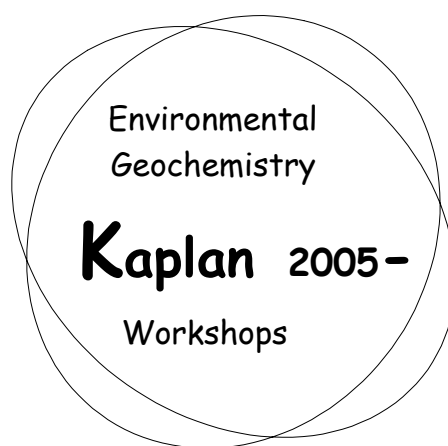


# The 3<sup>rd</sup> Kaplan Symposium

2010

## *Challenges of the Global Water Shortage*





## Introduction

On behalf of the Institute of Earth Sciences we are pleased to welcome you to the third Kaplan Workshop. This series of exciting workshops in environmental geochemistry was made possible by a generous donation from Ian R. and Helen Kaplan. The present workshop, *Challenges of the Global Water Shortage*, brings together different aspects of water research. We hope that the intimate size and scenic location of the workshop will generate the right atmosphere for free exchange of ideas and initiation of future collaborations. In addition, the workshop aims to allow Israeli students and scientists to present their own research and be exposed to some of the new directions in water research and management.

As noted in the introduction to the previous workshop booklets, Ian has been a teacher, a colleague and a friend of our institute for many years. Ian's first encounter with the Department of Geology at the Hebrew University (later to become part of the Institute of Earth Sciences) was during his stay in Jerusalem in 1962-1965 as a Jacob Ziskind Visiting Scholar and Guest Lecturer at the Department of Microbial Chemistry. It was at this time that students and faculty members at the Hebrew University were first exposed to the then emerging science of Biogeochemistry by one of its early leaders. The continuing contacts of Ian with Israeli science were primarily via his training a sequence of graduate students and post-docs from Israel in various aspects of low-temperature geochemistry. The Israeli graduates of the "Kaplan Group" on the fifth floor of Slichter Hall at UCLA returned to several Israeli universities, the Geological Survey, and industry. Ian's ties with the Hebrew University have never ceased. He is constantly there for many of us, always generous with mentoring and sound scientific advice. It goes without saying that these are but a small part of his achievements as a scientist and mentor. His contributions are many. His students are spread around the world.

We would like to warmly thank the contributions of our invited speakers, who all made huge efforts to join us and share with us their knowledge. We also thank the poster contributors, showing the high quality science of Israel.

We thank you all!



# The 3<sup>rd</sup> Kaplan Symposium - *Challenges of the Global Water Shortage*

## Program

### Sunday, April 11<sup>th</sup>

Field excursion

08:00 – Leaving Jerusalem.

8:00 – 12:00 - Traveling along the Jordan Valley and visiting KOCHAV HAYARDEN crusader site – guide: Ronnie Ellenblum, the Hebrew University of Jerusalem

12:00 - 12:30 – Lunch in KOCHAV HAYARDEN

12:30 – 15:00 – Traveling to Amud Valley and visiting the Paleolithic AMUD CAVE – guide: Mae Goder, the Hebrew University of Jerusalem

16:00 – 17:00 – Arriving at Maagan & check-in

17:00 – 21:00 - Session 1: **Changes in precipitation and evaporation** (chairman – D. Rosenfeld)

Potential impacts of climate changes on precipitation – Kevin E. Trenberth, NCAR, USA

Impact of particulate air pollution on rain clouds – Graham Feingold, NOAA, USA

19:00 – 20:00 – Dinner

20:00 – 21:00 - To know what we cannot know: Global mapping of minimal detectable precipitation trends – Efrat Morin, The Hebrew University

21:00 – 23:00 –**Poster session and snacks**

### Monday, April 12<sup>th</sup>

7:30 – 8:30 – Breakfast

8:30 – 10:30 - Session 2: **Contamination of water resources** (chairman – B. Lazar)

Eutrophication of water bodies – Bob Hecky, University of Minnesota, USA

Contamination by organic pollution – Walter Giger, EAWAG-ETH, Switzerland

10:30 – 11:00 – coffee break

11:00 – 13:00 - Session 2 continued: **Contamination of water resources** (chairman – Y. Erel)

Contamination by inorganic pollution - Janet Hering, EAWAG-ETH, Switzerland

The state of surface water reservoirs in Europe – Steve Eisenreich, Research Programs, JRC-Brussels, European Commission

13:00 – 14:00 Lunch

14:00 – 16:00 Session 3: **Salination of water resources** (chairman – S. Emmanuel)

Effects of Faults on Coastal Groundwater Salinity, Southern California - Grant Garven, Tufts University, USA

Modeling of groundwater flow and reactive transport – Jesus Carrera, Universidad Politécnica de Cataluña, Spain

16:00 – 17:00 Session 4: **Lessons from the past** (chairman – Y. Kolodny)

Climate Change and the Collapse of the east-Mediterranean in the mid 11th century (A.D.) –

Ronnie Ellenblum, The Hebrew University

17:00 – 19:00 - Rest, swim, enjoy facilities in Maagan

19:00 – 20:00 – Dinner

20:00 – 21:00 – Monitoring the wellbeing of the Sea of Galilee – Assaf Sukenik, Kinneret

Limnological Laboratory, Israel

21:00 – 23:00 – **Snacks and drinks**

**Tuesday, April 13<sup>th</sup>**

8:00 – 9:30 – Breakfast & checkout

9:30 – 13:00 - Session 4: **Management of water resources** (chairman – H. Gvirtzman)

Water Resources Management - Socio-Economic Perspectives – Uri Shani, Director, Israel Water Authority

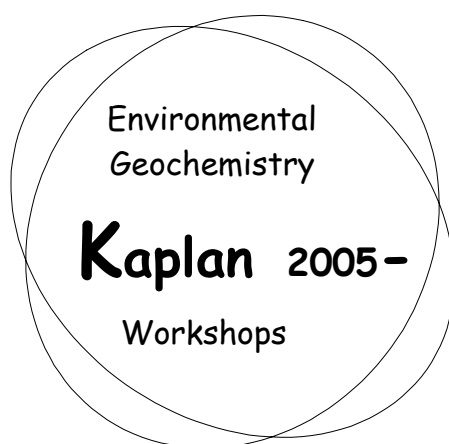
Water Resources Management - Technological Perspectives – Booky Oren, Chairman, MIYA, Arison Group

Water Resources Management - Legal Perspectives – Eyal Benvenisti, Tel Aviv University, Israel

Round table discussion on the challenges of water research and management - led by I. Kaplan, H. Gvirtzman, and D. Rosenfeld

13:00 – 14:00 – Lunch

14:00 – 18:30 – Guided tour to the Sea of Galilee Watershed – Doron Markel, Water Authority, Israel



# ABSTRACTS





## Potential impacts of climate changes on precipitation –

*Kevin E. Trenberth, NCAR, USA*

There is a direct influence of global warming on changes in precipitation. Increased heating leads to greater evaporation and thus surface drying, thereby increasing intensity and duration of drought. However, the water holding capacity of air increases by about 7% per 1°C warming, which leads to increased water vapor in the atmosphere. Hence storms, whether individual thunderstorms, extra-tropical rain or snow storms, or tropical cyclones and hurricanes, supplied by increased moisture, produce more intense precipitation events that are widely observed to be occurring, even in places where total precipitation is decreasing: *“it never rains but it pours!”* In turn this increases the risk of flooding. A discussion will be given of the critical role of the energy budget in the hydrological cycle and why total precipitation amount changes at a slower rate than for total column water vapor. The processes involved will also be discussed. With modest changes in winds, patterns of precipitation do not change much but result in dry areas becoming drier (generally throughout the subtropics) and wet areas becoming wetter, especially in mid to high latitudes: *the “rich get richer and the poor get poorer”* syndrome. This pattern is simulated by climate models and is projected to continue into the future. Because more precipitation occurs as rain instead of snow with warming, and snow melts earlier, there is increased runoff and risk of flooding in early spring, but increased risk of drought in deep summer, especially over continental areas. However, with more precipitation per unit of upward motion in the atmosphere, i.e. *“more bang for the buck”*, the atmospheric circulation weakens, causing monsoons to falter. In the tropics and subtropics, strong patterns of precipitation are dominated by shifts as sea surface temperatures change, with El Niño a good example. The eruption of Mount Pinatubo in 1991 led to an unprecedented drop in land precipitation and runoff, and widespread drought as precipitation shifted from land to oceans and evaporation faltered, providing lessons for possible geo-engineering. Most models have precipitation that occurs prematurely and too often, and with insufficient intensity, resulting in recycling that is too large and a lifetime of moisture in the atmosphere that is too short, affecting runoff and soil moisture. Understanding the profound consequences of climate change on water and the model capabilities and shortcomings is especially important for water managers.

# Impact of particulate air pollution on rain clouds

*Graham Feingold, NOAA, USA*

Predicting precipitation changes in future climate states is a problem of major concern. The increasing pressures on water resources associated with population growth underscore the importance of attempting to predict where the most significant changes in precipitation are likely to occur. From a global perspective the precipitation budget is well-constrained by the total evaporation from the surface, and in this sense the Earth's precipitation system can be viewed as buffered. However, the spatial distribution of precipitation is characterized by considerable regional and local variability. The problem has a number of components: First one needs to consider how greenhouse gas warming is likely to change circulation, and therefore precipitation patterns. Second, radiative forcing associated with aerosol scattering and absorption of solar radiation will affect regional circulation and therefore precipitation patterns. Third, aerosol effects on cloud microphysical processes and precipitation need to be taken into account. Therefore, to address this problem we have to improve our understanding of aerosol-cloud-precipitation processes, for a wide variety of cloud types, within the context of the spatial/temporal variability in the aerosol and its covariance with spatial/temporal meteorological patterns.

In this talk I will focus on the microphysical aspects of aerosol effects on precipitation. Although our knowledge of these processes has increased significantly over the past 50 years, we still have not been able to quantify aerosol effects on precipitation, as distinctly separate from meteorological influences. In fact, even the sign of the expected change is often uncertain. Therefore, even at these scales the aerosol-cloud-precipitation system may be buffered.

Focusing on the aerosol microphysical processes, I will present an approach that will help identify the regions of the Earth that currently have the potential to be most affected by aerosol perturbations. The relatively simple case of precipitation from warm clouds will be tackled using a combination of numerical models of different complexity as well as satellite remote sensing. The validity of simple relationships between rain rate and measurable cloud characteristics such as cloud depth, water content, drop concentration, and cloud lifetime will be explored. These will in turn be used to suggest the applicability of a new construct which we call precipitation susceptibility: the sensitivity of precipitation to a change in the aerosol. The more complex problem of mixed-phase convective clouds will also be touched upon, and potential ways of tackling those challenging issues will be considered.

# **To know what we cannot know: Global mapping of lower limits of statistically significant precipitation trends**

*Efrat Morin, The Hebrew University of Jerusalem, Israel*

Fresh water resources, human societies and ecosystems are expected to be strongly impacted by climate change, with precipitation trends being one of the most important factors involved; however, natural variability of precipitation data can often mask existing trends that as a result are found statistically insignificant. Information on limitations of trend detection is important for risk assessment and for decision making related to adaption strategies under these inherent uncertainties. This study reports an effort to quantify and map minimal detectable trends in annual precipitation data series on a global scale. This type of information is essential when searching for climate change fingerprints. Monte Carlo simulations were conducted to generate realizations of trended precipitation data for different precipitation means and coefficients of variance and the Mann-Kendall method was applied for detecting the trend significance. The GPCC VASClmO data set was used to compute mean and coefficient of variance of annual precipitation over land and to map the minimal detectable trends. It was found that for relatively large trends there is only a low chance to be detected as significant. The largest undetectable trends are in the tropics. Arid and semi-arid regions also present high values in terms of percent change from the mean annual precipitation. Although the presented analysis is based on several simplified assumptions such as a constant linear trend with independent normally distributed residuals, it is mainly aimed to point an inherent problem of potentially undetectable high trends that must be considered in analyzing precipitation data series and assessing risks in adaption strategies to climate change.

# **A short history of eutrophication science and the current state of knowledge**

***R.E. Hecky, University of Minnesota-Duluth, USA***

Concern about the eutrophication of lakes arose during the 1950s and 1960s as the negative consequence of excessive algal growth captured public attention in North America and Europe. Intensive research including experimental studies at multiple scales up to whole lakes identified the efficacy of controlling phosphorus (P) inputs to reduce algal biomass in lakes. Widespread experience in remediation has largely confirmed this efficacy on temperate lakes of all sizes. Research in continuously “warm” lakes has been less extensive globally, in part because of paucity of lakes and lake scientists in the subtropics and tropics. Warm lakes may be especially sensitive to nutrient enrichment because of their lower oxygen content and higher rates of microbial activity. Hypoxia and anoxia favor microbial denitrification which can reduce fixed nitrogen while also facilitating the release of sediment bound P for recycling to the water column leading to positive feedback of P. The result of these two processes in lakes with long flushing times are low N:P ratios which select for bloom forming N fixing cyanobacteria. The eutrophication of Lake Victoria, the world’s largest tropical lake, over the last century illustrates this sensitivity of tropical lakes. In estuarine and coastal waters the debate about the need for simultaneous N and P control to prevent or remediate eutrophication continues, but global estimates of N fixation in these environments continue to rise and support the need for P control as the ultimate nutrient limitation for algal biomass in most aquatic ecosystems.

# Contamination by organic pollution – from classic to emerging contaminants

**Walter Giger, GRC, Giger Research Consulting, Switzerland**

Organic pollutants are a highly relevant topic in environmental science and technology. This presentation briefly reviews historic developments, and then focuses on the current state of the art and future perspectives on the qualitative and quantitative trace determination of polar organic contaminants, which are of particular concern in municipal and industrial wastewater effluents, ambient surface waters, run-off waters, atmospheric waters, groundwaters and drinking waters. The pivotal role of advanced analytical methods is emphasized and an overview of some contaminant classes is presented.

In the first part of this lecture, organic micro-pollutants are discussed from a historical perspective by alluding to some key players, milestones and major types of activities. The crucial role of the advances made in the methods for trace determinations of organic chemicals is highlighted. A classification scheme for organic contaminants is proposed based on their polarity and volatility properties. Subsequently, an overview is presented on polar organic contaminants, which have been determined in wastewater effluents, ambient surface waters, aquifers and drinking water. Polar pollutants are pointed out that are already regulated or are suggested for inclusion in future monitoring activities.

During about four decades the prevailing focus in analytical environmental chemistry was on volatile and semi-volatile non-polar contaminants, because gas chromatography provided an excellent separation technique for this type of pollutants. In particular, analytical methods using mass spectrometry directly coupled to gas chromatography (GC/MS) play a key role for qualitative and quantitative determinations of contaminant traces in the environment. Polar and amphiphilic contaminants, however, could only be determined by gas chromatography after derivatization to more volatile species. Since about the mid 1990ies liquid chromatography directly coupled to mass spectrometry (LC/MS) became a routinely applicable and robust method based on new ionization techniques such as electrospray ionization and atmospheric pressure chemical ionization. LC/MS enables a much better coverage of polar/hydrophilic and amphiphilic contaminants. The extremely high selectivity and sensitivity of multiple reaction monitoring techniques in tandem/multi-stage quadrupole and ion-trap mass spectrometry make it feasible that complex mixtures can be analyzed. The analytical trend is that also semi-volatile contaminants will also be determined by LC/MS and that multi-component methods are applied across several compound classes. Current developments include the use of high-resolution and time-of-flight mass spectrometry. Another recent analytical development is the comprehensive two-dimensional gas chromatography/time-of-flight mass spectrometry that is also very promising for forensic purposes in environmental chemistry.

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- Giger W, A Alder, EM Golet, H-PE Kohler, CS McArdell, E Molnar, H Siegrist, MJ-F Suter (2003). Occurrence and Fate of Antibiotics as Trace Contaminants in Wastewaters, Sewage Sludges, and Surface Waters. *Chimia* 57(9), 485–491.

# Challenges of the global water shortage: contamination of water resources by inorganic pollution

*Janet G. Hering*, EAWAG-ETH, Switzerland

Inorganic contaminants can compromise the quality of both surface- and groundwater resources making them unfit for use as drinking water supplies. Such inorganic contamination can derive from both anthropogenic and geogenic sources. Principal anthropogenic sources include mining and smelting, industrial processes such as chrome plating or the manufacture of arsenical biocides or perchlorate-based rocket propellants, and loss of nitrogen and phosphorus from agriculture. Contamination by inorganic radionuclides can also be geogenic, but is more usually associated with the legacy of nuclear weapons production.

With the exception of radioactive decay and the transformation of inorganic compounds (e.g., nitrate and perchlorate) to their benign elemental components, the hazard associated with (elemental) inorganic contaminants cannot be entirely eliminated. The focus must therefore be on protecting sensitive receptors, whether through the containment or *in situ* immobilization of inorganic contaminants or through treatment of drinking water supplies. Particular challenges are posed by inorganic contaminants, such as mercury, that are biomagnified through the aquatic food web.

Here, an overview is provided of the scope of the problem with examples of contamination deriving from both anthropogenic and geogenic sources. Alternatives for mitigating impacts on the environment and human health are examined.

# "Good" ecological status of surface water in Europe: Science and practice

*Steven Eisenreich, JRC-EC, Ispra, Italy*

Contributions from: A.C. Cardoso, W.vd. Bund, S. Poikane, A.-S Heiskanen, A. Paya-Perez

In the last decade, there has been a paradigm shift in the science and methodology in the classification of surface water bodies in Europe. In 2000 the Water Framework Directive (WFD 2000/60/EC) introduced – amongst other requirements – a comprehensive ecological status assessment of all surface waters in Europe, based on a number of biological, hydro-morphological, chemical and physico-chemical quality elements. The aims are to expand the scope of water protection to all surface waters and groundwater, achieve "good status" for all waters by a set deadline, water management based on river basins, and a "combined approach" of emission limit values and quality standards.

Two of the main elements are:

**Ecological protection.** A general requirement for ecological protection, and a minimum chemical standard, was introduced to cover all surface waters. These are the two elements "good ecological status" and "good chemical status". Good ecological status is defined in terms of the quality of the biological community, the hydrological characteristics and the chemical characteristics. As no absolute standards for biological quality can be set which apply across the Community, the controls are specified as allowing only a slight departure from the biological community which would be expected in conditions of minimal anthropogenic impact. A set of procedures for identifying that point for a given body of water, and establishing particular chemical or hydromorphological standards to achieve it, is provided, together with a system for ensuring that each Member State interprets the procedure in a consistent way (to ensure comparability; inter-calibration).

**Chemical protection:** Good chemical status is defined in terms of compliance with all the quality standards (EQs) established for hazardous chemical substances at European level. The Directive provides a mechanism for updating the list of hazardous substances, renewing these standards and establishing new ones by means of a prioritisation and risk assessment mechanism for hazardous chemicals.

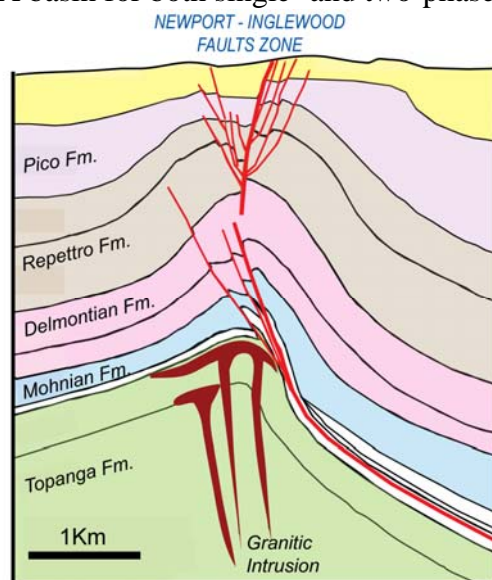
The WFD introduced a series of seemingly obvious questions on how does one scientifically define ecological quality status, 'good' status, reference conditions; how do you select and assess biological parameters as indicators; how do you ensure harmonization of procedures and status boundaries across water types and geographical boundaries; how does one integrate 'good' ecological quality status with 'good' chemicals status? These 'simple' questions have resulted in 10 years of aquatic research on concepts, tools, methodologies, and modeling expending > 500 M€ of EC and MS funds.

This presentation will first review what is known about the key processes affecting hazardous chemical residence times and interactions in linked air-water-land environments (link to my personal journey), then develop essential features of the European effort to develop the science to implement the WFD, and finally offer an overview of quality status of European waters, and how climate change may affect the systems.

# Effects of faults on coastal groundwater salinity, Southern California

Grant Garven, Tufts University, USA

Large faults known to affect the salinity of coastal aquifers in southern California include the Refugio fault (Transverse Ranges), Ellwood fault (Santa Barbara basin), and the Newport-Inglewood fault zone (Los Angeles basin). Subsurface geology, geophysical logs, aquifer fluid pressure-temperature, flow discharges, mineralization patterns, fluid inclusions, and structural models are being analyzed to characterize the geohydrologic effects of faults in this seismically-active and geologically-young setting. These field data also provide constraints for mathematical models that are being developed for forward modeling purposes. For example, I will present data for fluid fluxes that uniquely constrain fault permeability, for kilometer-scale migration of salty groundwater in the Santa Barbara basin. We are also constructing numerical simulations to characterize the geo-hydrology of the LA basin for both single- and two-phase fluid migration. Single-phase flow models



simulate the basin-scale groundwater flow associated with deep basin subsidence and later uplift of the San Gabriel Mountains (Fig. 1). Two-phase flow models characterize a more detailed resolution of the stratigraphy and structure, and constrain rates of two-phase fluid migration associated with the basin margin, where deep faults produced thick stacking of petroleum. Our modeling results suggest a long history of episodic flow from the depocenter towards the south flank of the LA basin and the Palos Verdes Peninsula. The models also predict a preference for focused flow along the NIFZ.

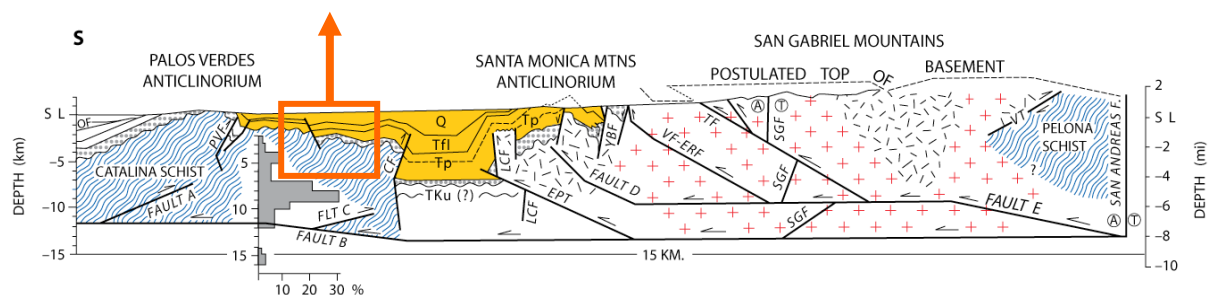


Figure 1. Structural cross section of the Los Angeles basin (Wright, 1991), along a south-north transect, with an expanded profile across the Newport-Inglewood fault zone (Plains Petroleum, per. communication, 2008).



# **Reactive transport modeling: An introduction**

*Jesus Carrera*, IDAEA, CSIC, Barcelona, Spain

I Review the basic concepts of reactive transport modeling. I start by formulating the basic equations for reactive transport, which are complex and make one wonder whether they are needed to begin with. I use an example of Rezaei et al (J. Hydrology, 2005) to show that many equilibrium reactions are controlled by transport, which determines the location, rate, and conditions for the reaction to occur. I then show that often reactive transport can be significantly simplified by working with components. In fact, in the case of constant activity (e.g., ideal minerals) the problem becomes very easy. To illustrate this point, I use the formulation of DeSimoni et al (WRR, 2005, 2007). This formulation leads naturally to the concept of mixing, which is used for quantifying the rate of equilibrium reactions. Mixing is represented by dispersion in the traditional formulation of transport. Unfortunately, dispersion has been traditionally evaluated using spreading measures. I finish describing on-going efforts by Willmann et al (2009, 2010), who use a Multi-Rate-Mass-Transfer formulation, and by Leborgne et al (2009, 2010), who use random walk formulations, to separate spreading and mixing.

# **The Collapse of the eastern Mediterranean in the mid 11<sup>th</sup> century AD**

*Ronnie Ellenblum, The Hebrew University of Jerusalem, Israel*

The paper relates the story of a historical climate change that altered the face of the eastern Mediterranean in the mid-eleventh century AD. The change was manifested in a series of well documented climatic disasters— exceedingly long droughts and cold spells that affected at the same time, the Nile Valley, the eastern Mediterranean coast, and the steppes of central Asia, between the mid-tenth and late eleventh centuries, and especially between 1025 and 1075 leading to the physical decline of some of the most important cultural centers of the time.

The ecological disaster created an enormous wave of dislocation and outbound emigration of pastoralists who created violence in the neighboring drought-stricken provinces. The domino-effect of the dislocation and the violence led to the decay, abandonment, and destruction of countries and cultures.

Scores of cities and urban centers, from Nishapur to Fustat and from Baghdad to Qayrawán, were decimated and deserted by their leading elites. Many other cities were abandoned or destroyed. Populous agricultural regions, such as eastern Asia Minor and Ifriqiya or the Jazira and the Negev, underwent desertification and never recovered. The change was also accompanied by the collapse of bureaucratic and political institutions, the looting of cultural treasures, inter-religious strife, and the sudden disappearance of classical learning.

## **Monitoring the wellbeing of Lake Kinneret (Sea of Galilee), Israel**

***Assaf Sukenik, The Yigal Alon Kinneret Limnological Laboratory, IOLR, Israel***

Lake Kinneret, known also as Sea of Galilee, is the only natural freshwater lake in Israel, supplying nearly half of the nation's drinking water. Lake Kinneret is a warm, monomictic lake, located at the northern end of the Afro-Syrian Rift Valley in Northern Israel (32°50'N, 35°35'E; -209 m above sea level), with a surface area of 165 km<sup>2</sup>, a maximum depth of 43 m (a mean depth of 24 m) and shoreline length of 53 km. The climate is hot and dry in summer, with winter rains from November through April and May. The catchment area of Lake Kinneret (2,730 km<sup>2</sup>) is extensively used for agriculture. The lake is fed by The River Jordan and a number of smaller fresh water streams. The average annual fresh water inflow to the lake is 650 million cubic meters (MCM). There are also salty springs at the lake bottom and along its shores that control the salinity of the lake water.

To ensure the wellbeing of this vital water source, a limnological research center was established on the shore of the lake in 1969. The Kinneret Limnological Laboratory (KLL), a branch of Israel Oceanographic & Limnological Research (IOLR) operates a multiannual monitoring program integrated with research activities aimed to enhance the understanding of the lake ecosystem and identify the processes that affect its water quality. The on-going monitoring program has developed and expanded over the years to include a wide range of meteorological, physical, chemical, and biological parameters. In recent years a remotely operated series of synoptic and near real-time measurements of various parameters were added to provide hourly and daily records. Several long and short term changes in various limnological parameters and their reflection in the monitoring program will be demonstrated and discussed. The data collected help advising regional and governmental authorities on lake management and water related issues.

## **Water resources management - technological perspectives - overcoming the innovation to implementation ("i2i") challenges via partnership**

*Booky Oren, WATEC, Miya Arison Group, Israel*

There is a growing demand for water while the worldwide supply is continuously decreasing. In order to overcome this gap there is a need to introduce technological innovation. Due to its continuous necessity supported by unprecedented entrepreneurial culture, Israel has become a Water Solution Hub. Although technological innovation is the solution for the growing water market, the water market is an extremely conservative one. There are only a few examples of significant technological innovation implementation that were successfully commercialized in the water arena in the last decades (for example - AMR / MBR technologies). Water companies are risk-averse and prefer not to be the first ones to implement new technologies. This is known as the "Water Innovation Catch". Innovation to Implementation - "i2i" - is one of the most significant challenges in the global water's arena today. It has the power to improve the situation of billions of people. In order to overcome the innovation gap, companies need to partner in order to lower the risks. Partnering can create attractive business opportunities to all involved. It is essential for Israel in order to successfully leverage its capabilities in the world's water market. Since water management is a complex issue that differs from one place to another, success in Israel does not ensure success in North America or Asia. It takes a joint local effort to address the complexity. Partnership can assist in bridging between all the key stakeholders in the market, while leveraging all the existing capabilities of the parties and fulfilling the needs of a specific water utility.

Creating partnership is essential for all of the eco-system including the technological provider, water utility, government, regulator, consultants, financial institutions, water organizations and the municipality. Partnership can assist in overcoming the "i2i" challenges, by providing: Know How in the local markets, credibility, local experience and financial leverage. It can create a "Win-Win" situation for all.

# **Water Resources Management - Legal Perspectives**

*Eyal Benvenisti, Tel Aviv University, Israel*

The management by riparian states of shared freshwater resources requires a constant balancing of conflicting states' interests while ensuring individual and group rights, under constraints imposed by nature and by the limited ability of humans to assess risks. To meet these challenges, international law defines trans-boundary water resources as collectively owned by the riparian states, sets forth obligations and criteria for the "equitable, reasonable and sustainable" allocation of such resources among its different users, as well as procedures that riparians must follow when planning and executing policies with respect to such resources. International law also encourages the setting up of accountable and transparent joint-management institutions as the preferable way for ensuring compliance with the goals of equitable, reasonable and sustainable use.



POSTER

ABSTRACTS





# Methanogenesis rates in Lake Kinneret, Israel

*Michal Adler<sup>1</sup>, Orit Sivan<sup>1</sup>, Werner Eckert<sup>2</sup>*

<sup>1</sup>Department of Geological and Environmental Sciences, Ben Gurion University, Beer Sheva 84105, Israel.

<sup>2</sup>Israel Oceanographic and Limnological Research, The Yigal Allon Kinneret Limnological Laboratory, P.O. Box 447, Migdal 14950, Israel.

Methane (CH<sub>4</sub>) is an important greenhouse gas, where terrestrial emission contributes more than 70% of its natural source. Nevertheless, methane production (methanogenesis) and consumption (methanotrophy) rates in that environment, including their depth distribution and controlling parameters, have been only partially quantified.

This research used a geochemical approach in order to calculate methanogenesis rates in Lake Kinneret (Israel) using seasonal chemical and isotope profiles in the water column and the sediments' porewater, a diagenetic model and incubation experiments.

The results suggest that sulfate is depleted within the upper 10 cm of the sediment by bacterial sulfate reduction (BSR). Maximum sulfate reduction rates calculated from sulfate concentration profiles occurred at the water-sediment interface (0-1cm -  $1.4 \times 10^{-12} \pm 0.2 \times 10^{-12}$  mol·cm<sup>-3</sup>·sec<sup>-1</sup>). Methane concentrations and the modeling of the stable carbon isotopes of dissolved inorganic carbon ( $\delta^{13}\text{C}_{\text{DIC}}$ ) suggest that methanogenesis has maximum rates of  $2.5 \cdot 10^{-13} \pm 1.5 \cdot 10^{-13}$  mol·cm<sup>-3</sup>·sec<sup>-1</sup> at 5-12 cm depth in the sediments, and that it ends around 20 cm depth. The rates calculations indicate overlap between sulfate reduction and methanogenesis. The incubation experiments support the model findings and show that maximum methanogenesis rate is at 0-8 cm depth section and that methanogenesis ends in the deep sediments. Methane production mechanism in the upper sediment section was found to be through CO<sub>2</sub> reduction, probably since acetate was available for sulfate reduction and not for methanogens. In the lower sediment section, where acetate concentration increased, the main mechanism of methanogenesis was acetate fermentation.

The findings from this study contribute to understanding the processes involving methane in lacustrine systems, and also shed insight into suggested mechanisms in marine sediments that are difficult to track due to analytical challenges in measuring under such high pressures.

# **Anthropogenic impacts of industrial and urban development on lacustrine environments and their adjacent watersheds at the north-east USA.**

*Bookman R.<sup>a</sup>, Driscoll T.C.<sup>b</sup>, Engstrom D.R.<sup>c</sup>, Effler S.W.*

*d*

- a) Dept. of Marine Geosciences, Charney School of Marine Sciences, University of Haifa, Israel.
- b) Dept. of Civil and Environmental Engineering, Syracuse University, NY, USA.
- c) St. Croix Watershed Research Station, Science Museum of Minnesota, MN, USA.
- d) Upstate Freshwater Institute, NY 13214, USA.

Lake-sediment records around the world show the effects of atmospheric contamination and land cover change over the last 200 years. In this study, we present geochemical analysis of <sup>210</sup>Pb-dated sediment cores from lakes in an urban/suburban setting of central New York affected by local and regional industrial emissions and watershed disturbance.

Cores were collected from the Otisco and Skaneateles lakes from the Finger Lakes region, Cross Lake, a hypereutrophic lake on the Seneca River, and Glacial Lake, a small seepage lake. The complex recent lacustrine history and the linkages between sources and sinks in terrestrial and aquatic ecosystems were revealed by geochemical and sedimentological indicators. Organic carbon (OC), inorganic carbon (IC), and nitrogen (N) were used to determine changes in carbon supply, trophic state conditions and primary production. Mercury (Hg), a hazardous air pollutant, was analyzed to characterize the atmospheric deposition over the lakes and watersheds.

The lacustrine records represent two main categories: records of atmospheric-controlled lakes and records of watershed-controlled lakes. Skaneateles and Glacial lakes have a low ratio of watershed to lake surface area, low and relatively constant sediment accumulation rates, and thus are excellent indicators for atmospheric pollution deposition. In these lakes, we found strong correlations with industrial Hg emission records for the Great Lakes region that markedly increased in the early 1900s, and peaked during WWII and in the early 1970s. Declines in modern Hg fluxes are generally evident since air-pollution regulations were enforced on industrial Hg emission sources in the United States.

Dramatic increases in sediment accumulation rates over a period of a few decades reflect the effect of watershed disturbance on lakes. Deposition conditions in Cross Lake (15-fold increase in sedimentation) represent a highly disturbed landscape, and are likely controlled by the change in land use, (i.e., agriculture, urbanization). The effects of anthropogenic activities on material inputs to the Otisco Lake were analyzed in detail by examining the watershed land cover change using historical aerial photos (1930s) and modern Landsat images (2001) in conjunction with vertical patterns in IC, OC, N, and Hg. We described the effects of anthropogenic activities as forest clearance and agricultural development, and increases in lake productivity and eutrophication. The land cover analysis and paleolimnological interpretations enabled the study to provide a broad overview of landscape processes that are generally thought to have occurred in the northeastern US after European settlement.

# **Atmospheric Aging of Pesticides: Heterogeneous Reaction of Cypermethrin with Ozone and UV radiation**

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Pesticides are highly toxic compounds that unlike other pollutants are intentionally introduced, in large quantities, to the environment. The vast majority of them are applied to agricultural lands, but they are also widely used in urban areas as herbicides, insecticides and fungicides. Pesticides may be promoted into the atmosphere during their application via drift of aerosols, as well as by volatilization or dust erosion from treated surfaces after application. In the atmosphere, semi-volatile pesticides may remain as pure aerosols or become adsorbed upon background aerosols. During transport, they undergo chemical degradation processes due to their interaction with atmospheric oxidants or solar radiation. Quantification of the reaction rate constants and degradation products will allow for better risk assessment and environmental fate evaluation of these hazardous materials. Here, we focus on the investigation of the heterogeneous reaction of cypermethrin, a common used insecticide, with gaseous ozone and UV radiation. The reactions are monitored in real time using novel apparatus that combines ATR/FTIR and Long path IR gas cell for simultaneous monitoring of the condensed and gas phases. The environmental implication of the observed kinetics and degradation products are also discussed.

# From P to N limitation in Lake Kinneret (Sea of Galilee)

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The impact of cladoceran metabolic activities on the C, N, and P dynamics in Lake Kinneret (Israel) was studied. The study is based on the incorporation of field data and experimental measurements. Grazing, respiration and production rates were experimentally measured at three temperatures, and the results were extrapolated to the field biomass concentration at these respective temperatures. The increase in P, decline in N and decrease in the TN/TP mass ratio in the epilimnion of Lake Kinneret created N limitation. An increase in C and decline in TN, with a consequential increase in the C/TN ratio were documented. TP was augmented but the C/TP ratio was only slightly increased. During 1975 – 2004, P was probably, a minor limitation for cladoceran growth. The positive impact of recycled P by cladocerans under the N limitation in Lake Kinneret is presently existing. There is a current threat to the water quality, derived from N limitation (mostly in summer-fall) and consequent *Cyanophyta* blooms. Thus, the role of recycled P by grazers may be significant. A temperature decline until the mid 1980's and an increase thereafter by 0.5 °C were documented. This corresponds to a change of 1.2% / °C of metabolic efficiencies ranging between 17.5 – 26 °C. A decline of cladoceran density from 1970 until the early 1990's and an increase thereafter were documented. A temporal increase in values of "small" to "large" ratios (S/L) of cladoceran densities was observed. It is mostly due to the decline in large organisms, resulted by fish predation which was intensified. The "large" probably became more productive due to the need to supply the unchanged densities of "small". Such a change may be due to a higher availability and quality of food resources and/or increase in metabolic efficiencies. The increase in P, decline in N and decrease in TN/TP mass ratio in the epilimnion which probably initiated N limitation, and encouraged nano-planktonic algal growth were documented. Under these ecosystem conditions, cladoceran metabolism may have an effective role on the entire ecosystem. The field capacities of consumption, respiration and production were correlated with biomass density, the F% from consumed energy was augmented with the increase in the carbon concentration, i.e. the more carbon that is available, the more energy that is assimilated and the larger the portion that is excreted. An increase in the assimilated energy (respiration and production), when the epilimnetic TN load was enhanced was also indicated. N limitation for zooplankton grazers during the last 10 – 15 years is suggested. The epilimnetic N stock was depleted and that of P enriched during 1970 – 2004. These changes are not attributed to the water level (WL) decline. Cladoceran Nitrogen deficiency occur when TN/TP ratio was lowered below 50, and was accompanied by the enhancement of defecation (and its %) and the recycling of P. When TN/TP is above 50, F% is fairly stable, and recycled N is enhanced, but P recycling is diminished.

# Adsorption and precipitation of radium during saline water circulation in the Dead Sea aquifer

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The continuous lake level drop of the Dead Sea provides a unique opportunity to study the interaction between hypersaline brines and the aquifer in this extremely dynamic system. We studied the behavior of radon and radium isotopes in groundwater whose salinity ranges between fresh water and the Dead Sea salinity.

Radium and radon isotopes are commonly used as tracers for submarine groundwater discharge and for estimating adsorption distribution coefficients. The possibility to study the Dead Sea water after it enters the aquifer and mixes with fresh groundwater offers a natural case, which demonstrates the effect of salinity on the activity of radium.

The Dead Sea lake water is enriched in <sup>226</sup>Ra with an activity of 145 dpm/L. Radium is removed from the Dead Sea water as it enters the aquifer, resulting in a reduced <sup>226</sup>Ra activity of 60 dpm/L in groundwater with Dead Sea salinity. The relationship between salinity and <sup>226</sup>Ra activity is linear indicating mixing between Dead Sea aquifer water with a reduced activity of <sup>226</sup>Ra and fresh water which contain lower activity of <sup>226</sup>Ra (5 dpm/L).

Unlike the <sup>226</sup>Ra, the short-lived radium isotopes are produced from the aquifer sediments and are almost absent from the Dead Sea lake water. The relationship between the short-lived radium isotopes and salinity is an asymptotically convergent function and shows an adsorption process.

Considering the dynamic conditions of the Dead Sea level drop, an approach of studying radium isotopes in a dynamic flow field was taken. Analysis and simulations with SUTRA-MS were performed in order to describe the processes controlling radium and radon distribution in the Dead Sea aquifer.

The large decrease of <sup>226</sup>Ra on entering the aquifer cannot be explained by adsorption because of the high salinity of the water where adsorption is expected to be very low. This is also supported by the simulations. Therefore, we suggest removal of radium via the precipitation of barite. This is supported by the reduced concentrations of barium in this groundwater compared with the Dead Sea water.

According to the simulations, the relationship between <sup>226</sup>Ra activity and salinity over time changes during the lake level drop. On the other hand, the relationship between the salinity and the activity of short-lived radium isotopes is constant in time and is not affected by the Dead Sea level drop. The simulations show a relatively good fit with field data and may allow a good estimation of the radium adsorption distribution coefficient.

## **On Combined Evaporation and Salt Precipitation in Heterogeneous Porous Media**

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Evaporation is a major process in the global water cycle. The literature on micro-scale evaporation mechanisms and the influence of the resulting salt precipitation within pores on the evaporation processes is limited. Moreover, the role of matrix heterogeneity, including cases of fractured mediums, on the combined evaporation-salt precipitation processes is poorly understood. This research focuses on salt deposition occurring inside matrix pores and on its surface during evaporation process and its effect on evaporation rates. Three methods are being used: (1) X-ray CT scanning to quantify salt deposition within pores; (2) long-term monitoring of evaporation and salt deposition in soil columns with different scales of heterogeneities; and (3) measuring of salt concentration on simulated fracture walls, exposed for long-term evaporation.

Investigation of the salt deposition mechanism and evaporation measurements in homogeneous porous media indicates that the salt is being precipitated homogeneously at the matrix upper regions, resulting in blockage of the surface and a reduction in evaporation rates. In heterogeneous matrices, the salt tends to precipitate in the upper regions of the small pores areas, in opposed to large pores which remain relatively free of salt. This is due to preferential flow of solutions towards the small pores regions, resulting in preferential evaporation and salt precipitation in these areas. This pattern of preferential salt accumulation at the fine pores causes that the coarse pores regions acts as pathways for the vapor flow, enabling it to bypass the clogged fine pores. Thus, pore size heterogeneity moderates salt effect on evaporation. In fractured medium, salt accumulated on the fracture walls as this is where evaporation is taking place. Salt precipitation patterns on fracture walls are affected by air convection flows within the fracture which forcing preferential evaporation and salt precipitation according to the geometry of convection cells.

# Hydrological models for perched springs in the Judea and Samaria Mountains

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Perched aquifers are formed by water accumulation on aquitard layers. Merely a small fraction of the total amount of precipitation recharges the perched aquifer. The groundwater flow toward springs is composed of two components: the slow-matrix flow and the quick-karst flow. The perched springs slowly discharge the aquifer throughout the year, while a small amount of water from the aquifer penetrates downward through the aquitard, recharging the regional aquifer or a lower perched aquifer.

The geo-hydrology flow model allows an analysis of several phenomena: (1) estimating the annual recharge for the perched aquifers, (2) defining the hydraulic parameters of the perched aquifers and the underlying aquitards, (3) exploring the “memory length” (storativity) of the perched aquifers, (4) defining the amplification effect of the perched springs and (5) describing the flow regime of a complex two-level spring system.

Finite element numerical model (FEFLOW code) is introduced to describe the groundwater flow regime within the perched aquifer. The model was calibrated by comparing the measured spring hydrograph to the computed hydrograph. Validations of the model, as well as sensitivity analyses, were conducted as part of the research.

# Gypsum nucleation kinetics

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In order to understand the key parameters which affect the nucleation kinetics of gypsum, batch experiments were conducted. Three series of experiments were conducted differing from one another by their mixing ratio between Dead Sea brine (DS) and Red Sea water (RS). The degree of saturation with respect to gypsum (DSG) of each mixture was artificially increased by adding various amounts of sodium sulfate and calcium chloride dehydrate salts. The ratio between the added salts was calculated in order to maintain the same calcium to sulfate ratio as in the DS-RS mixture prior to the addition of the salts.

The induction time was assessed in each experiment by monitoring the time from the establishment of the supersaturated solution until a noticeable change in sulfate concentration was recorded. Using classic nucleation theory it was possible to identify and differentiate between two zones of degrees of supersaturation at which homogeneous and heterogeneous mechanisms dominate, at far and close to equilibrium conditions, respectively.

Integrating data from the literature from He et al., (1994) with the current study reveals that induction time decreases with increasing DSG (which is the most dominant factor) and gypsum solubility. The effect of the solubility on the induction time is not constant, but increases towards equilibrium. These effects were quantified using an empirical model. The model serves as a powerful tool for estimating the induction times of gypsum from solutions under various compositions, calcium to sulfate ratio and ionic strength. So far it has been verified using synthetic NaCl solutions, DS-seawater mixtures and mixtures between DS and concentrated seawater. According to the model, the reason for which the DS remains supersaturated for prolonged time periods is the low degree of supersaturation and low solubility of gypsum in the brine.

He, S., Oddo, J. E., and Tomson, M. B., 1994. The Nucleation Kinetics of Calcium Sulfate Dihydrate in NaCl Solutions up to 6 m and 90°C. *Journal of Colloid and Interface Science* 162, 297-303.



# Radium Co-Precipitation in Evaporitic Systems

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Radium is an abundant naturally occurring radioactive material (NORM) in groundwater, lakes and ocean. Its concentration is often technologically enhanced when these water resources are utilized in the industry (TENORM). The concern regarding the fate of Ra TENORMs in high ionic strength environments in general and evaporitic system in particular was expressed in two recent technical reports of the EPA [1] and the IAEA [2].

The present study aims to examine the fate of Ra in evaporitic systems. For this purpose, three such systems are investigated both in laboratory experiments and field: 1. brine of a desalinization plant; 2. evaporated seawater; and 3. evaporated Dead Sea brine. These systems altogether provide a wide range of ionic strength (from 0.7m to ~16.5m) and variable chemical compositions.

While the adsorption of Ra from seawater and brine of a desalinization plant onto MnOx fibers was almost complete (>95%), the adsorption of Ra from the Dead Sea brine was very low. Similar observations were made by Y. Kiro and Y. Weinstein (personal communication). Interestingly, dilution of the brine to sea water ionic strength did not lead to complete adsorption. Preliminary results suggest that extensive dilution by a factor of 25 is required to achieve similar Ra retention. These observations indicate that a simple competition mechanism over adsorption sites cannot explain this behavior.

Evaporation batch experiments of the desalinization concentrate indicated that Ra and Ba co-precipitate into barite. Although gypsum is the major mineral to precipitate in this system (gypsum/barite=10<sup>5</sup>), it has no significant role in determining Ra fate. The value of the apparent partition coefficient in these experiments was calculated to be  $K'_{D,barite}=1.0\pm 0.1$ . This value of  $K'_D$  is significantly lower than the accepted value for relatively dilute solutions (1.8±0.1). By numerically modelling these experiments, we suggest that the decrease in  $K'_D$  is a result of both kinetic and ionic strength effects. Thus, Ra removal from brine is reduced compared to low ionic strength conditions. Generalization of this observation to other systems is currently being examined using evaporated seawater and Dead Sea brine.

[1] EPA, 2008, Technical Report 402-R-08-005. [2] IAEA, 2003, Technical Reports Series No. 419.

# Nitrogen and oxygen isotopic compositions of nitrate in contaminated groundwater, Central Arava Valley

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The main water resources in the central Arava valley are the three shallow aquifers of the Hazeva Gr., Arava Fm. and the alluvium. These aquifers are ‘suffering’ from ongoing nitrate contamination due to intensive agriculture over the last decades. The most likely contamination sources are synthetic  $\text{NO}_3^-$ -fertilizers, which are used in cultivated fields. However  $\delta^{15}\text{N}_{\text{NO}_3}$  and  $\delta^{18}\text{O}_{\text{NO}_3}$  values in the nitrate-contaminated groundwater cannot be explained by simple mixing between natural nitrate and the synthetic  $\text{NO}_3^-$ -fertilizers. Other possible sources of anthropogenic nitrogen are synthetic  $\text{NH}_4^+$ -fertilizers and manure, which is used as organic fertilizer in the cultivated fields.

To explain the measured  $\delta^{15}\text{N}_{\text{NO}_3}$  and  $\delta^{18}\text{O}_{\text{NO}_3}$  values in the nitrate-contaminated groundwater, a mixing/reaction model was used. The model considered the following nitrogen sources: 1. natural nitrate in groundwater; 2. synthetic fertilizers ( $\text{NO}_3^-$  and  $\text{NH}_4^+$  fertilizers); 3. manure. The biogeochemical processes that fractionate the stable isotopes of nitrogen and oxygen in the above sources included in the estimates were: 1. ammonia volatilization which may occur in manure or  $\text{NH}_4^+$ -synthetic fertilizers and cause large isotopic enrichment in the remaining nitrogen; 2. evaporation of the water used for irrigation that might change the oxygen isotopic composition of the nitrate produced by nitrification; 3. nitrate or ammonium uptake by plants which result in small isotopic fractionation. On the other hand it was assumed that all the  $\text{NH}_3$  based fertilizers were nitrified either in the soil or in the unsaturated zone, and therefore there is no isotopic fractionation in this reaction.

The calculations suggest that the nitrate in most of the contaminated wells was derived from synthetic  $\text{NO}_3^-$ - and  $\text{NH}_4^+$ -fertilizers and manure in equal proportions. The alluvial aquifer south to Zofar showed different isotopic values (higher  $\delta^{18}\text{O}_{\text{NO}_3}$  values), suggest that it derived its N from synthetic fertilizers only.

# **Development of a method to characterize the size and morphology of gypsum crystals formed from Dead Sea – seawater mixtures**

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Mixing sulfate-rich seawater water with calcium-rich Dead Sea brine may result in gypsum precipitation, depending on mixing ratios. To determine whether the formation of gypsum crystals will result in whitening of the surface water upon introduction of Red Sea water to the Dead Sea, it is essential to characterize the size and morphology of gypsum crystals as these parameters dictate the suspension time of crystals in the water column.

To examine the size and morphology of the crystals, one first needs to separate the crystals from the brine. The purpose of this research is to develop a reliable and efficient method of separating the crystals from the mixture and to characterize their size and morphology. Separating the gypsum precipitate from the brine is not an easy task. After the brine is filtered, crystals and some residual solution are present on the membrane. Simple drying of the filter will lead to undesired secondary precipitation of various minerals from the residual brine.

Single-point-batch-experiments were used in the study. Synthetic solutions were prepared by dissolving  $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$ ,  $\text{Na}_2\text{SO}_4$ , and  $\text{NaCl}$ . The initial degree of supersaturation with respect to gypsum was 2.43. Several batch-experiments were set up simultaneously with identical composition; however termination time differed from one experiment to another. Upon terminating an experiment, the solution was filtered through a  $0.22\mu\text{m}$  membrane using a vacuum filtering flask. Two kinds of membranes were used: Durapore and Isopore. In order to reduce the amounts of residual solution and secondary precipitation, filter membranes were then washed with various solvents (ethanol, isopropanol, methanol, DDW). The most efficient solvents in reducing the amount of secondary precipitation were found to be ethanol and isopropanol. Additionally, it was found that the mass of the residual solution was reduced when using Isopore membrane. It is assumed that this reduction is due to the thickness of the filter.

Similar experiments were conducted with the complex Dead Sea – Red Sea mixtures and different types of bottles: glass, polyethylene and Teflon. The mass of gypsum that was found on the membrane was compared to the mass estimated by the change in the solutions sulfate concentrations. The glass bottle experiments were the only ones to reveal a perfect match between measurements. Therefore, to retrieve most of the precipitate and avoid the attachment of crystals to bottle interiors, which may result in discrepancies in the crystal size distribution, only glass bottles will be used henceforth.



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