T2R, 100% ETc) and farmer's schedule (T3R, 237 % ETc) on root zone salinity and solute return fluxes to groundwater. The calculated values of soil water content and electrical conductivity of soil solution (ECsw) were in good agreement with the observation values, as indicated by mean RMSE values (0.005 m3/m and 0.008 m3/m for soil water content, 0.17 dS/m and 0.28 dS/m for ECsw) for calibration and validation subsets, respectively. The results of the different simulated treatments showed that relative yield accounted for 54 %, 70 % and 85.5 % of the potential maximal value when both water and solute stress were considered for deficit, full and farmer's irrigation, respectively. Root zone salinity was the lowest and root water uptake was the same with and without solute stress for the treatment corresponding to farmer's irrigation schedule (273 ETc). Solute return fluxes reaching the groundwater were the highest for T3R after two subsequent rainfall seasons. Beyond water efficiency of DI with brackish water, long term studies have to focus on its soil and groundwater salinization risks under changing climate conditions.

**Keywords:** Irrigation return fluxes; Deficit Irrigation; Brackish water; Soil and groundwater salinity; HYDRUS-1D



### A Modelling Framework For Simulating Groundwater And Surface Water Dynamics And Their Interactions

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**Abstract:** In the scope of the study of groundwater and surface interactions in the Ljubljansko polje (Slovenia) we applied numerical modelling of the transient state of groundwater flow using FEFLOW 6.2 from the MIKE Powered by the Danish Hydrological Institute (DHI; URL: https://www.mikepoweredbydhi.com/). FEFLOW was coupled with MIKE 11 via the ifmMIKE11 plug-in for modelling the Sava River water flow, which also belongs to the MIKE Powered by the DHI. Additionally, with an indirect communication link between FEFLOW and Water Flow and Balance Simulation Model (WaSiM) from the Hydrology Software Consulting J. Schulla (URL: http://www.wasim.ch/) was determined the upper boundary condition in FEFLOW, which defines the percolation of local precipitation. This comprehensive modelling framework was also used to project the groundwater and surface water behaviour for the period 2036–2065. Climate projections are derived from a combination of three General Circulation Models (GCMs) forcing different Regional Climate Models (RCMs) under Representative Concentration Pathway 8.5 (RCP8.5) originating from the EURO-CORDEX initiative: SMHI-RCA4, KNMI-RACMO22E and CLMcom-CCLM4-8-17.

A combination of the different tools used in this study creates a clear picture of the water cycle in the study area in space and time. The results provide a quantification of the water balance and answers to all our questions: where, to what extent and under which conditions do groundwater-surface water interactions happen in the Ljubljansko polje.

Acknowledgements

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Keywords: hydrological modelling; groundwater-surface water interaction; projection



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### Novel Travel Time Based Approaches For Groundwater Modelling Education And Management

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Abstract: In this talk, a set of Eulerian travel time-based approaches for modelling flow and solute transport processes in groundwater systems are presented. A new grid-based method has been developed to compute groundwater trajectories. The method holds more promise than particle tracking because the interpretation and visualization of travel and residence times are easier. It was shown to be more powerful in practice than the conventional particle tracking method. Furthermore, it is easily extended for visualizing capture, swept, and connection zones between well pairs. Therefore, it is promising as an educational tool not only in the classroom but also among practicing groundwater engineers and scientists. Advanced aspects using concepts will be also presented. First, a novel algorithm is developed for automatic optimal grid generation for transient solute transport models. First results show that this approach can lead to a substantial speedup in practical applications presenting a tradeoff between computational accuracy and computational resources. Next, steady-state grid-based travel time simulations are used as physically-based surrogate models in the framework of groundwater quality management models. This approach does not only simultaneously optimize well rates and locations but drastically reduces the involved computational cost. In particular, examples will be presented for three-dimensional models with random and layered subsurface heterogeneities presenting a bottleneck for standard approache). They all show that groundwater modelling interpretations and management practices are significantly enhanced by applying such concepts.

Keywords: Travel time; Solute transport; Groundwater management; Surrogate models



### Using Statistical Models, Gis And Fuzzy Logic In The Delimitation Of The Groundwater Recharges Potential Areas: A Case Study Of Nadhour-Sisseb-El Alem Basin, Tunisia

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**Abstract:** The Groundwater resources in the Nadhour-Sisseb-El Alem Basin undergo unfavorable weather conditions and a qualitative degradation that require interventions to rationalize integrated management in decision-making. Establishment of a recharge map becomes so a necessity to preserve the resources. Eight factors affecting the potential recharge are determined, that are lithology, soil, slope, topography, land cover/use, runoff, drainage and lineaments. The Multi-Criteria Decision-Making (MCDM) and Analytic Hierarchy Process (AHP) methods have been used to determine the contribution and the occurrence of each factor. The class membership ratios for each class were assigned according to the Fuzzy set theory. GIS tools and Remote sensing are used to elaborate thematic maps. The recharge map shows the potential areas that are represented by streambed. The center of the basin is occupied by the class with a high infiltration potential. Potential areas of moderate infiltration class are located at the northern and western areas.

**Keywords:** Potenial recharge; Remote sensing; Groundwater statistics; MCDM; Nadhour-Sisseb-El Alem; Tunisia



# **ORAL SESSION**

# **TOPIC4: Special Session on Regional**

### **Groundwater Flow Systems**



### A Review Of The Groundwater Flow System In A Thermal Aquifer System, Southern Tunisia

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Abstract: The Aquifer System of Northern Sahara (ASNS) is the main groundwater source in the south of Tunisia, which contains two main aquifer units. The first is the Complex Terminal (CT) and the second, a deeper unit, is the Continental Intercalaire (CI). This study aims to present a regional groundwater flow system in the complex ASNS. For this, a geochemical, hydrodynamic parameters, and isotopic data were analyzed for some locations; a reviewed was made from others works. Along flow line, the Continental Intercalaire aquifer is described using geochemical, major ions and stable isotopic indicators. The CI aquifer is hydraulically continuous from the Atlas Mountains in Algeria to the El Hamma in Tunisia. Chloride concentrations increase from 200 to 800 mg /L, its concentration is correlated to groundwater depth; this and the thermal nature of its flow suggesting a regional groundwater flow (Toth, 1963). Geothermometry suggests that the maximum temperatures reached during groundwater circulation are around 94 °C. Geochemical composition indicate that despite the complex of both structure and stratigraphy, uniform evolution with continuous water-rock interaction takes place along the groundwater flow lines, which are only disturbed near the Chotts El Fijej in Tunisia by groundwater converging from additional flow lines. The CI aquifer is bounded by more saline waters both above and below and especially in the discharge zones where there is also the risk of highly saline encroachment by near-surface waters from the Chotts of Tunisia being drawn and induced during groundwater abstraction.

**Keywords:** Continental intercalaire; complex terminal; modeling; groundwater flow;



### Study Of The Origin Of Salinity In Alluvial Groundwater Flows In The Ain Chabro-Hammamet Region, W. Tebessa (North-East Algeria)

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Abstract: Tebessa is located in North-Eastern Algeria; it is characterized by a semi-arid continental climate with an average annual precipitation of less than 400 mm. It belongs to the Eastern Saharian Atlas located along Tunisian borders. The region is drained by a number of wadys such as the Chabro and Bouakous, being the most important. The surface extent of the studied region is over 420 km<sup>2</sup>. This region has witness a very intense drought during the last twenty years which has generally led to a general lowering of the water-table; an intensive water extraction from shallow wells, in particular, the desiccation of the submergible pump, involving also a reduction of the extraction yield and drying-up of natural springs. Therefore, quantitative and qualitative repercussions have been shown on the groundwater sources in the region. Four sampling campaigns within two years have been made during the expected high and low water periods. The chemical analysis (major elements Ca<sup>2+</sup>, Mg<sup>2+</sup>, Na<sup>+</sup>, K<sup>+</sup>, Cl<sup>-</sup>, SO4<sup>2-</sup>, HCO3<sup>-</sup>, NO3<sup>-</sup>) and piezometric measurements have been carried out to gain representative quantitative measures and to chart current watertable position. The surveys of the groundwater quality, as well as its evolution in time and space become necessary, especially, when the water is intended for drinking water supply; the quality of groundwater some flows have been reported to deteriorate continuously.

Analyses prove that groundwater salinity is up to about 4 g/l, electric conductivity varies between, 997 to 9120  $\mu$ S/cm, in shallow wells and, 468 to 2500  $\mu$ S/cm, in deep drilled boreholes; extracted water temperature has values between 12 and 23°C, respectively. The chemical and hydrogeological behavior of groundwater data interpretation within the Tóthian Groundwater Flow System methodology assisted by saturation indexes suggest the origin of water salinity is associated with the development of short-shallow, and lengthy deep paths, related to flow systems of local (conductivity 997  $\mu$ S/cm, Temperature 12°C) and intermediate (conductivity 9,120  $\mu$ S/cm, Temperature 23°C) nature, respectively.

**Keywords:** Drought; Salinity; Contamination; Saturation index; Local and intermediate GW Flow Systems



### Insights into the Groundwater Salinization Processes in Menzel Habib Shallow Aquifer, South-eastern Tunisia

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**Abstract:** Salinization is a common environmental response linked to groundwater flow in arid and semiarid regions such as Menzel Habib, south eastern Tunisia. This work aims to understand groundwater salinization processes and factors controlling its mineralization. For this, 43 groundwater samples were taken in April-May and analyzed. Chemical data and field acquaired measurments were used to identify the origin of groundwater salinization starting along the flow path from 1.598 g/l to 8.706 g/l. Bivariate diagrams show a high correlation between total salinity to Na, Cl, Ca, Mg and SO4. Furthermore, the saturation indices of Halite, Gypsum and Anhydrite are negative which justifies the tendency of groundwater samples to dissolve these minerals. Indeed, these minerals have been reported to be present in the evaporitic Triassic rocks which is related to the tectonic context of the region.

Ordianary kriging was used to establish the piezometric map which has a major direction west-east with some disturbance due to anthropogenic activities, and to establish the salinity distribution. Statistical analyses, essentially Principal Component Analysis (PCA), reveal that high groundwater mineralization might be interpreted to be due to the evaporatic dissolution; groundwater Flow Systems provide further support due to a vertical communication between deep aquifer and shallow aquifer.

Keywords: groundwater; salinization; PCA; stables isotopes; Menzel Habib



### Tóthian Flow Systems Contribution To The Hydro-Structural Study Of The Thermo-Mineral Waters Of Guelma Region (East Algeria)

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**Abstract:** The study area is located in the north-east of Algeria covering a large watershed; it is distinguished by a mountainous terrain (ie, 1,411m amsl, Mouhna Mountain). The area belongs to the great Seybous Basin (with 6,471 km2). It has a Mediterranean climate, humid from October to late March and semi-arid from late May to early October, with 594mm/year rainfall in the north, and 708mm/year in the south. The geological framework of Guelma is very complex due to the plate tectonics that affected most parts of the region; the landscape is defined by outcrops of sedimentary formations from Triassic to Quaternary ages. This work has mainly focused on the determination of the effects of structural-geology and groundwater quality, A main concern was also on groundwater and its physicochemical characteristics and their distribution. The purpose of the study was to answer the following questions using a Tóthian flow system reference: what would explain the deference of temperature of gushing water from two geysers close to each other? Is there a link between plate tectonics and the appearance of springs? To this end and although data are insufficient, the joint use of geological maps and a hydrochemical approach was very helpful to achieve valid results. The interpretation of results from a Tóthian flow systems perspective allowed to draw these conclusions: the distribution of groundwater in the area is undeniably linked to deep regional flows associated to plate tectonics; most of the water sampling points are located in a collapse-basin. According to the geothermal gradient, the temperature of thermal waters is proportional to their travel depth, shallower travelling water produces some regional flows with a relative low discharge temperature. The difference in temperature from one spring to another may be due to the length and depth groundwater travels from the recharge to the discharge zone; this could imply the existence of different unit flow basins, as proposed by Tóth.

**Keywords:** Chemical composition; geothermal gradient; groundwater discharge; thermalwater; tectonics



### Hydrogeological Characterization Of The Regional Groundwater Flow In El Hamma Thermal Aquifer System, Southeastern Tunisia

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**Abstract:** The territory of El Hamma, located in the southeast of Tunisia, is a geothermal area. It has been known, during the last decades, the presence of a quantitative and qualitative degradation of its flow regime, expressed by a yield reduction of the thermal springs, a large drawdown of the water-table in the area and an increase in salinity, all which have been a common landmark. In study area, Upper Cretaceous rocks are represented, from old to new as follows: a Senonian formation formed by marl and gypsum surmounted by a limestone. Finally, the Mio-Pliocene is represented by gypseous marls, red marls and clays, conglomerates, pebbles and sands. Groundwater occurs in two main aquifers units in the region. The first aquifer unit is represented by the Senonian limestone. The second aquifer unit is deeper and is present in Lower Cretaceous sediments, known as Continental Intercalaire (CI). Variographique analysis and ordinary kriging techniques were used to map the spatial variability of temperature and the hydrodynamic properties of the aquifer in the study area. These results propose the existence of two flow systems: one has a southeastnorthwest direction while the second is from southwest to northeast with local disturbances influenced by human intervention. Geostatiscal techniques in addition to geological data confirm the existence of the vertical communication of groundwater flow between the Continental Intercalary aquifer and the superficial Senonian aquifer through system of vertical faults.

**Keywords:** Groundwater flow; Senonian aquifer; Con Inental Intercalaire; Geosta Sc: El Hamma



# **POSTER SESSION**

# **TOPIC1: Global Change &**

### Groundwater



### Monitoring Soil Plant Interaction In An Orange Orchard Using Electrical Resistivity Tomography

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**Abstract:** In the framework of seven Mediterranean sites, the ERANETMED-WASA project, which focuses on water saving and management in agriculture, we present a scale-based application of electrical resistivity tomography (ERT) in an agricultural parcel. The goal of this project is developing, testing and establishing a general protocol to reduce water consumption for irrigation of high value crops, with important socio-economic consequences for current and future scenarios of water scarcity in the Mediterranean region The Tunisian study site is based in the agricultural plain of Mornag located at 20 km SE of the city of Tunis. The measurements (ERT) were installed on a plot of orange trees with an area of 6400 m2 of about 176 orange trees of different variety (orange and mandarin) planted in rows spaced 6 m. In order to present the approach of quantification of the soil-plant-atmosphere mass exchange, monitoring changes in soil resistivity was carried out on different wet and dry soil conditions (i) after three days of rain corresponding to wet conditions (ii) dry conditions before the start of irrigation and then (iii) following the duration of drip irrigation. Electrical resistivity tomography (ERT) applied under different soil moisture conditions provided an image of the static and dynamic for sub surface characteristics.

Keywords: ERT; Agriculture; Water Saving



### Assessing The Coevolution Of Climate And Groundwater Resources In A Semi-Arid Region (Grombalia Catchment, Tunisia)

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**Abstract:** Groundwater is an important buffering water resources in Mediterranean regions, which are exposed to large precipitation variability and eventual changes. This study aims to jointly assess evolutions of rainfall and of groundwater resources in the Grombalia catchment, semi arid Tunisia.

We deal with monthly, seasonal and annual observed precipitations and subsequent statistical coefficients available from a network of fifteen rainfall gauges over and around the Grombalia catchment, with series stretching from 1960 to 2015.

The trend and its significance are analyzed using Mann-Kendall trend analysis and Sen's slope estimator; while four methods (Pettitt test, Hubert's segmentation test, Lee Heghinian's Bayesian method and Statistic U of Buishand) were also used to explore eventual tests in time series.

Results of long-term rainfall at the Grombalia basin show a considerable rising trend over the two last decades. Also, a significant break was detected in 2002, especially, in Soliman, BouArgoub, Barrage Tahouna and Ain Tebounok rain gauges. These methods allowed the characterization of change in rainfall with meaning at the regional level. Effects of these changes coupled with the mismanagement of water resources have caused a clear perturbation of groundwater piezometry: a groundwater rise is observed in the centre area causing agricultural, environmental, and economic problems linked to suffocation of plants, trees and crops. Water resources management strategies under changing climate are consequently suggested as a way forward for sustainable development.

**Keywords:** Semi-arid region; Rainfall variability; Climatic and anthropogenic change; Groundwater rise; Agriculture

**APPLIED GEOSCIENCES FOR GROUNDWATER** 

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### Source Rocks Geochemical Characterization And 1-D Burial And Maturity Modeling In The Marine Chebba Block, Offshore Northeastern Tunisia

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**Abstract:** Selected samples spanning Cretaceous to Tertiary series from one drilled well in the marine Chebba block, offshore northeastern Tunisian were analyzed using Rock-Eval pyrolysis and GC/MS techniques. The study geochemically aimed to characterize organic matter-rich intervals in terms of source rock potential and to determine the origin of oil shows recorded in the Serdj equivalent as well as the origin of crude oil from the Isis well (nearby the marine Chebba block).

The results show that the lower Fahdene source rock is moderately rich in essentially marine organic matter. It is found fairly mature to mature and was deposited in a suboxic, normal salinity marine environment. The Bahloul and Bou Dabbous source rocks are rich in immature type II organic matter that has been deposited in normal salinity suboxic environments. In addition analyzed samples from "equivalents" of Sidi Aich, the Serj, the Upper Fahdene, El Haria, and the Halk El Menzel formations are found fairly-rich in organic matter and may "locally" bear some source-rock potential.

However, the biomarker-based oil-oil and oil-source rock correlation indicates that the Serdj equivalent (IH-ES) oil show was mainly generated from the lower Fahdene source rock with a contribution from the Bahloul source rock. The Isis crude oil was generated from the Sahel of Mahdia typical Lower Fahdene source rock.

Burial and thermal maturity basin modeling using BasinMod-1D software carried out in two (W1 and W2) indicate that at this level, they have, so far, generated very small quantities of hydrocarbons due to their relatively low maturity status. However, the simulation was carried out on high structures drilled wells and it is most likely that, laterally, within the deep grabens, the source rocks have already generated and expelled their hydrocarbons as proved by the Serj occurring oil show.

**Keywords:** Marine Chebba block; Rock-Eval; GC/MS, Oil-Oil correlation; Oil-Source rock correlation; biomarker; BasinMod-1D



### Characterization Of The Upper Albian Oceanic Anoxic Event (Oae1D) Of The Lower Fahdene Mouelha Member In The Fkirine Area (El Djehaf Anticline)

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**Abstract:** This study targeted the uppermost Albian-Cenomanian deposits of El Djehaf outcrop section, Zaghouan area, northern Tunisia. The research aimed to achieve a detailed sedimentological, mineralogical and geochemical investigation in order to identify the Upper Albian Oceanic Anoxic Event OAE1d. An attempt was made to correlate the Tunisian section to that located in Monte Petrano Italy. On this basis, a new 70 m thick sedimentary section supposed to have recorded a significant period of organic matter-rich interval, which may globally correlate to the Breistroffer OAE1d, was logged in detail. In addition, 68 samples were selected for microfacies description and geochemical and XR analyses.

Throughout the section, we note the occurrence of an oscillation between black to grey, organic-rich pelagic limestones and black laminated limestone, increasingly rich in CaCO3 (77% to 97%). A low biostratigraphic framework has been employed using well preserved planktonic foraminifera and allowed to place the Late Albian-Early Cenomanian boundary, based on the first occurrence of the Rotalipora Globotruncanoides and its associated species, signing by that the beginning of the Cenomanian in El Djehaf section. The black laminated limestones (Mouelha Member) marks the highest Total Organic Carbon content reaching 9.07% and indicating a very good oil prone (type II/III) mature source rock and materialize an anoxic environment at basin floor during transgressive periods. This could be foreseen as a good play for unconventional resources. Based on TOC data and constrained by biozonation, the section was successfully correlated to that of "Monte Petrano" in Italy. This study underlines the OAE1d event in the El Djehaf section and reconfirms its occurrence as a global anoxic event.

Keywords: Albian–Cenomanian boundary; El DJehaf section; Correlation; Sedimentology



### Preliminary Results Of Geotechnical And Geophysical Investigations For Infiltration And Seepage Detection Of El Kebir Dam

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**Abstract:** El Kebir dam (Zaghouan, North-Eastern Tunisia) presents a problem of infiltration and seepage probably associated with the fractured Eocene carbonates and the presence of two principal NW-SE faults. Gravity and Electrical Resistivity Tomography were used to better image the role of these faults and the seepage flow pathways in the transverse direction of the dam. Further, geotechnical analysis were complied to identify the nature of the sediments trapped by the dam.

The El Kebir dam was constructed since 1925. The reservoir has been progressively silting up to reach its maximum today. Most of the deposits in the reservoir consist of terrigenous sediments resulting from its watershed erosion. The distribution of detrital material in the reservoir is mainly effected by density currents. The finer sediments are deposited at the foot of the dam, thus reducing the storage capacity, increasing the risk of filling the uptake and draining structures and also affecting the stability of the dike.

The results show that the El Kebir dam presents a progressive subsidence on the left bank side, leaks spreading along the dam, especially on the right bank side. A population of plants invaded the reservoir from the tail to the central part and kept advancing towards the dike. Thus, the water storage area moved toward the lower wadi in a narrow part causing real flood hazards during heavy flooding events making these floods uncontrollable.

The results of electrical resistivity tomography clearly show the internal state of the dike, which is stable, the existence of a plume of infiltration of water that flows into fractures of the Lutetian limestone. The gravity data of El Kebir dam and surrounding area were also analyzed to better understand the subsurface faulting network distribution. A regional density section derived from residual gravity anomalies was elaborated to image hidden features inaccessible from surface observations.

**Keywords:** El Kebir dam; silting; Geotechnical; Gravity; Electric tomography



### The Potential Of Feed Forward Neural Network For Assessing Hydrological Impacts Of Climate Change In The Beja Catchment

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**Abstract:** The present paper deals with exploring the use of Artificial Neural Networks (ANN) for forecasting the impact of climate change on the hydrolgy of Beja watershed. An ANN model based on the structure of Feed Farward Neural Network (FF-NN) is developed. This model use the daily rainfall and temperature for the period (2008 to 2011) as inputs. The FFNN model was trained, validated and tested using the daily observed discharge measurement. After evaluation of the performance of the FFNN, by comparing measured against simulated discharge, the final weight giving the best simulation as compared to observation were kept constant while the FFNN was fed with an ensemble of Regional Climate Models developed within the CORDEX project with a resolution up to 10 km to assess hydrological impacts of climate change on the Beja catchment. The results highlighted the potential of FFNN hydrological modelling in particular for assessing climate change in data-poor catchments.

Keywords: Hydrological modelling; Climate change; Neural Network; Beja



# POSTER SESSION

# **TOPIC2: Groundwater Quality &**

## Pollution



### Wastewater Treatment By Biological Contractors Coupled To Local Clay Membranes For Reuse In Agriculture

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Abstract: Several industrial activities generate various types of effluent (liquid, solid and gaseous) discharged into the natural environment whose concentration may exceed standards currently in place. Therefore, the elimination of these pollutants is required and is of major concern to scientists. The study carried out concerns the treatment of wastewater using a technique of biological disks coupled to membranes before their use in agriculture. Currently in Morocco 550 million m<sup>3</sup> of wastewater are discharged per year, of which 45% are purified through 117 sewage treatment plants. Only 47.5 million m<sup>3</sup> /y are reused or a rate of 9%. Morocco has adopted the "treatment and reuse" model and sets a goal of reusing 325 million m<sup>3</sup> of wastewater by 2030. The treatment of wastewater by biological disks coupled to membranes, has been carried out on the wastewater collected upstream of the treatment plant. The measured physicochemical parameters show that the values obtained comply with the standards: The retention of the heavy metals contained in the liquid effluents was carried out on a membrane pilot, using zeolite type A as a membrane. The results obtained show that the percentages of the retention for (Pb<sup>2+</sup> lead, Cobalt CO<sup>2+</sup> and Cadmium Cd<sup>2+</sup>) reach 98% for a time of 33 minutes, whereas for Cr6 +, chromium does not reach 10%. In perspective we plan to carry out the following activities: retention of other metals and possibly the mixing of metals, elimination of the polyphenols contained in EU of vegetable water and testing other membranes that have important specific surfaces, such as zeolites Y, P and X.

Keywords: wastewater; biological disks; clay membranes; heavy metals; zeolit.



#### Study On Defluoridation Of Water Using Natural Mineral Clay

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**Abstract:** Fluoride is an essential component for normal mineralization of bones and formation of dental enamel. However, excessive intake could result in teeth mottling, dental, and skeletal fluorosis. Therefore, two different natural tunisian raw clays were used as adsorbent in batch process to eliminate the excess of fluoride ions from drinking water and thus avoid the fluorosis phenomena. Physicochemical characterization and chemical constituents of raw clays were done by X-ray fluorescence, X-ray diffraction and BET method. For fluoride removal, the effect of contact time, adsorbent dose and pH were evaluated. The optimum defluoridation capacity was at 30 min of contact time, 20 g/L of clay dose and at pH=3. The used kaolinite clay shows a higher removing fluoride percentage compared to smectite one, which is near to 73% removal. The selected clay was successfully applied for the removal of fluoride from contaminated natural water with high concentration of foreigner ions exceeding the potability limits. Adsorption isotherms revealed that the data fitted well to both the Langmuir and Freundlich adsorption isotherms. Hence confirming both monolayer and multilayer adsorption.

Keywords: Fluoride removal; natural mineral clay; Adsorption; Natural water; isotherm


#### Identification Of Nitrogen Pollution And Salinization Sources In Sminja Aquifer (Ne Of Tunisia) Using Stable Isotopes Of S, N, O And H

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Abstract: Groundwater in sminja aquifer contains more than 50 mg.l-1 of nitrate, which exceeds the World Health Organization limit for drinking water. The aquifer is also characterized by high values of salinity which exceed 13 g.l-1. Contamination sources are still poorly understood and they need to be clarified. The integrated use of isotopes in the framework of a complete hydrogeological and hydrochemical study of the groundwater flow system was applied in order to identify SO4<sup>2-</sup> and NO3<sup>-</sup> sources. To distinguish the source of pollutants an isotopic sampling campaign (23 samples) were carried out, in 2017, in groundwater bodies in order to trace the origins of each pollutant. The present study identified different pollution sources of dissolved NO3<sup>-</sup> in groundwater and quantified the percentage of natural and anthropogenic SO4<sup>2-</sup>. The  $\delta$ 15N and  $\delta$ 18O values indicated that in a first group, of shallow water samples, with high NO3<sup>-</sup> concentrations, the latter resulted from soil organic N and nitrification of manure used on agricultural fields. In contrast chemical and isotopic data also revealed that NO3<sup>-</sup> concentrations for deep and shallow groundwater are significantly lower due to denitrification. Results of δ34S and δ18O indicate that most of samples corresponding to shallow wells located in the irrigated perimeter, and areas of land dedicated to arboriculture have SO4<sup>2-</sup> derived from inorganic chemical fertilizers. Remaining samples are characterized by higher isotopic values, closer to the natural signal derived from evaporites dissolution. This study emphasizes that isotope data are very effective for discriminating different sources for the waters with high SO4<sup>2-</sup> and NO3<sup>-</sup> concentrations. Results can constitute an important asset for decision makers for undertaking suitable countermeasures to reduce pollution effect on groundwater at Sminja plain.

**Keywords:** Groundwater salinization; Stable isotopes (S, N, O and H); geochemical data; Sminja aquifer



#### Hydrogeochemical Study Of The Groundwater Flow System Of Chebba-Ghedhabna, Central East Of Tunisia

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Abstract: Soft climate and economic activities are usually the main causes which attract the population to coastal areas. Consequently, diverse effects on coastal water resources are registered. For example, in recent years, the Sahel region, and specifically the Chebba-Ghedhabna aquifer in Mahdia prefecture (central east of Tunisia), has showed a remarkable drawdown as result of over-exploitation. The present work seeks to understand the hydrogeochemical functioning of the Chebba-Ghedhabna aquifer using hydrodynamic and hydrochemical investigations. A field survey was conducted in May 2018 and during which in-situ parameters were measured and groundwater samples were collected and analyzed for major chemicals in the Georesources Lab. The obtained data was used to establish spatial distribution maps, chemical facies, correlation diagrams and mineral saturation indices of the collected groundwater samples. The study identified the shallow aquifer boundary which is coincided with the watershed limits. Groundwater depression is occurring near shore line between Ghedhabna and Chebba cities, which indicate a possible seawater intrusion. The measured salinities vary between 0.7 and 12  $gL^{-1}$ . The brackish water (2 and 6  $gL^{-1}$ ) are dominants, while the salty ones are located near to Sabkhet Ndjila and the Chebba's city. The mineralization of the waters is influenced mainly by the dissolution of carbonate and evaporate minerals, ion exchange and marine intrusion. The salinization of the aquifer is associated to high nitrate values (significant correlation of EC and NO3) which prove that additional aquifer salinization is resulting from the return of irrigation water flow.

**Keywords:** Hydrogeochemistry; coastal aquifer; overexploitation; salinization



#### Pollution Potential Assessment Using Gis-Based Drastic Model In The Shallow Aquifer Of Hajeb Layoun-Jelma Basin (Central Tunisia)

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Abstract: Most of the agricultural regions in the world are plagued with the problem of water pollution. The quality of aquifers has been degraded due to farming activities using nutrients in huge quantities. To overcome these problems, water managers need to intervene in order to protect and preserve available resources. The central Tunisia contains important aquifers with groundwater resources mainly used for agricultural and drinking purposes. Facing the increase of water demand and the economic and irrigation areas development in the region, an accurate assessment of groundwater vulnerability to pollution is considered an effective tool in managed water resources especially in arid and semi-arid areas. The Hajeb El Ayoun-Jelma multilayer aquifer is among the important aquifers in the central of Tunisia. The overexploitation of this groundwater and the agriculture activities led to the degradation of the water quantity and quality. The multilayer aquifer system covering an area of about 1380 km<sup>2</sup> consisted of three aquifer layers: the Cretaceous, the Miocene, and the Mio-Plio-Quaternary aquifers which coincide with the following local formations (from the bottom to the top): Abiod, El Gueria, Ain Grab, Béglia, Segui, and Quaternary deposits. This study aims to assess the vulnerability of the Quaternary aquifer of Hajeb El Ayoun jelma basin, to pollution, using the drastic model. Mapping was done using Arc GIS software. The parameters used as input data are Depth to water table, net aquifer Recharge rates, Aquifer media, Soil media, Topography, Impact of vadose zone media and hydraulic Conductivity. The vulnerability map shows four classes: highest (15%), high (29%), low (42%), and lowest (14%). The validation of the model was assessed by overlapping pollution risk map and the calculated water quality index, the results showed that the places with "good water classes" were located in the part of Low pollution confirming the accuracy of the model.

**Keywords:** Hajeb El Ayoun Jelma basin; vulnerability; Drastic; Geographic Information System



#### Groundwater Vulnerability Assessment To Pollution Using Drastic Method A Case Study On Mornag Plain, Tunisia

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**Abstract:** The groundwater of Mornag (governorate of Ben Arous), that covers an area of approximately 200 km<sup>2</sup> and that represents a part of the northern Tunisia, is a source of supply for the region. Since it is located in an agricultural area so it is predominant source of irrigation water. But agriculture is a diffuse source of pollution like Nitrates and Pesticides which can easily migrate through soils to groundwater and cause contamination and then they can affect the quality of underground water. The study of vulnerability of this groundwater to pollution was performed using standard DRASTIC method. Established vulnerability maps show both vulnerability classes: small and medium. The results of the validity of standard vulnerability DRASTIC method and DRASTIC pesticide pollution by nitrates shows an average coincidence rate of approximately 43% for the standard vulnerability DRASTIC map and also DRASTIC pesticides.

**Keywords:** Groundwater; pollution; vulnerability; DRASTIC

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#### Elaboration Of Alginate-Starch Filled Graphene Oxide Beads And Its Evaluation In Adsorption Of Congo Red Dye

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**Abstract:** Nowadays, the pollution of the environment becomes a serious concern which leads the researches to elaborate novel green adsorbents with high characteristics such as biodegradability, sustainability and abundance. Synthetic dyes are one of the most common contaminants which are habitually found in dye manufacturing and textile finishing production. Congo red is an organic dye known by its toxicity and carcinogenic properties. It can be complicated to uptake Congo red dye from contaminated wastewater due to its complex aromatic structure and its resistance to biodegradation and photo degradation. The choice of the adsorbent is the critic step that could make the difference with the utilized one in literature. Polysaccharides-based adsorbents show a high affinity for the removal of dyes owing to their renewability and biocompatibility; on the other hand, by adding a certain percentage of nano-charge to the matrix, the adsorption capacity will be enhanced. Within this context, graphene oxide has been chosen as reinforcement filler due to its outstanding properties such as large specific surface area and high water solubility. To be in line with the concept of green processes, the suspension of graphene oxide will be entrapped in alginatestarch beads. In this study, Millimeter sized alginate-starch and alginate-starch/graphene oxide beads were elaborated via ionotropic gelation in presence of Ca<sup>2+</sup> ions. Graphene oxide was synthesized via Hummers method and characterized by FTIR analysis. The Alg-St and Alg-St/GO adsorbents beads were examined in adsorption of Congo red dye utilizing batch mode. The capability of the as-prepared adsorbents for the uptake of Congo red as an anionic dye was evaluated by varying the contact time. Adsorption kinetic of the beads was discussed using pseudo-first and second order equations models. The adsorption removal of Congo red dye was found to be about 86% for alginate-Starch/graphene oxide beads.

**Keywords:** Alginate beads; Starch; Graphene Oxide; ionotropic gelation; Congo red removal



#### Hydrogeological And Hydrochemical Characterization Of Groundwater In A Semi-Arid Region (Northeast Of Tunisia)

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Abstract: The Guenniche plain located in the northeast of Tunisia is characterized by semiarid climate and, mean rainfall of 600 mm/year. It is a collapsed basin covered by guaternary sediments in its major area. It contains phreatic and deep aquifers, which are important for the economic activities of the region. The aquifers are intensively exploited by the local farmers. The piezometric maps of the tow aquifers show that the direction of flow is from the East to the West. The wadis contribute to the phreatic aquifer recharge in the plain upstream while they drain the aquifer in the downstream. The deep aquifer is mainly recharged by leakage. The agricultural activities affect water quality. Two sampling campaigns are carried out in wet and dry seasons to assess the groundwater quality. The analysis results for nine trace elements As, Cd, Cu, Cr, Fe, Hg, Mn, Se and Zn in 20 samples for the shallow aguifer and 10 samples for the deep aguifer, are compared to national (TN) and international (WHO) standards. With regard to the shallow aquifer, the cadmium and mercury showed values higher than standards in some samples. The deep aquifer is healthy regarding these elements and all the results in all of the boreholes, do not exceed standards. We employed the Water Quality Index to present the suitability of this shallow and deep groundwater of the drinking water. 25% of the studied water samples fall under 'poor', 'very poor' and 'unsuitable' categories, for the shallow aquifer. But for the deep aquifer, all samples present water type ranging from 'Excellent' to 'Good' water. We established the maps of the spatial distribution of the different elements for both aquifers by using the ArcGIS software. The wells which present a danger of the human health are located in the borders of the some streams. They indicate groundwater pollution, due to the chemical pesticides spraying in agriculture and discharges of uncontrolled household garbage.

**Keywords:** piezometric levels; shallow and deep aquifer; pollution; water quality index



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#### Response Surface Methodology Approach On The Removal Of Methylene Blue By Green Carboxymethyl Cellulose Based Gel Beads

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**Abstract:** Actually, the contamination of the environment by the effluents that contains dyes becomes a serious problem for the aquatic system as well as human beings. Then, the challenge is to develop a green adsorbent with high characteristics such as sustainability and abundance. Methylene Blue (MB), a cationic dye, was selected herein because of its widespread application in textile dyeing and by virtue of being present in the human and veterinary pharmacopoeia for a long time. The response surface methodology (RSM) is an excellent choice for estimating relationships among experimental factors and responses and representing main and interaction effects. It is possible to create a predictive polynomial equation that expresses the correlation between factors and responses. In this study, Green carboxymethyl cellulose-alginate gel beads reinforced with graphene oxide were prepared as effective adsorbents for Methylene blue (MB). The structure and morphology of the prepared gel beads were characterized by Fourier transform infrared (FTIR), scanning electron microscope (SEM) coupled by (EDX), Thermogravimetric (TGA) and differential Thermogravimetric analysis (DTA). During the treatment process of the adsorbent, response surface methodology (RSM) based on three-level Box-Behnken design was applied. The effects of three independent variables such as adsorbent amount (0.3-0.7 g), pH (6.5-9.5) and initial concentration of MB (15-45 mg/L) on the adsorption removal capacity for MB (as dependent variable) were investigated. The polynomial equation, 2D-contour and 3Dresponse surface plots of the design space were used to investigate the relationship between independent variables and the dependent variable (response).

Keywords: Box-Behnken; response surface methodology, methylene bleu removal



#### Methylene Blue Removal By Adsorption And Fenton-Like Process

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**Abstract:** In this work, the removal of methylene blue in aqueous solution by adsorption and Fenton-like process using raw palygorskite rich clay and Fe-impregnated palygorskite as adsorbent and catalyst, respectively. The raw clay, namely AJ, was sampled in southern Tunisia. The studied clayey materials characterization and presence of palygorskite was assessed by XRD, electron microscopy and FTIR. The effects of experimental variables such as catalyst dosage, initial concentration and pH of the dye solution, volume of hydrogen peroxide, contact time were examined. The results show the relatively good uptake of methylene blue by both raw AJ and treated Fe- AJ. With an adsorbent amount 0.005 g, dye solution discoloration efficiency reached 78.42 and 68.21%, respectively. On other hand, the increasing of initial concentration led to an increase in dye uptake until saturation occurred from 30mg/l. This adsorption behavior, related to the fixation sites' availability, fitted more with Langmuir than Freudlish model. It illustrated the adsorption property of these palygorskite based materials. By addition of H2O2 to the Fe-AJ batch system, a consequent improvement in discoloration rate was recorded (92,17% in 300 min). In other hand, photolysis of H2O2 just achieved to remove 19, 17 % of MB. This suggests a higher HO• radicals generation achieved via Fenton-like process, using coupled Fe-AJ and H2O2, confirming the elevated catalytic activity of the iron impregnated palygorskite.

Keywords: Dye removal; Methylene blue; Adsorption; Fenton process



#### Valorization And Optimization Of A Bio-Flocculant Coagulant Extracted From **Opuntia Ficus-Indica For The Treatment Of Polluted Water**

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**Abstract:** The purpose of flocculation coagulation is to destabilize colloids and fine particles in suspension, causing their agglomeration. It is used for clarification, discoloration, agglomeration of precipitates and improvement of taste and odors. Opuntia Ficus-Indica is of great interest as a coagulant flocculant of biological origin because it is biodegradable and virtually non-toxic and can replace industrial mineral flocculants that are toxic to flora and fauna. Coagulation-flocculation tests were performed with fig juice and its gelatinous extract (GE) on a kaolin solution. The result shows a slight reduction in turbidity due to the low methylation of their pectin. This led to the methylation of pectin with a divalent ion (Ca++), which improved their yield. Their purifying power was tested on two solutions of iron and lead (0.5 10-3 M), then on industrial wastewater. The result is the complete elimination of iron and lead in the two metallic solutions, and the sharp drop in the turbidity of industrial wastewater. By testing the effect of adding GE as a flocculant to the FeCl<sub>3</sub>, 6H<sub>2</sub>O and AlCl<sub>3</sub> mineral flocculants, we noticed that GE can act as a flocculant for these industrial coagulants. To perform the optimization tests of these two flocculants as a function of salinity and pH, the effect of the ionic strength on the flocculation process was tested. The optimal concentration of NaCl as a biofoculant for minimum turbidity was evaluated for GE and juice. The pH values appropriate for good flocculation are obtained for the two pH values ranging below 3 and greater than 11. From these facts, these two biofloculants (GE and Nopal juice) therefore have a very strong purifying and clarifying power and can be used for the treatment of industrial wastewater and polluted water intended for human and animal consumption as well as for irrigation.

**Keywords:** bio-floculant coagulant; extracted gel; pectin; methylation; turbidity



#### Application of Geochemical And Isotopic Techniques In The Study Of Groundwater In Sidi Merzoug-Sbiba Basin, Central Tunisia

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**Abstract:** The Sidi Merzoug – Sbiba basin is located in Central Tunisia and belongs to semiarid regions with annual precipitation less than 350 mm. It consists of a succession of groundwater reservoirs logged in the Campanian limestones, Miocene sandstones and continental Mio-Plio-Quaternary deposits. It constitutes the main water resource for water supply and agricultural activities. As a result, the number of deep wells has increased during the last years as well as illegal and unregulated groundwater pumping. This situation has caused intensive exploitation marked by lowering in groundwater levels, the subsequent decline in the available water quantity and the deterioration of groundwater quality. The hydrogeological study of the aquifer system has identified a hydrodynamic regime largely influenced by tectonics, lithology and climate. The aim of this study is to identify the chemical and isotopic properties of groundwater, to determine the sources of salinity, the possibility of Groundwater mixing and the recharge areas. The results of geochemical analysis of the samples show a high variation of the salinity in the different aquifers mainly in Mio-Plio-Quaternary, where it could reach 6060 mg/l. This investigation indicates that the salinization of the system aquifer is controlled by the dissolution of evaporate minerals (halite and gypsum) and the existence of interactions between water and clay minerals known as cation exchange process. Stable and radioactive isotopes (<sup>2</sup>H, <sup>18</sup>O and <sup>3</sup>H) indicate a recent recharge by rainwater infiltrated directly through rivers and the Cretaceous and Miocene outcrops. It also showed the role of dissolution and evaporation processes in salts concentration. Two recharge periods were identified in the study area: before and after the nuclear tests

Keywords: Geochemistry; Isotopes; Groundwater; Sidi Merzoug-Sbiba basin



#### Geochemical And Isotopic Investigation Of The Aquifer Systems Of Majel Bel Abbes Basin (Central Tunisia)

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Abstract: The studied aquifer system is the basin of Majel Ben Abbes in Central Tunisia between Gafsa and Kasserine. The climatic conditions are those of semiarid. This aquifer system has good quality groundwater, which is the main source for drinking water and irrigation. However, it is confronted with quantitative and qualitative constraints as many regions subjected to a semiarid environment with an increasing anthropic pressure. The purpose of this study is to define the hydrogeological and hydrochemical of Mejel Ben Abbes's basin. The plain is covered by Plio-Quaternary in its center and bordering by Miocene formations. These geological units rest directly on Upper Cretaceous rocks. Groundwater samples (58) were collected; 14 from shallow wells of the Plio-Quaternary aquifer; 37 from deep wells of the Mio-Plio-Quaternary aquifer; 7deep wells tapping Upper Cretaceous rocks. The sampling procedure included field measurements of pH, electrical conductivity, and temperature. In the laboratory major element and isotopes Stable ( $\delta$ 180,  $\delta$ 2H) were determined. Those constructed in the Mio-Pliocene aquifer show the piezometric surface slopping from the north towards the south, its deepest value regarding the ground surface is towards Majel Ben Abbes, suggesting this is a recharge zone. Regarding TDS they are from 0.35 g/L to 2.43 g/L. A preliminary interpretation of the high TDS values seems to correlate with shallow wells suggesting the influence of anthropic activities. Concerning major elements, three types of water may suggest three different flow systems: one as SO4-Cl-Ca; the second as SO4-Na-Ca; and the third one of mixed characteristics. Results also show exchange between groundwater and hosting rock (water-rock interaction). Isotopic composition varies from -8.48 to -5.73 for  $\delta$ 180; and  $\delta$ 2H have values from -34.15 to -54.99. Most of the samples appear near or along the Global MeteoricWater Line, suggesting groundwater samples are of meteoric origin, implying recharge has not been affected by evaporation processes.

Keywords: Arid regions; Majel Ben Abess; Groundwater mineralization; Stable isotopes



#### Adsorption And Thermodynamic Studies On The Removal Of Methyl Red From Aqueous Solutions Using Clays Of Sejnane

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**Abstract:** : Water pollution by dyes is becoming a severe global issue due to toxicity and accumulation nature of its components. Although, the adsorption on clays is one of the most effective, economic and simplest methods for the removal of dyes from aqueous solutions.

Numidian clays of Sejnane are used as a physical treatment of colored wastewaters. An experimental study has been done in order to investigate the capacity of this adsorbent to clarify the water from the methyl red MR, which is the adsorbate.

During this experimental study, many parameters were tested, such as initial adsorbent mass, initial dye concentration, effect of pH and temperature, to study the adsorption of the azodye "methyl red" by the raw and purified clays (ANb and ANp).

The study of the thermodynamic parameters of the adsorption process for the raw and purified clays confirmed that it is endothermic and the values of the standard enthalpy are negatives ( $\Delta H^{\circ} < 0$ ). It confirms that is a spontaneous type of adsorption. The comparative assessment established between the ANb and the ANp allowed us to note that 0.25g of raw clay can adsorb 397mgg<sup>-1</sup>, while 0.08g of pure clay can only adsorb 132.3mgg<sup>-1</sup>. Therefore, So some of this dye is retained by other components which are probably organic matter and carbonates. In addiction, the adsorption energy is high when the clay is purified but it is significantly lower for raw sample. Thus, adsorption by carbonates and organic matter might involves small amounts of energy.

Keywords: water pollution; adsorption; clays; azodye; thermodynamic study



#### Assessing The Risk Of Pb, Zn And Cd In Jebel Ressas Mining Environment

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**Abstract:** The Jebel Ressas is located in the North of Tunisia. Under the semi-arid Mediterranean climate, hydraulic erosion triggers the transport of contaminated towards the agricultural soils. The site characterized by dominant formations of Jurassic. The most abundant mine minerals are galena and sphalerite. Mining activity in Jebel Ressas were conducted during 70 years and it generated important quantities of wastes mainly composed of silt and clay. This study aims to assess of the risk of heavy metals distribution after hydric erosion.

The Jebel Ressas mining materials samples present a pH which varies from 6.9 to 9. The mining environment is carbonated and characterized by the abundance of calcite. The chemical analysis of twenty-nine sediment samples show that these wastes present high concentrations of heavy metals (13916 ppm for Pb, 13019 ppm for Zn, 103.9 mg.kg<sup>-1</sup> for Cd). The mobility of heavy metals is controlled by several parameters, such us pH, OM content, CaCO<sub>3</sub> content, particle size, etc. A basic pH favors the stability of heavy metals, but an acidic pH promotes their solubility and mobility and increases their bioavailability. MO is also present as a support in which the metals chelate with these complex molecules. The highest percentage of CaCo<sub>3</sub> show that Jebel Ressas waste have a significant influence on the particle size and chemical composition of nearby agricultural soils. In addition Soil contamination due to surface water transport. There is a higher risk intensity in a perimeter of a few hundred meters around waste. In addition, the existence of potentially high-risk areas in agricultural soils located downstream of waste.

Keywords: heavy metals; Jebel Ressas; mobility; pollution



#### Characterization Of Heavy Metals Of The Mining Disharges : Case Of The Former Jbel Ressas Mine (Ne Of Tunisia)

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**Abstract:** The former lead-zinc mining activity at Jebel Ressas (NE of Tunisia, south of the Ben Arous region) generated significant quantities of fine, unconsolidated discharges rich in potentially toxic elements. These releases, abandoned to the open air without any prior development, are the site of wind and water erosion, which can damage ecosystems affected by the distribution of these pollutants. Several representative samples were the subject of this work, which aims to separate heavy metals by minimizing Pb and Zn contents in the Jebel Ressas mine waste with the possibility of lead and zinc recovery. To do this, a mineralogical, petrographic and chemical characterization will be carried out, followed by treatment tests using the flotation process.

The mineralogical study by DRX showed the presence of the following minerals: anglesite, cerusite, hemimorphite, hydrozincite, gypsum and quartz in an essentially carbonate gangue. The petrographic study confirmed these results. Chemical analysis by atomic absorption showed the presence of high levels of total Pb and total Zn in the order of 20236 and 20899 ppm respectively. Treatment tests on these flotation release samples were carried out. After optimization of the operating parameters: grinding time, pulp density, reagent quantity; the results of this mineralurgical process made it possible to recover Pb and Zn in the concentrate and to have a final discharge moderately depleted in Pb which is 17100 ppm and in Zn which is 1800 ppm. Thus these discharges can be treated by the flotation process and minimize heavy metal contents in the environment.

Keywords: Jebel Ressas; Tailings; Heavy metals; Flotation



#### Role Of Saltwater Intrusion In Increasing Salinity Of The Mahdia-Ksour Essef Water Table

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**Abstract:** The salinization of groundwater is becoming a major concern in groundwater management. In Tunisia this phenomenon is affecting coastal aquifers such as Mahdia Ksour Essaf's aquifer. This Mio-Plio-Quaternary aquifer, located in the eastern coast of the country in the governorate of Mahdia, is characterized by a semi-arid climate. In situ measurements show that the groundwater feeding from the salt water of sebkha and sea. Hydrochemical and geophysical investigations have made it possible to characterize the water table and identify the processes and chemical reactions that govern the salinization of the aquifer and determine their various sources, and to delimit the most contaminated areas. Furthermore, geophysical based on electrical resistivity tomography and Vertical Electrical Sounding have been adopted to obtain high-resolution electrical sections imaging, which allows delineation of the areas characterized by a high salinization and reconstructs the geometry of the saline wedge front.

Hydrogeochemistry, Vertical Electrical Sounding and Electrical Resistivity tomography have been widely applied in the coastal area to map the seawater/freshwater interface. The results obtained by this approach, which combines several methods, have made it possible to identify an intrusion of salt water and to identify the areas most sensitive to salinization. These areas are located on the coastal fringe and near sebkha Moknine. This could probably be due to intensive pumping associated with rainfall deficiency and/or the lithological nature of aquifers (alteration, dissolution). These factors cause a disruption of the freshwater-salt water interface and increase the flow of salt water to the aquifer. Indeed, the geochemical processes have about two facies of chlorinated water relatively rich in calcium and magnesium and the other sodium hyperchloride.

The results of the geophysical method complete and confirm those obtained with hydrochemistry. The imbalance between the two types of water has caused salinization of the coastal groundwater, which is significant laterally by marine waters and vertically by sebkhas waters (only in the northern part of the study area).

**Keywords:** Hydrogeochemistry; geophysics; water table; sebkha; tomography; salt water intrusion; salinization



#### Spatial Distribution Of Organic Pollutants In Surface Sediments From El Bey River Northeast Of Tunisia

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**Abstract:** Sources of persistent organic pollutants like polycyclic aromatic hydrocarbon (PAH) and polychlorinated biphenyl (PCB) are mainly anthropogenic. Sedimentary pollutants were higher in sites located near industrial and densely populated area. Once in the atmospheric compartment these pollutants are carried on more or less long range depending on the meteorological conditions and pollutant polarity. In the present study, we investigated the spatial distribution of organic pollutants under anthropic stress. Our interest has been targeted for polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) in sediment of El Bey River in north east of Tunisia. In surface sediments, the concentration of total PAHs, PCBs ranged from 239.99 to 5362.19; 39.67to 643.97  $\mu$ g kg<sup>-1</sup> respectively. The content of the total organic matter dissolved in the organic solvent varied from 266.7 to 600  $\mu$ g kg<sup>-1</sup>.

The chromatographic profiles of PAHs in sediment showed a predominance of high hydrocarbons (4-6 rings) with value percent varying between 50 and 100%. High-molecular weight is detected from Boucharray to seashore. In fact, the High molecular PAH are hydrophobic and more sorbed in a solid matrix due to their low SW, high Kow and KOC.

The PCBs with more chlore are found near the industrial and urban site. The PCB concentration of higher molecules is predominant near industrial sources. But near the sea, the lightest molecular weight of PCBs are detected (29.30 and 28%), which proves that the transport of PCBs is preserved during a short transport distance. The congener PCB 209, the most toxic in PCB indicator of pollution was detected in surface sediment with PCB, their concentration reached 0.00062mg.g<sup>-1</sup>.

The spatial distribution and the mapping of the level of organic pollution (PAHs and PCBs) confirmed the direct impact of wastewater effluent on the organic pollution on sediment and the high risk of groundwater contamination.

**Keywords:** Organic pollution; HAPs; PCBs; spatial distribution; sedimentary quality



## **POSTER SESSION**

# TOPIC3: Groundwater Exploration & Monitoring



#### Hydrogeophysics Study Of Oligocene Reservoirs In The Kairouan-Souassi Basin (Tunisian Sahel)

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**Abstract:** The Tunisian Sahel area is undergoing increasing urbanization and economic development. The Souassi-Kairouan area has an irregular rainfall and very low water resources that does not meet the needs of the region development. In addition, the deepwater resources are under-explored.. The Oligocene reservoir levels in subsurface, as well as its hydrogeological potential is not yet well studied. Few hydraulic wells has exploited this aquifer in this region due to the investigation depth and acknowledge of its subsurface structuring, despite its great potential as reservoir and water quality.

Two main methods were used in this studied including; 2D seismic reflection grid used for the picking and the identification of the reservoir levels geometries and extensions, the isochronous and isopach mapping of the Oligocene aquifer reservoirs. In the other hand, petrophysical well logging were studied for better identification and characterization of the stratigraphic and the depositional system of these sandstone reservoirs.

The evolution of the Oligocene lithology of these reservoirs of the based on the logs shows that sandstone levels top depth ranges from 450 to 1400 m and final depth from 600 to 1850 m. These levels show laterally thickness and facies variations, composed by five coarse and fine sandstone decametric multilayer water saturated packages. The time depth map of top Oligocene reservoirs was determined using the seismic sections, borehole data, and TWT and velocity maps. This map highlighted the important roles of NS, NE-SW and EW major tectonic faults in the structures of the reservoir gridding. Uplifts and depressions follow the fault corridor's directions. The top depths of Oligocene reservoirs vary between 600 ms and 1300 ms.

The preliminary results in this area are encouraging to do more specific studies to identify the target reservoirs extension and volumetric resource estimations.

**Keywords:** Tunisia; Sahel; Oligocene; Reservoirs; Groundwater; Seismic



#### Groundwater Potential Mapping Using Frequency Ratio Probabilistic Model In The High Valley Of Medjerda Basin, Tunisia

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**Abstract:** In the present study, the groundwater potential zones were delineated by adopting a frequency ratio (FR) model. Landuse, hydro geomorphology, slope, geology, lineament density, drainage density, spring well locations and ground water level were the thematic factors considered for groundwater potential zone mapping. There are 85 spring wells located in the study area, of which 43 wells were considered for success rate and remaining 42 wells considered for prediction rate in the FR model. The final groundwater potential map was classified into five zones as very high, high, moderate, low, and very low.

Keywords: Probabilistic; Model; FR; GWP



#### A Primary Study Of Aquifer Storage And Recovery (Asr) Feasibility In Chegarnia – Sidi Abiche Aquifer, Ne Of Sousse Prefecture, Tunisia

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Abstract: The groundwater flow system of Chegarnia-Sidi Abiche is located in the northeast of Enfidha area, East of Tunisia. It is constituted by multilayered aquifers, where a shallow and deep units are separated by semi-permeable layers. From the geological view point, the reservoir is stored in a synclinal structure composed of Miocene-Pliocene-Quaternary deposits. Chegarnia-Sidi Abiche aquifer has recently showed a general trend of piezometric level decline associated to some seasonal fluctuations, which might be explained by an overexploitation and limited natural recharge. At the same time, the study zone constitutes a passing point of pipes transferring water from the North of the country until Sfax prefecture in the South (North Water Transfer Project). Benefiting this situation, artificial recharge of groundwater by direct injection of these waters can be realisable by ASR method. Therefore, a feasibility study of ASR was carried out with primary objective of studying the potentialities of the groundwater flow system to store an allowed amount of the transferred water. A field survey was carried out in the study area and in-situ measurements of physicochemical parameters and groundwater level were measured. The taken samples were subject of chemical and isotopic analysis. The reservoir geometry was clarified through boring data observations, well loggings and lithostratigraphic correlations. Hydrodynamics investigations highlighted the spatiotemporal behavior of aquifer piezomety. Geochemical and isotopic data were used to clarify recharge and flow mechanisms. A conceptual model describing the hydrogeochemical functioning of the aquifer was established. It was concluded that central zone of Chegarnia - Sidi Abiche syncline is primarily the favorable zone for implementing the ASR technique. A numerical model of groundwater flow will be soon constructed in order to verify the primary results and to simulate the aquifer behavior under different ASR scenarios.

Keywords: ASR; feasibility; Chegarnia-Sidi Abiche aquifer



#### Balance, Trend And Hydro-Dynamism Of The Salinization, Of The Artificial Refill Korba Site (Tunisian Oriental Coast)

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**Abstract:** Arid and semi-arid regions are experiencing recurrent water stress. To satisfy the increasing demand, the excessive groundwater abstracting at a rate greater than replenishment led to water table decline and quality deterioration. In Tunisia, to face groundwater depletion, artificial refilling as a water management program was decided in the coastal aquifer of Korba. This city is located on the oriental coast of the Cap Bon region (North-East Tunisia) and limited in the East part by the Mediterranean Sea and the coastal lagoons. Before the artificial refill of the site, a geochemical study was carried out in order to evaluate the salinization trend and its origin, the groundwater balance, and the hydro-dynamism of the korba zone. These collected data will help monitor and evaluate the quantitative impact of wastewater ingress towards the groundwater.

The cations and anions concentrations showed that groundwater is highly mineralized and that electric conductivities varied between 5.1 and 16.7 mScm<sup>-1</sup>. Based on the results of Na, K, Mg, Ca, Cl, sulphate, bicarbonate and Br concentrations, the ratios of  $rMg^{2+}/rCa^{2+}$  and  $rBr^{-}/rCl^{-}$  and the correlation coefficients between the analyzed parameters, the salinization increase of groundwater is mainly due the infiltration of marine and lagoon water and irrigation return flow. Also, we noted that local artificial refill with fresh water and runoff water which regain the aquifer helped improve the salinity of a part of the refill site and its surroundings.

The salinity variation of this groundwater depends on the type and quantities of the infiltrated water, the geologic nature of the saturated and unsaturated zones, the flow inertia and the infiltration rate of the various water types which are determining factors in the salinization, balance, water quality evolution and the aquifer dynamism.

Keywords: coastal aquifer; salinization; artificial refill; Tunisia



#### Improved Integrated Water Resource Management In The Mornag Area– Engineering Component - Artificial Aquifer Recharge

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**Abstract:** To ensure integrated and sustainable water resource management in the Mornag plain, the Ministry of Agriculture, Hydraulic Resource and Fisheries represented by CRDA Ben Arous initiated a project in 2014 with funding from the KfW to protect the Mornag Aquifer, located south of Tunis.

The project includes two components: (1) Rehabilitation of the irrigated schemes of the Mornag plain and (2) the artificial recharge of the Mornag aquifer with treated wastewater. This poster focuses on the second component.

The activities of the Primarily Design Study (1st phase) included: (1) Groundwater model development, and simulation of possible recharge techniques and variants alongside an assessment of their impacts, (2) evaluation of effluent suitability for groundwater recharge from two Wastewater Treatment Plant (WWTP); and (3) hydrogeological and geophysical sampling programme for updating the current status of the aquifer. Results have shown that the treated effluent from the two WWTP currently is incompatible with the required quality standards for artificial recharge purposes due to high heavy metal content. With regards to the artificial recharge, results suggest that a hydraulic barrier through deep injection wells may be the only possible solution which prevents further propagation of marine salt water intrusion and contributes moderately and partially to the recovery of the piezometry.

Activities carried out as part of the Detailed Preliminary Design Study (2<sup>nd</sup> phase) are prerequisites to the planning of infrastructure of the hydraulic barrier. The activities include the collection of additional data and conducting field measurements and tests in the coastal zone, primarily to acquire further details for the development of a hydrogeological sub-model for the coastal area. Therefore, a series of six multi-level piezometers equipped with telemetric data logger along two parallel lines perpendicular to the coast, as well as two test infiltration wells are installed.

**Keywords:** Seawater intrusion; Artificial recharge; Mornag aquifer; Injection wells; Multi-Level-Piezometers



#### Delineation Of Groundwater Contamination Plumes Using Electrical Resistivity Tomography: Maâmoura, Jebel Ressas And Borj Chakir Cases Study

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**Abstract:** The High resolution electrical tomography is an efficient technique used essentially to study the contaminated areas. Therefore, we proposed in the following study to test the reliability of this method in different Tunisian contaminated sites. The first case study is the seawater intrusion at El Maâmoura region (Cap bon coastal plain). The second case study concerns the waste heavy metals contamination at the ancient laundry of Jebel Ressas and surrounding areas. The third case study is related to the landfill of Borj Chakir contaminated by wastes and leachate. In this study, electrical profiles were performed using the Terrameter Lund Imaging System with an array of 64 electrodes. The Wenner configuration was used with a unit electrode spacing of 5 m.

Finally, we use hydrogeological data, and ERT data superimposed with the location of wells to provide a conceptual framework for the delineation of groundwater contamination.

**Keywords:** electrical tomography; contamination; seawater intrusion; heavy metals; leachate



#### Geophysical Contribution For The Characterization Of Deep Aquifers And Conceptualization Of A Hydrogeological Operating Model: Moghrane-Zaghouan - Bouficha Area (Northeastern Tunisia)

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**Abstract:** The deep Tertiary and Quanternary aquifer of the Moghrane-Zaghouan-Bouficha plain (NE of Tunisia) was studied on a regional scale in order to locate the most interesting zone for future hydrogeological exploration. This aquifer was identified by a petroleum well, that is located at the center of the structured graben and reveals the presence of Triassic salt with abnormal contact under a thick Tertiary layer. Gravity data and seismic reflection were analyzed using advanced interpretation to understand the geometry of Tertiary and Quanternary aquifers and their relations with possible Triassic salt contamination.

Finally, the Domain Electromagnetic Method (TDEM) coupled with Electrical Resistivity Tomography (ERT) studied has made it possible to improve the reservoir characteristics of this aquifer and to construct a hydrogeological operating model in the Zaghouan plain region.

Keywords: Graben; Oligo-Miocene aquifer; gravity; seismic; TDEM



#### Gravity Analysis For Geometric Insights In Mornag Plaine

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**Abstract:** For a few decades now, the Mornag plain, which represents a very important agricultural district in Tunisia, suffers from excessive exploitation of its water resources. For this, this area has been the subject of several studies that called upon to several disciplines of geology, hydrogeology and hydrology. Under this framework comes this study in which we conducted a qualitative and quantitative analysis of gravity data to give a clearer structural vision of the region.

The geological map of the region shows that the Mornag plain is covered by quaternary sediments. However, the massifs located around the plains show outcrops ranging from Trias to Miocene with great structural complexity. This complexity seems to continue below quaternary deposits.

The analysis of the Bouguer anomaly map and the residual anomaly map show very heterogeneous mass distributions in the subsurface. A negative anomaly with a large wavelength and large amplitude characterizes the Mornag area. This anomaly is bordered by very tight gradients, suggesting the existence of an important normal faults dipping system. This gravimetric response is likely associated with graben structures. However, small residual wavelengths appear in the same region. These can testify the existence of a rather complex geometry within the graben itself.

Gravity data inversion provided a better understanding of the geometry of the study area Tunisia, suffers from excessive exploitation of its water resources. For this, this area has been the subject of several studies that called upon to several disciplines of geology, hydrogeology and hydrology. Under this framework comes this study in which we conducted a qualitative and quantitative analysis of gravity data to give a clearer structural vision of the region.

Keywords: Gravity; Mornag; Geometry



#### The Sebkha Kelbia In Central Tunisia: Is It The Main Outlet Of The Large Plio-Quaternary Aquifer Of The Kairouan Plain?

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**Abstract:** The Plio-Quaternary aquifer of the Kairouan plain (central Tunisia, 3000 Km<sup>2</sup>) represents a key resource for the agricultural development of the region. To date, hydrological studies suppose that groundwater of this large aquifer is discharged in the Sebkha Kelbia depression (120 Km<sup>2</sup>) by evaporation. In front of the continuous groundwater level drop observed since the 1970s, quantify the volume of groundwater discharge is important for an advanced water balance analysis of the aquifer. This study investigates exchanges between groundwater and surface water and describes water flow paths in the Sebkha Kelbia basin by combined two approaches such are environmental tracers and geophysical investigation (TDEM). Two types of groundwater were distinguished in Sebkha Kelbia basin based on their piezometric and geochemical behaviors. Geophysical study shows that a deep fresh groundwater is confined below a clay layer and separated from shallow saline groundwater. According to stable isotopes (d18O, d2H), deep groundwater in the north of the Sebkha is characterized by enriched d180 and d2H contents, reflecting the existence of another source of recent recharge. Further south, the isotopic composition of deep groundwater is characterized by depleted isotopic levels of stable isotopes. This isotopic signature is very similar to that of the Plio-Quaternary aquifer, confirming that the Sebkha Kelbia is recharged by the groundwater of Kairouan aquifer in this area. Results make clear that, not the entire amount of groundwater of the Plio-Quaternary aquifer in Kairouan plain are discharged in the Sebkha Kelbia. A flow path from upstream to downstream of the Sebkha Kelbia is defined on the basis of the piezometric map, showing that groundwater continues partly towards the sea. This study highlights another role of the Sebkha Kelbia. It represents not only a discharge area of groundwater but can also recharges the shallow groundwater in the north of the basin.

**Keywords:** semi-arid area; hydrogeology; environmental tracers; geophysical investigation; surface and groundwater exchanges



#### Geophysical Mapping Of Hidden Geological Features Under Gaafour-El Aroussa-Bouarada: Hydrogeological Implication

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**Abstract:** As a first step of a regional geophysical study, gravity and seismic analysis, was established in order to perform geophysical mapping of Gaafour-El Aroussa-Bouarada study area (Northwestern Tunisia).

After applying a Gaussian Residual-Regional Filter, a residual gravity map was produced. The derived Tilt map reveals that the Gaafour-El Aroussa-Bouarada plains are composed by Gaafour/El Aroussa/Bou Arada Grabens separated by horsts and affected also by anticline/syncline systems. The regional density transects calibrated by seismic sections show also some interesting areas from hydrogeological point of view. So this study, aims to more highlighting the hydrogeological characteristics and deep water flow pathways related to hidden geological features under Gaafour-El Aroussa-Bouarada plains.

Keywords: Geophysics; Gravity; Seismic; Grabens; Hydrogeology



#### Characterization Of The Cherita Water Table (Mahdia / Tunisia) Using Geochemistry And Geophysics

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**Abstract:** The overexploitation of groundwater causes several problems for the arid and semi-arid regions. Salinization of groundwater is one of the most important consequences of this phenomenon. It is specific for coastal aquifers and this is not the case of our aquifer, which is close to the sebkha Cherita. The Chérita water table of plio-quaternary age belongs to the Sidi El Hani watershed, west of the Mahdia governorate (Sahel platform domain), characterized by semi-arid climate.

Field surveys and piezometric calculations show the Sebkha feeding by groundwater. Hydrochemical and geophysical investigations made it possible not only to characterize salinization of groundwater but also to identify the different sources of contamination. The geochemical processes detected, according to the overall direction of flow, are the dissolution of gypsum and halite, which leads to the chlorinated facies sulphated calcium from the waters of the aquifer. Overexploitation of the water table and the decrease in annual rainfall rates are the origin of contamination of the water table by salt water, especially in the northwestern areas of the Sebkha Chérita, due to the imbalance between salt water and fresh water. Geophysics with electrical resistivity tomography has identified the special distribution of salinity and plumes at groundwater level, and the intrusion of salted pathways from the Sebkha to the Chérita water table.

Salinization of groundwater is one of the most important consequences of this phenomenon. It is specific for coastal aquifers and this is not the case of our aquifer, which is close to the sebkha Cherita. The Chérita water table of plio-quaternary age belongs to the Sidi El Hani watershed, west of the Mahdia governorate (Sahel platform domain), characterized by semi-arid climate.

Field surveys and piezometric calculations show the Sebkha feeding by groundwater. Hydrochemical and geophysical investigations made it possible not only to characterize salinization of groundwater but also to identify the different sources of contamination. The geochemical processes detected, according to the overall direction of flow, are the dissolution of gypsum and halite, which leads to the chlorinated facies sulphated calcium from the waters of the aquifer. Overexploitation of the water table and the decrease in annual rainfall rates are the origin of contamination of the water table by salt water, especially in the northwestern areas of the Sebkha Chérita, due to the imbalance between salt water and fresh water. Geophysics with electrical resistivity tomography has identified the special distribution of salinity and plumes at groundwater level, and the intrusion of salted pathways from the Sebkha to the Chérita water table.

Keywords: Hydro-geochemistry; Water table; Sebkha; Tomography; Salt water intrusion

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#### Deep Groundwater Investigation Using Combined Gravity And Seismic Reflection Methods: Case Study Of Ain El Beidha Basin, Central Tunisia

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**Abstract:** A geophysical investigation involving the Gravity and the Seismic Reflection methods was carried out in the Ain el Beidha Basin, to the West of Kairouan area, in Central Tunisia, for deep groundwater study. In this area, the Tertiary groundwater tables are the best sources for drinking and irrigation water.

The study aims were to understand the subsurface Ain el Beidha Basin structuring and to determine the Eocene, Oligocene and Miocene aquifer thicknesses and geometries throughout the area.

Used Data consisted of 1 Km<sup>2</sup> Gravity coverage (performed by ONM) and thirteen seismic lines that cover all the area (Obtained from ETAP). The lack of petroleum well within this Basin led us to use the deep hydraulic wells to calibrate the seismic lines.

Advanced gravity data analysis and seismic interpretation confirmed that in subsurface, Ain El Beidha basin is structured in two synclines: the very subsiding syncline of oued Ben Zitoun situated to the NW and the syncline of Ain El Beidha situated to the SE of the plain.

These two synclines are separated by the NE-SW directed anticline of Kroumet Zemla. This structuring affected all the Tertiary aquifers.

Major normal faults directed NW-SE emphasized the individualization of Oued Ben Zitoun syncline and increased the subsidence at this structure.

Keywords: Ain El Beidha; Groundwater; Gravity; seismic reflection; Tunisia



#### A Comprehensive Study Of The Groundwater Regionalization In Jeffara Basin Using Gis Tools, Multivariate Analysis And Geostatistics

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**Abstract:** Advanced approaches such as GIS tools, Multivariate Analysis and GeoStatistics has become very handy tools in assessing, monitoring and conserving groundwater resources. In this regard, a thorough study of physical and chemical characteristics of the Jeffara basin aquifer systems has been performed, the results of which are presented in this communication.

The aim of the study is to integrate such investigating methods to provide an original methodology, that involves both structural and functional approaches, to i) understand the geological architecture, ii) to analyze the water quality status, iii) to understand the spatial correlation between the stacking pattern of the aquifers and the fluid flow paths and hence iv) to build a conceptual hydrogeochemical functioning of the aquifer system.

The geostatistical estimation taking into account the geological knowledge, in the modelling procedures, allowed to build realistic models of the different parameters: reservoir units geometry and discontinuities, piezometric head, TDS and major ion concentrations. On the other hand, the spatial cross-analysis between the significant water groups obtained with the hierarchical cluster analysis method, and the structural aquifer compartments defined by the geological studies, reveals the spatial dependence between the geochemical properties (c.e., hydrochemical facies and mineralization rate) and the hydrogeological and structural context (recharge area, piezometric level, flow paths, lithology, layering of aquifers and faults). This procedure results in a robust interpretation that helps to understand the hydrochemical functioning at both the regional and local scales, i.e. inside each compartment and from one compartment to another.

The relative importance of the defined processes in controlling groundwater chemistry and its spatial distribution is influenced by groundwater flow paths (depth and lateral extent) and/or groundwater residence time. These two factors are governed by the geological configuration that characterizes the aquifer system, i.e. the structural compartmentalization by NE-SW and NW-SE normal faults and the sediment composition and layering within each aquifer compartment. Moreover, the presence and/or the thickness of the "upper Mio-Plio-Quaternary unit" are crucial factors controlling the geochemistry of the groundwater within the different compartments.

Keywords: GIS tools; Multivariate Analysis; GeoStatistics; Structural features; Cross-analysis



## **POSTER SESSION**

## **TOPIC4: Groundwater Modelling &**

### **Risk Management**



#### Hydrodynamic And Hydrochemical Study And Numerical Simulation Of Seawater Intrusion In The Mornag Aquifer (Tunisia)

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**Abstract:** Coastal aquifers located near highly populated areas are often operated under stress management with an over pumping, which may lead to saltwater intrusion. The development of agricultural activities in the Mornag region has generated an inversion of the hydraulic gradient and as consequence the freshwater/seawater interface has already moved considerably inland. To protect the Mornag aquifer, a hydraulic barrier is planned to be created which is performed by means of freshwater injection in a battery of wells. This artificial recharge would raise the hydraulic head and pull back seawater interface.

The aim of this research is to assess the phenomenon of seawater intrusion in the aquifer by a multidisciplinary approach. It mainly focuses on hydrodynamic and hydro-chemical processes using piezometric monitoring data between 2008 and 2017 and hydrochemical interpretation methods. Then, flow and solute transport in vertical 2D models are simulated using the software FEFLOW. Different scenarios are simulated in order to assess the model's sensitivity and results to the geometry meshing, the parameters, and the boundary conditions. The simulations allowed to understand the groundwater flow and solute transport process, and to evaluate the propagation of seawater intrusion and the impact of hydraulic barrier with injection wells.

**Keywords:** Groundwater; Hydrodynamic and Hydrochemical processes; Seawater Intrusion; Artificial recharge; Numerical Modeling; FEFLOW



#### Identifying Key Controls On The Behaviour Of Soluble Salts In The Sidi El Hani Aquifer Using Reactive Transport Modeling

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Abstract: The shallow aquifer of Sidi El Hani, situated between the Sidi El Hani and Cherita sebkhas, is recognized as one of the most important agricultural water resources in Ouled Chamekh Plain (Mahdia). The flow directions are oriented from the west to the Sabkha Sidi El Hani in the north east and to the Sabkha Cherita in the south. The hydraulic heads vary between 80 and 35m above sea level. In the last decades this aguifer was affected by salinization and showed a significant level of chlorides, sodium and sulphates, due to the dissolution of the halite and hypsum. Understanding the long-term trend of ground water chemical elements behavior is fundamental. This study uses a reactive transport model in order to investigate the spatiotemporal evolution of water chemical elements. The model was built and calibrated for two transects of the aquifer oriented along the groundwater flow lines using the numerical code KIRMAT (Kinetic Reaction and Mass Transport) that combines geochemical reactions and 1D mass transport equations. The two transects are discretized with a horizontal spacing of 300 m-long meshes. The modelling approach is based on available geological, mineralogical, thermodynamic, kinetic and hydrodynamic data. The simulation covered 50 and 100 year periods. These periods were chosen to explain the chemical compositions of groundwater in 2015, which was used as the initial state. The results show a good agreement between the simulated and measured concentrations for most chemical elements and a dominance of (Cl, Na and SO4). This dominance is due to halite dissolution, anhydrite and gypsum dissolution and precipitation, calcite dissolution and dolomite precipitation. The sensitivity analysis results indicate that the model parameter is sensitive, especially to the Darcian velocity.

**Keywords:** Groundwater; Hydrogeochemical modeling; KIRMAT; Salinization; Sidi El Hani aquifer



#### Impact Of Anthropogenic Activities On Surface Sediment Wadis In The Gulf Of Tunis

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**Abstract:** This study aims assessing the levels and potential sources of selected contaminants in the surface sediments of wadis in the Gulf of Tunis which wil have impact on groundwater in a long or chort term. Polyaromatic hydrocarbons levels in the surface sediments were very variable (189.8  $\mu$ g/kg –1969  $\mu$ g/kg). The highest concentrations of the sixteen main PAHs are found in wadi Meliane (1969  $\mu$ g/kg), wadi el Bey (1835.6  $\mu$ g/kg) and khlij channel (1082.6) sediments. The lowest concentration are found in the sample of new mouth of wadi Majerda (189.8  $\mu$ g/kg).

The analyses showed that 4-ring PAHs (fluoranthene and pyrene) comprised a greater proportion of the TPAH concentrations in old mouth of wadi Majerda (76%) and in wadi Abid (46%). 5-ring PAHs characterize the wadi Méliane and wadi Majerda new mouth samples (41% and 54%) and 6-ring PAHs (70%) are found in wadi el Bey.

To differentiate between petrogenic and pyrolytic sources of PAHs in sediments, diagnostic PAHs ratios were used. PAHs ratio indicates petrogenic inputs in wadi el Bey, wadi Meliane and Khlij channel and pyrolytic source in wadi Majerda and Wadi Abib. Wadis el Bey and Meliane are vectors of groundwater pollution.

**Keywords:** Gulf of Tunis; sediment; pollution; PAH; index

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#### Groundwater Management And Hydrogeological Modeling Of The Sminja-Oued Rmel Aquifer System In The Zaghouan District (North-Eastern Tunisia)

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Abstract: Hydrogeological modelling is a tool assisting in the efficient management of groundwater related data. The Sminja-Oued Rmel Aquifer System (SORAS) is located in Northeastern Tunisia, consisting of 312 km<sup>2</sup>, of continental detritic deposits mainly of the Quaternary Period formed by a joint thickness of 200 m of clays and sands. The SORAS has beed divided for convenience in two aquifer units with hydrogeological continuity forming a monolayer unconfined structure. The use of Modflow software and Geographic Information Systems (GIS) are used aiming to evaluate both, the hydrodynamics and geometry of the SORAS, as well as to test the response of the piezometric level under different extraction Simulations. The application of Modflow model in steady state, considering that the piezometry of the SORAS is invariable over time, with steady groundwater inflow and outflow, made it possible to refine the spatial distribution of the hydraulic conductivity, with values varying from 3.5  $10^{-6}$  to 2.5  $10^{-5}$  m/s. Despite the inadequacy of the hydrogeological information in some parts of the SORAS, a satisfactory agreement between the calculated piezometric levels and those measured reflects the reliability of the model under initial conditions. The estimated inflow and outflow is of 477 l/s. On the other hand, the calibration of the model in transient state made it possible to determine the piezometric drawdown during the period 1982-2015 in response to an increasing extraction. The largest drawdowns (>3m) are recorded at the eastern and southwestern part of the SORAS, where the majority of the extracted water (0.04 m<sup>3</sup>/s) is taking place. Predictive simulations show that increasing operating rates lead to a significant drawdown increase. Indeed, a first scenario using 2015 field data shows drawdowns of the order of 5 m; consequently, a twofold extraction scenario shows a further drawdown increase of 9 m.

**Keywords:** Hydrogeological modeling; Sminja-Oued Rmel aquifer system; Modflow; water resource management; Tunisia



#### Assessment Of Seawater Intrusion For Sustainable Groundwater Management: Case Study Of Tunisian Coastal Aquifer

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**Abstract:** In Tunisia, water scarcity is a significant constraint to development, with limited available water and financial resources. In addition, effective groundwater-management using numerical simulation techniques is an important tool for long-term sustainability of its productivity and quality. This paper is dealing with the formulation and solution of saltwater intrusion management models, by linking a 3D density-dependent flow and transport model to assess the potential of seawater intrusion in Korba coastal aquifer and to predict responses of water level and TDS with pumping alternatives for the next 36 years. Calibrated model have indicated that the overexploitation induced an additional 5.15 Mm<sup>3</sup>/year of seawater inflow as compared to using steady state budget of 1965, while it caused a reduction of the submarine discharge of 9.74 Mm<sup>3</sup>/year. Under scenarios management, it was determined that a reduction in extraction of 20.4 Mm<sup>3</sup>/year is the optimal-volume of replenishment water in order to prevent overexploitation and make the best use of available water resource on a long-term basis.

These management schemes for the prevention of saltwater intrusion as proposed here are new for the Korba aquifer and can be applied in areas where there is a potential risk of saltwater intrusion. Therefore, the saltwater intrusion management problem presented will give more insight in the sense of planning rather than the current management scheme of the study area.

**Keywords:** Seawater intrusion; Coastal-aquifer; Numerical simulation; Groundwatermanagement; Tunisia
