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Keynote Lecture

Communicating Science in the Post-Truth Era

Dr. Yael Barel-Ben David

Dr. Yael Barel-Ben David is the director of the Citizen Lab, a collaboration between the Technion and the MadaTech. The Citizen lab's aim is to connect science education and public engagement with science with local communities' needs and interests through citizen science projects. Yael holds a PhD in science communication from the faculty of education in science and technology from the Technion and she is leading science communication training programs in Israel and abroad.

As researchers and scientists, we find ourselves in front of cutting-edge science and we are exposed to new developments and finding in a variety of scientific fields. But it is important to remember that the public, which influence these research's funding, does not share this knowledge. Furthermore, the modern world requires public (in most cases non-scientists) to make science related decisions concerning numerous technologies effecting quality of life. In many countries the public's main source of information about science and technology is the internet and mass media. Unfortunately, in recent years we witness the collapse of traditional journalism all over the world with science journalism being a major casualty. Therefore, these sources can sometimes be inaccurate, confusing or even misleading and plain wrong. To this situation science communication comes to play – by helping scientist to communicate their science in an accessible way to different stakeholders and publics as a way to counter misinformation and misconceptions

Storage water Quality Modeling - Inclusion in Water Distribution Systems Management

Biniam Abrha Tsegay, Avi Ostfeld

Faculty of Civil and Environmental Engineering, Technion – Israel Institute of Technology

Water storage tanks are one of the main and critical components of water distribution systems (WDS) which are used to manage supply of water by maintaining pressure. In addition to that, In the case of emergency or failure they can be a source of water. To gain those advantages, storages tanks with huge

volumes were incorporated and used in most WDS. Despite of those advantages they often pose negative impacts on water quality which can affect the water utilities. The water quality problems happen due to longer residency time and inadequate water mixing. This paper tries to develop a model of a water quantity and water quality of a tank after posing, a governing equations which considers the inlet/outlet configurations and process that control the movement of water and chemical substance inside it ,and solving them subsequently . It uses a compartment model to characterize the mixing behavior inside the tank. Water distribution systems example applications will be solved to test the model validity through base runs and sensitivity analyses.

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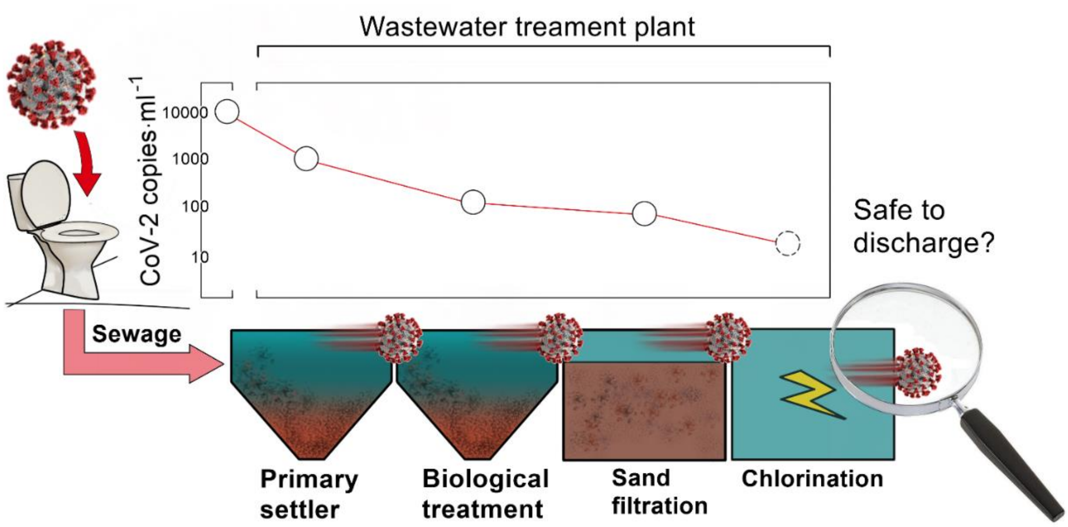
Tracking SARS-CoV-2 RNA Through the Wastewater Treatment Process

Hala Abu Ali, Karin Yaniv, Edo Bar-Zeev, Sanhita Chaudhury, Marilou Shagan, Satish Lakkakula, Zeev Ronen, Ariel Kushmaro and Oded Nir

The Zuckerberg Institute for Water Research, Ben Gurion University of the Negev

The municipal sewage carries the new coronavirus (SARS-CoV-2), shed by COVID-19 patients, to wastewater treatment plants. Proper wastewater treatment can provide an important barrier for preventing uncontrolled discharged of the virus into the environment. However, the role of the different wastewater treatment stages in reducing virus concentrations was, thus far, unknown. In this work, we quantified SARS-CoV-RNA in the raw sewage and along the main stages of the wastewater process from two different plants in Israel during this COVID-19 outbreak. We found that ~2 Log removal could be attained after primary and secondary treatment. Despite this removal, significant concentrations of SARS-CoV-RNA (>100 copies·mL^{-1}) could still be detected in the treated wastewater. However, after treatment by chlorination, SARS-CoV-RNA was detected only once, likely due to insufficient chlorine dose. Our results highlight the need to protect wastewater treatment plants operators, as well as populations living near areas of wastewater discharge, from the risk of infection. In addition, our results emphasize the capabilities and limitations of the conventional wastewater treatment process in reducing SARS-CoV-RNA concentration, and present preliminary evidence for the importance of tertiary treatment and chlorination in reducing SARA-CoV-2 dissemination.



Iohexol Removal and Degradation Product Formation via Biodegradation by the Microalga *Chlorella vulgaris*

Patricia K. Akao [1], Hadas Mamane[2], Aviv Kaplan [1], Igal Gozlan [1], Yaron Yehoshua[3], Yael Kinel-Tahan[3] and Dror Avisar [1]

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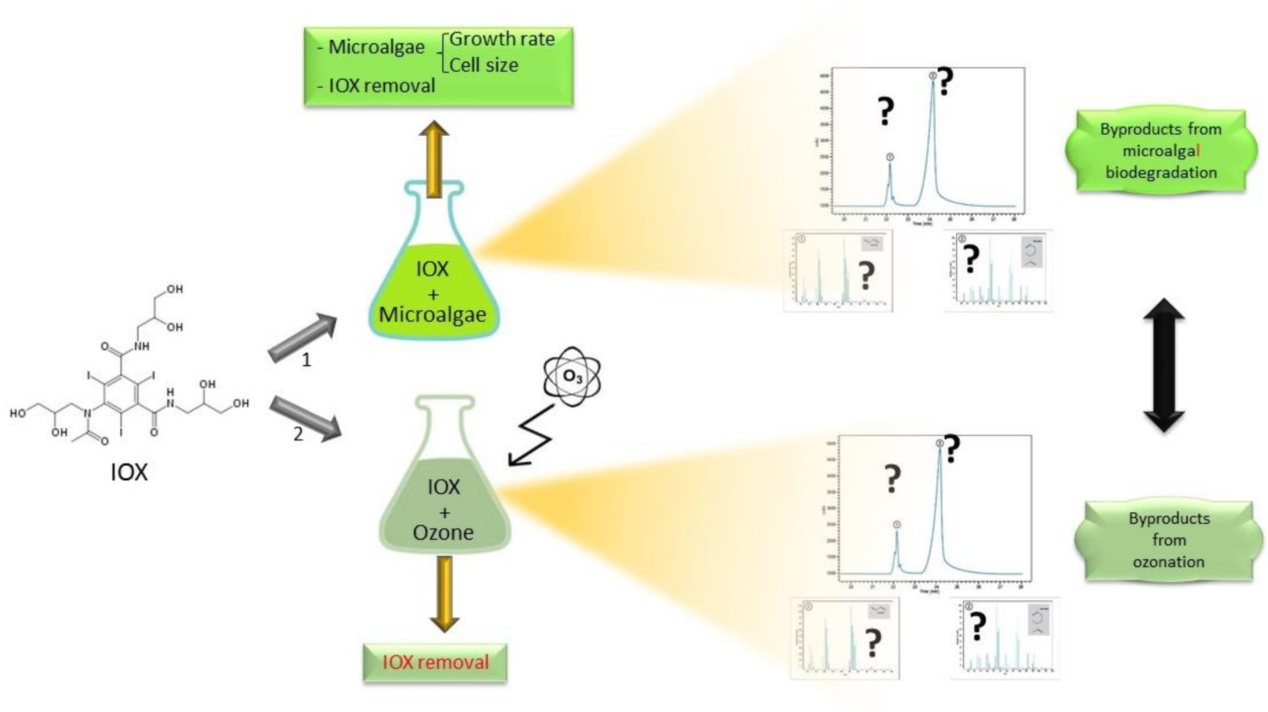
Microalgae applications are becoming more and more diverse, from wastewater treatment to biofuel and plastics production. Another promising and sustainable application is the removal of organic compound from drinking water and wastewater sources. This study focused on the removal of the iodinated contrast media, iohexol by the microalga *Chlorella vulgaris*. *C. vulgaris* removed 40–50% of the iohexol from the medium in 27 days, 23–30% of which was biodegraded through two main pathways: oxidation and hydrolysis. Similar transformation pathways, producing the same degradation products, were observed for incubation with microalgae and for ozonation.



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Carbon Nanotubes based Membrane Electrode in a Flow-Through System for the Detection of Micropollutants in Water

Nufar Allouche, Daniel Mandler

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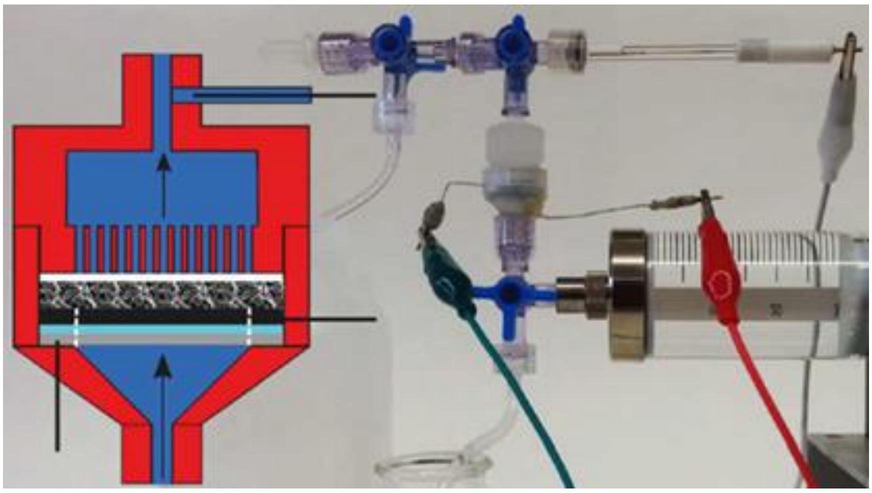
One of the challenges in water quality control is monitoring micropollutants such as hormones, drugs, and cosmetics. In this study, we will describe our results involving the electrochemical detection of the micropollutant 4-nonylphenol by a flow-through system. The detection is carried out by a carbon nanotube (CNT) based membrane electrode (Figure 1) where the goal is to monitor continuously the concentration of 4-nonylphenol in recycled water.

The detection limit in electrochemistry is often related to the diffusion of materials from the solution to the electrode, which can be time-consuming for low concentrations of the analyte. However, using stripping voltammetry and by flowing the solution through the electrode while collecting the analyte the measurement time can be significantly reduced. The CNT electrode comprises a thin membrane onto which the analyte can be adsorbed or electrochemically deposit resulting in a high collection efficiency and improving the sensitivity. The different parameters that affect the sensitivity of the flow system, such as the rate flow and the areal mass of the CNTs will be presented and discussed.



Technology-Critical Elements as Indicators of Anthropogenic Groundwater Contamination

Nitai Amiel[1], Ishai Dror[1], Arik Zurieli[2], Yakov Livshitz[2], Guy Reshef[2], and Brian Berkowitz[1]

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Groundwater contamination originating from anthropogenic industrial activities is a global concern, adversely impacting health of living organisms and affecting natural ecosystems. Monitoring contamination in a complex groundwater system is generally limited by sparse data and poor hydrogeological delineation, so that numerous (organic, inorganic, isotopic) tracers are often used simultaneously to reduce uncertainty. We suggest that Technology-Critical Elements (TCEs), which are usually found in very low concentrations in the environment, might serve as groundwater contamination tracers by creating a unique TCE "fingerprint" of the contamination, which can be monitored through the groundwater system. In this study, we demonstrate the use of TCEs as tracers for monitoring anthropogenic groundwater contamination in two different groundwater systems, in the Negev area, Israel. Using selected TCEs (in particular, Y, Rh, Tl, Ga, and Ge), we show that the sources of local groundwater contamination are phosphogypsum (PPG) ponds located adjacent to fertilizer plants in two industrial areas (Mishor Rotem, Zin Valley). In addition, we monitored the spatial distribution of the contaminant plume to determine the extent of well and spring contamination in the region. Results show significant contamination of the groundwater beneath both fertilizer plants, leading to contamination of a series of wells and two natural springs (Ein Boqeq and Ein Zin/Aqrabim). The water in these springs contains elevated concentrations of toxic metals; U and Tl levels, among others, are above the maximum concentration limits for drinking water, as determined by the United States Environmental Protection Agency and the Israeli Ministry of Health.

The Effect of Air Injection on the Biogeochemical Efficiency of a Soil Aquifer Treatment (SAT) System

Ido Arad, Shany Ben Moshe, Noam Weisbrod and Alex Furman

Faculty of Civil and Environmental Engineering, Technion – Israel Institute of Technology

With the growing global population and an increased need for potable and non-potable water, wastewater reuse has become more prevalent all over the world. Soil aquifer treatment (SAT) is a natural system for tertiary wastewater treatment and reuse in which secondary effluents are infiltrated through the vadose zone, into the aquifer, in cycles of flooding and drying. During infiltration, physical and biochemical processes (e.g., adsorption to the soil minerals, biodegradation) take place and water quality is enhanced.

Dissolved oxygen (DO) is necessary for aerobic microbial oxidation of carbon and nitrogen species in effluents, e.g., dissolved organic carbon (DOC) and NH^{4+}. Therefore, oxidizing conditions are important for maintaining an efficient process. Looking at the biogeochemical state of an SAT system, previous studies show that long drying periods (DPs) led to better oxidizing conditions in the soil profile and resulted in higher quality outflow. However, long DPs allow for the infiltration of smaller water volumes. As the population grows, the quantity of secondary effluents directed to SAT sites increases, and long DPs become less feasible.

In this study, we will explore the ability to actively inject air to the subsurface as an alternative for long DPs, that would allow higher reclaimed effluent quantities without compromising water quality. We will examine, at the laboratory scale, the effect of the air injection on the biogeochemical state of the soil, ultimate outflow quality and infiltrated amounts.

Our experimental setup includes a ~1.40-meter sandy soil column connected to an air supply system (air pressure and flow rate will be controlled/measured continuously). Along the column, sensors will monitor pH, water content and oxidation-reduction potential. First, a set of experiments designed to determine the suitable wetting and drying periods will be conducted. Afterward, three sets of experiments will take place, each considering two scenarios (with and without air injection) and different wetting/drying ratios. DOC, Total Kjeldahl Nitrogen (TKN), NH^{4+}, NO^{3-} and selected contaminants of emerging concern (CECs) will be tested at the outflow as well as along the profile through rhizons. In addition, the infiltrated amounts of secondary effluents will be measured and compared between the different experiments.

Preliminary results show that the air injection led to better oxidizing conditions in the soil and resulted in a higher quality outflow. It improved the DOC and total nitrogen (TN) removals by 66% and 30% respectively.

Self-Regenerating Bio-Clays for Chemical and Biological Remediation of Aldehydes

Or Argaman, Adi Radian

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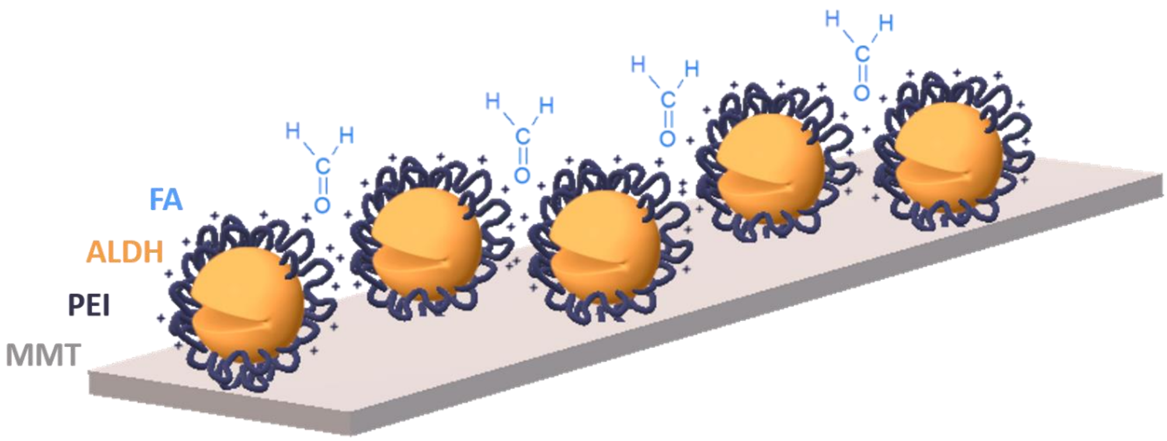
Small aldehydes, such as formaldehyde (FA), are organic compounds often as precursors in industrial processes. Due to their small size, solubility, and toxicity there are significant challenges that prevent efficient remediation of these compounds. Chemical adsorption, for example, only concentrates the compounds on the solid matrix requiring further handling of the spent sorbent. Bioremediation, on the other hand, can be employed to degrade many different aldehydes, yet is difficult to implement due to the sensitivity of the enzymes to unfavorable environmental conditions. In this study, we aimed to combine the two remediation strategies, biological and chemical, to improve on the separate systems and overcome the major pitfalls of each. For that, we designed a bio-material that can rapidly capture the aldehydes which are then destroyed by a co-localized aldehyde-degrading enzyme. The bio-material is synthesized by coating an Aldehyde dehydrogenase (ALDH) using the polyelectrolyte Polyethyleneimine (PEI) and then immobilizing the enzyme-polymer complex on montmorillonite clay (MMT). The resulting material was optimized and characterized to achieve maximum aldehyde removal from water. Our results suggest that such enzyme-polymer-clay composites can help maintain long-term activity of the enzyme, solve separation issues, and serve as an efficient platform for bioremediation technologies.



Optimizing Irrigation in Jojoba

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Jojoba (*Simmondsia chinensis*) is the sole species of the family Simmondsiaceae, which belongs to the order Caryophyllales. It is a perennial, dioecious, evergreen shrub native to the arid Sonora Desert characterized by harsh and dry climate. Annual rainfall in the region varies between 120 mm and 500 mm. It is grown globally in arid and semi-arid areas as an oil (jojoba wax) crop because of its unique chemical composition, which is desirable as a raw material for cosmetic, pharmaceutical, lubricant and petrochemicals industries. Jojoba yield is strongly influenced by alternate bearing cycle phenomena meaning that a year with high fruit load will be followed with low fruit load. Irrigation amount and timing has been found to be a key tool in obtaining higher seed weight and wax yields. Since the 1980s, there has been little to no research addressing increasing water efficiency in intensive and modern jojoba farming. A 5-years (2016-2020) field experiment was conducted in order to evaluate the responses of yield and water productivity in 5 irrigation regimes. Stem water potential (Ψ_{stem}) measurements and diagnostic leaf analyses were performed to assess the plant's response to the different treatments. In addition, assimilation rates were measured. Three of the irrigation strategies were based on returning a proportion of estimated evapotranspiration calculated according to the Penman-Monteith equation multiplied by a crop coefficient (Kc). We considered a Kc of 0.5 as a baseline (control treatment) for evaluating higher (125% of control) and lower (75% of control) application. The 4th treatment received same annual water amount as the control, but with irrigation halting during fruit dehydration. Another treatment was based on sensors (Dendrometers), continuously measuring the trunk diameter daily fluctuations representing plant water status.

The experimental field is located next to Kibbutz Hazerim on a 13-year-old "Hazerim" cultivar commercial plantation. Field area is 0.5 hectare, which was divided to 5 treatments with 5 repetitions in a randomized block format. Each plot contained three rows with nine plants, and only the middle five plants of the middle row were measured. In 2019, RDI yield was statistically lower than the control treatment with 5.3 and 7.2 kg fruit per plant respectively. No significant difference in yield was observed between the treatments, suggesting that lowering commercial irrigation amount can be possible without harming potential yield. Wax content and individual seed weight were not affected by the treatments. Individual seed weight averaged 9 gr consisting roughly of 50% liquid wax. In 2020, RDI plants showed a decrease from -40 down to -51 bar during July when irrigation was halted. After irrigation resumed, Ψ_{stem} recovered to levels similar to the control treatment (-41 bar). Assimilation rate peaked relative early during the day (9-10 am) for all treatments and was distinctly lower in the leaves tested from the RDI treatment compared to the control treatment. Irrigation amounts did not influence dry leaf mineral content. Sensor-based irrigation regime was applied in 2018 by using a proposed algorithm, which detected water-stressed plants according to the daily trunk diameter changes over time. Differences in the trunk diameter behavior was visible when comparing years with high/low fruit load but not between the treatments. By evaluating the plant's response to different irrigation regimes we hope to optimize commercial jojoba plantation water use, thus increasing water savings with no negative effect on yield.

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Stripping and Recovery of Ammonia from Centrate Liquid of Anaerobic Digestion using a Sulfuric Acid By-Product: a Case Study

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The Shafdan plant is the largest Wastewater Treatment Plant (WWTP) in Israel and among the largest and most advanced in the Middle East. On a daily basis, the plant produces: 1. High-quality reclaimed water, which is used for extensive irrigation in the desert area of Israel, 2. Class-A bio-solids (sludge) used as agricultural fertilizer, and 3. Biogas used for renewable energy production. During these processes, two by-products are created: the first one, a stream called "centrate", which originates from the sludge dewatering system as part of the sludge conversion to commercial fertilizer. Treating this stream is one of the major challenges facing WWTPs, mainly due to its high ammonia and phosphorus concentrations. As a result, this stream is currently being discharged into the Mediterranean Sea, a move that violates the Barcelona Convention and may cause problems in the marine ecosystem. The second by-product created is sulfuric acid (H_2SO_4), which originates from the process of removing hydrogen sulfide (H2S) from the biogas before using the gas for renewable energy production. Most of the studies examined diverse technologies which require external additives such as acids, bases and minerals. Alternatively, some offer biological solutions which are less stable.

The presented study offers an integrated solution for treating the centrate using recovered sulfuric acid. The product of this process is a marketable agricultural fertilizer called "Ammonium Sulfate" ($(NH_4)_2SO_4$) which is required in the agricultural industry in Israel and worldwide.

The study was carried out in a laboratory experiment with two stages, which were performed between 4 to 6 times. In the first stage, the stripping unit, the ammonia was evaporated by heating the centrate. In the second stage, the scrubbing unit, the ammonia was recovered using sulfuric acid, resulting in agricultural fertilizer. The results showed high efficiency in both stripping and recovery of ammonia (93.1% and 77.2% respectively). From the results of the experiment, it was found that the proposed solution could be used as a good alternative to the treatment of by-products in the Shafdan plant and other WWTPs around the world.

As the scarcity of raw materials escalate, the significance of solutions which recycle existing materials grows. In accordance, the illustrated solution utilizes two environmental nuisances created in the WWTP to create one valuable resource. Such a process is a clear example of resource recovery, which is a prominent component in circular and zero-waste economies.

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Novel Heat-Driven Water Pump For Developing Communities

Nathan Blanc, Joseph Cassel, Rui Yang, Avishai Meir, Yehuda Agnon, Guy Z. Ramon

Water and Energy Technologies laboratory (WET), Grand Technion Energy Program, Technion

Water pumping, for potable use and irrigation, is one of the biggest challenges for rural communities in developing countries. For example, transition from rainfed to pump-irrigated farming can triple the crop yield. Here, we report work on a cheap, reliable, heat-driven pump, based on a thermoacoustic air compressor and a geyser pump.

The compressor is a thermoacoustic engine, in which heat is converted to pressure oscillations, connected to a check-valve. Thermoacoustic engines can convert heat to acoustic power with up t0 40% of Carnot's efficiency. The heat source can be solar power, waste heat from cooking fires, or a combination of the two (see schematic in Figure 1(a)).

Near the check valve, acoustic pressure oscillations lead to flow into the pressure chamber during the over-pressure periods, while preventing backflow during under-pressure periods (see Figure 1(b)). The pressurized air is then used to pump water using a geyser pump.

The geyser pump features a novel design, allowing for high air to water ratio and minimizing backflow and flow dissipation. The resulting system will have zero moving parts, making it cheap, reliable, and easy to maintain.

We present results from an initial prototype of the pump, demonstrate its ability to pump water with heat as the only energy input, and characterize its performance. We also present some of the working methods used to characterize and optimize the pump, and outline the current and future challenges in the project.

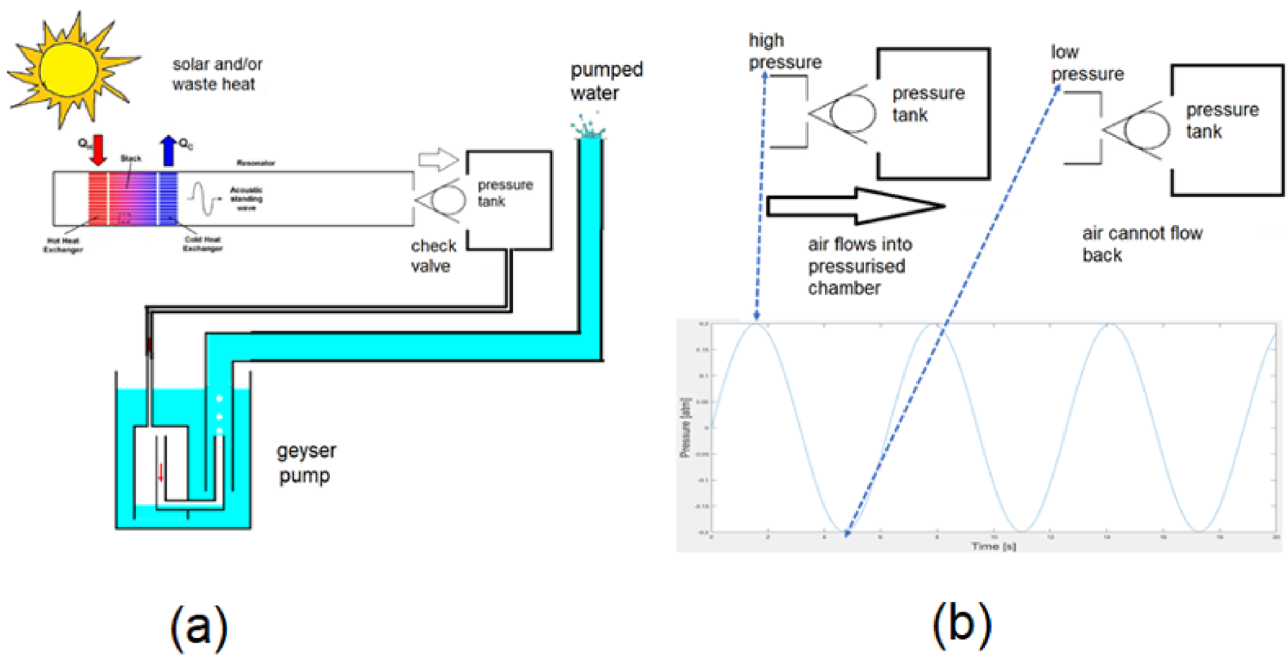

Figure 1 (a)- schematic of the system. Heat is converted to acoustic power, that is used to pressurize air. The pressurized air is used to pump water via a geyser pump. (b) - description of the pressurization mechanism. Air is pressurized during the acoustic overpressure period, and backflow is prevented via a diaphragm check valve

Analysis of Carbamazepine in Chicken Eggs

Daniela Calero, Prof. Benny Chefetz and Vered Mordehay

Department of Soil and Water sciences, Robert H. Smith Faculty of Agriculture, Food and Environment, The Hebrew University of Jerusalem

Carbamazepine (CBZ) is an aromatic anticonvulsant that is widely used in therapy of epilepsy and trigeminal neuralgia. CBZ is one of the most frequently detected pharmaceuticals in bodies of water, soil, vegetables and fruits that are wastewater treated. For the purposes of this experiment was develop an analytical method to detect and quantify carbamazepine in Leghorn laying eggs in yolk and albumen. Through this effective extraction method were detected and quantified levels of carbamazepine residue by testing chicken eggs of hens in yolk and albumen that were exposed to carbamazepine. Concentrations of CBZ were detected in the tested eggs, indicating that CBZ passed down to offspring that were not directly exposed to CBZ. The total concentrations found were determinate by LS-MS.

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Environmental Assessment of Coal Fly Ash Leaching Properties and Beneficial Use in Infrastructure Works

Sarah Curpen, Konstantin Kovler, Nadya Teutsch

Technion – Israel Institute of Technology

Industrial waste recycling has gained enormous popularity over the years since the link between waste disposal and its consequent environmental impact became evident. Coal Fly Ash (CFA), is a secondary raw material produced as a residue of coal combustion for electricity generation in power stations. One of the main environmental backlashes regarding the use of CFA in infrastructure works is the risks which threaten freshwater reserves. In Israel, the average annual rainfall is plummeting whilst the quality of drinking water is under serious threats of contamination from industrialization. The re-use of CFA could place even more pressure on the water quality. Six hundred and forty-six thousand tons of CFA were produced locally in 2018 which is currently mainly re-used in concrete and cement production. However, a potential disruption in the disposition of CFA led to consideration of its use in embankments and road bases. This re-use of CFA could increase the potential of freshwater contamination. Under local hydro-geological conditions, freshwater reserves are likely to be exposed to accumulated pollution of constituents of potential concern (COPC), e.g. Cr, Se, whose availability in the CFA is relatively high. Thus, the presence of COPC in CFA strengthens the need of an environmental examination of the ash itself and its use in infrastructure works. Therefore, this work is aimed at characterising the leaching properties, using the Leaching Environmental Assessment Approach (LEAF), of compacted Israeli CFA and to evaluate the environmental effects through life cycle assessment and using LeachXS, data management tool from LEAF.

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Identify Flow Patterns of Seawater in the Coastal Aquifer of Indian River Bay, Delaware

Dror Ettlinger, Yael Kiro

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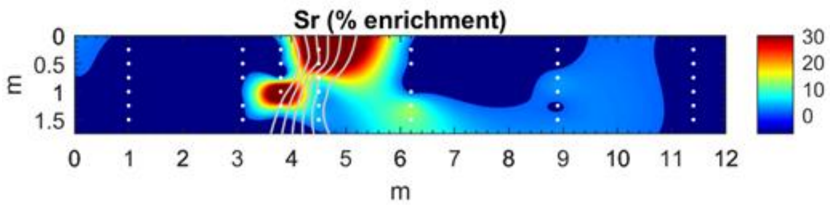
Submarine groundwater discharge (SGD) has been proven significant in geochemical environmental processes in coastal aquifers. Understanding the geochemistry of the interaction between the seawater and the coastal aquifer may shed light on the long-term circulation of seawater in aquifers, which affects ocean chemistry.

By using seepage meters, piezometers, and geochemistry as a new approach, this study seeks further to understand the long-term seawater circulation flux in aquifers. Our new approach is based on the typical behavior of the enrichment of Sr and Ca and depletion of K in coastal aquifers (Sivan et al., 2005).

Samples were taken from the Indian River bay, Delaware using seepage meters and piezometers. These were titrated using Titroline 7000 for chloride concentrations. Neutralization was performed using silver nitrate ($AgNO_3$) at a concentration of 0.01 M to determine the unknown concentration of chloride in the sample. Major elements were measured using ICP-OES.

The Sr enrichment (compare to conservative mixing determined by Cl) reflects the flow path of the long-term circulation cell (see figure below).

Figure 1 shows the area of transition between fresh and saltwater by the white lines. The flow mechanism can be traced by the Sr enrichment. Enrichment of strontium in the water-rock interaction process shows the flow path of the water.



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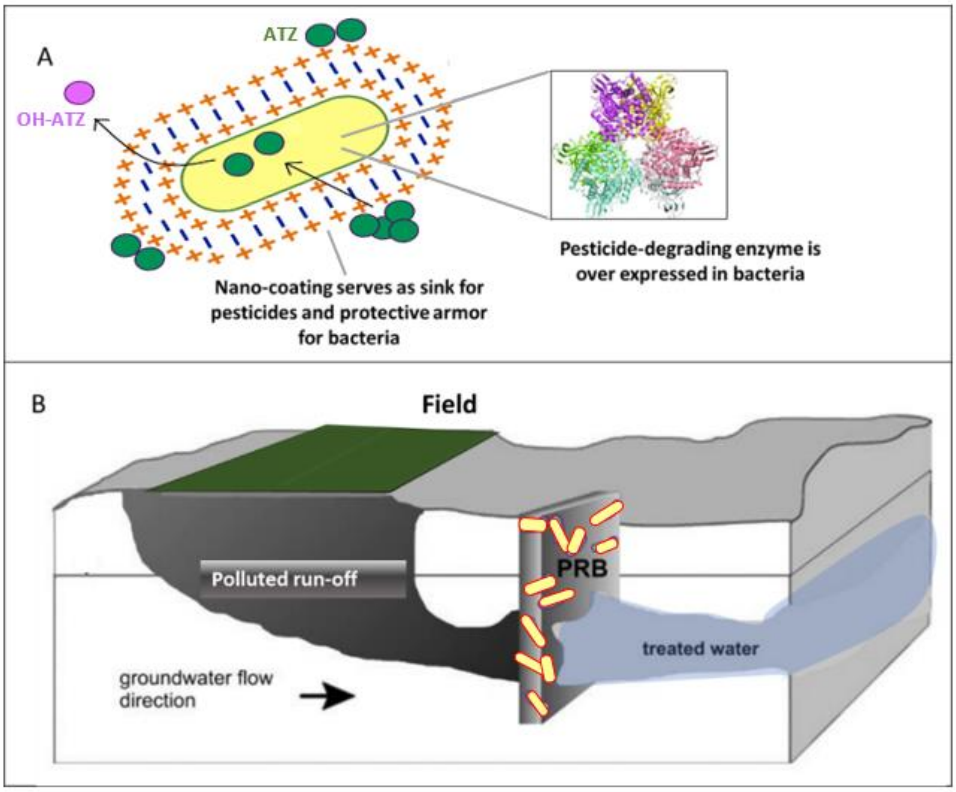
Layer-By-Layer Nanocoating of Bacteria for Enhanced Pollutant Biodegradation Efficiency

Reut Gal, Neriya Peretz, Adi Radian

Faculty of Civil and Environmental Engineering, Technion – Israel Institute of Technology

Pollutant biodegrading-bacteria were armored with a nano-tech, ecological shield using polymer layer-by-layer (LbL) deposition. The LbL nano-coating was designed to attract the model pollutant atrazine (ATZ) and increase uptake kinetics compared to free cell bacteria. Several polycations were tested including PDADMAC, Chitosan and Polyvinylpiridine-co-styrene, the polyanion chosen was Poly(4-styrenesulfonic acid) (PSS). *E.coli* over- expressing the ATZ degrading enzyme AtzA, were effectively wrapped using the polymers carrying alternating positive and negative charges. Charge reversal of the surface after each layer was confirmed using zeta potential measurements. The degradation kinetics of ATZ was followed as a function of polymer type and the number of layers added. PDADMAC/PSS layering was found to be most effective, allowing high degradation efficiency compared to the free cells, when coating consisted of 1 or 3 layers. The chosen PDADMAC/PSS LbL-bacteria were further characterized using electron and light microscopy, BET and size measurements. Soil-activity studies were preformed to assess the efficiency of the LbL-bacteria as reactive particles in soil permeable reactive barriers (PRBs). After incubation in soil, LbL-armored bacteria were tested for degradation activity and viability via a dead/live assay and ability to form colonies. The resulting platform showed several strengths: a. enhanced biodegradation rates compared to free cells and, b. controlled biological activity - the LbL-bacteria are essentially bags of enzymes unable to proliferate, thus ecological damage by non-native organisms could be prevented. These novel nano-biodegrading particles can allow continued yet responsible use of agrochemicals while significantly decreasing their environmental footprint. The novelty lies in tying three remediation technologies together – bioremediation, nanoremediation and PRB technology in a very simple and complimentary fashion. Such platform could be further tailored and adjusted to remediate a wide range of anthropogenic pollutants.



Energy Recovery from Waste Activated Sludge Using Hydrothermal Carbonization Coupled with Anaerobic Digestion

Rubia Gaur, Osama Khoury, Matat Zohar, Yael Laor, Roy Posmanik

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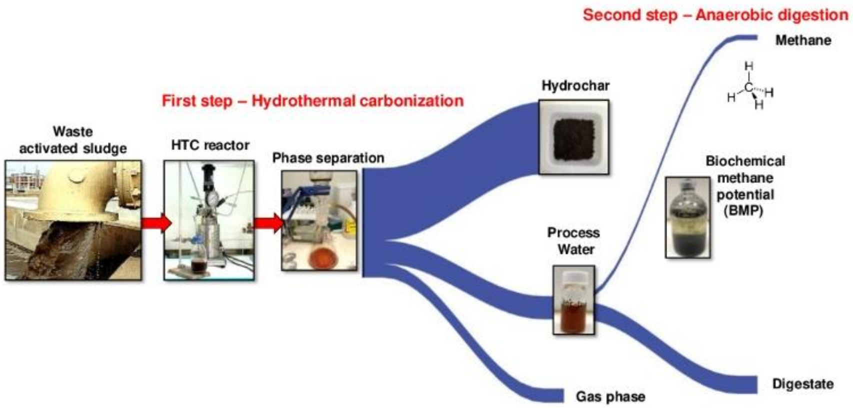
Worldwide rapid population growth increases the pressure on wastewater treatment plants (WWTPs). Managing the sludge produced at WWTPs challenges the activated sludge process, due to high organic matter, high moisture content and the risks of toxic micro pollutants and pathogens. Sludge treatment is therefore the most expansive stage in a WWTP, from the economical and the carbon footprint perspectives. On the other hand, high organic carbon in waste activated sludge can be potentially used for renewable energy applications. Recovering energy from waste activated sludge can potentially increase the energetic efficiency at the WWTP while minimizing operational costs related to sludge discharge. Anaerobic digestion (AD) is a mature technology, used for primary and secondary sludge stabilization at WWTPs to recover energy as biogas. However, land application of anaerobically digested sludge is problematic and facing many regulatory barriers mostly due to public health issues. Hydrothermal carbonization (HTC) allows the degradation of waste activated sludge in an aqueous medium of subcritical water, while producing hydrochar – a carbon-rich pathogen free solid material together with process water. To move towards sustainability in WWTPs, HTC can be integrated as a platform for on-site sludge treatment.

In this study, HTC of waste activated sludge was performed at increasing temperatures (200, 250 and 300 °C) and retention times (30, 60 and 120 min), providing a wide spectrum of reaction severities ($\log R_0$=4.4–8.0). The goal of the study was to quantify the energy recovery from hydrothermal co-products (i.e., hydrochar and process water) for their use as a solid fuel and a feedstock for AD, respectively. The hydrochar yield was quantified and its quality was evaluated for elemental composition, higher heating value and combustion behavior using thermogravimetric analysis.

The highest hydrochar yield of 73% was obtained at the lowest severity ($\log R_0$ of 4.4, 200°C for 30 min) and the lowest value of 49% was obtained at the highest severity ($\log R_0$ of 8.0, 300°C for 120 min). On the other hand, the hydrochar quality was found to be positively influenced by reaction severity, which enhanced the reduction of oxygen from 19.3% to 4.3% by decarboxylation processes. The hydrothermal process water was analyzed for its chemical oxygen demand (COD) and biochemical methane potential (BMP). The BMP was also affected by the reaction severity, with the highest value of 227 mL CH_4 g COD^{-1} at the lowest severity and the lowest potential value of 28 mL CH_4 g COD^{-1} at the highest severity. An overall energy balance suggests that mild reaction severities can serve as a suitable platform returning more than 70% of the energy from waste activated sludge using the integrated HTC-AD process. The majority (53-73%) of the energy is recovered via HTC while additional energy (1-12%) is recovered via AD. This process integration is therefore, expected to reduce: 1) the overall energy consumption; 2) the operational costs; and 3) the carbon footprint of WWTPs.



Breakthrough in Applied Hydrogeology and Petroleum Geology

Isaak Mark Gershanovich

Independent researcher

This innovative methodology is intended for aquifers and oil deposits analyzing. It uses conventional pump off data from single wells. The application of the equation of variable mass motion to inflow into pumped well is the key point in the invention. At the same time, the Theis - Cooper - Jacob's solution is retained as the template for evaluating transmissibility, diffusivity, and storativity subject to all restrictions to apply this solution which are eliminated via means of this innovative methodology. It also yields many supplementary features about aquifer's environment, near-wellbore zone, potential replenishment or depletion, and some others. These abilities are out of known methods of hydrodynamic tests or math simulation. Modern technologies of math modeling operate with lack of actual data. From this point of view the developed methodology represents a breakthrough in applied hydrogeology. But it did not reach the consumer as a user's software yet. The author is quite aged man to finish this part of the development on his own. Therefore, he wants to attract the colleagues' attention to this innovative methodology in a hope that there will be found a person or company that will undertake to produce software for users around the world. Few months ago, the Scientific and technical association «Ecology Imperative» (Israel) proposed its partnership to advance the project to such a goal. All others are welcomed to cooperate too.

Predicting the Impact of Water Efficient Scenarios on Sediment Accumulation in Sewers Using Machine Learning

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Attractive water efficient solutions to replace or complement existing centralized water and wastewater systems are widely being developed and promoted. These systems are expected to significantly contribute to the sustainability of the urban water cycle. The optimal transition from the current "business as usual" practice to a more sustainable urban water system can, nevertheless, only be achieved when the negative influence it may have on the operation and maintenance of existing centralized systems is considered. Of the expected and concerning effects of such a transition are the accumulation of solids in sewers and their negative contribution to sewer blockages and formation of toxic gases. Model predictions of solids deposition locations require setting up and simulating detailed sewer models. Many times, precise details of the networks layout and diurnal flows patterns are not available, limiting the applicability of using models' predictions for such hazards. Development of a simplified model predicting sediment accumulation in sewers will spare the need to conduct complex simulations. It may be used to analyse any existing and future systems, where the transition from its traditional centralized systems is considered. It will potentially indicate where the most affected points in the system are expected to occur. A more detailed model can then be calibrated only for these sensitive locations and simulated for more precise predictions of the effects.

In this study, a detailed sewer model integrating stochastic generation of domestic wastewater streams (Penn et al., 2017) and hydrodynamic simulations of flows using SWMM software (Rossman 2004) was set up to investigate the sewer network characteristics that are more prone to sediment accumulation. 117 highly variable synthetic sewer networks were generated using DrainNetGen (Muranho et al., 2016) and simulated for various water efficient transition scenarios. Supervised classification and regression machine learning (ML) techniques were applied for developing simplified models to predict sediment accumulation locations. The hydraulic simulation data was used to indicate the locations prone to solids accumulation. A critical bed shear stress of 2 Pa was set to determine whether a pipe accumulates sediments or not. The models were tested on unseen test data to evaluate their performance. The simulated data is a 196,889 x 17 matrix, which constitutes of 196,889 data examples. The target parameter in the classification models is the binary label for solids accumulation in a specific pipe, where "1" was set to be the value for solid accumulation, and "0" otherwise. The regression models predict the maximum shear stress in each pipe.

The ML models showed an increase in predictive accuracy with the increase in the model's complexity. The classification models showed very high predictive accuracy of 0.9, 0.93, 0.96, 0.97 for linear regression, logistic regression, decision tree and random forest, respectively. In a similar way, the regression models predictive accuracy was 0.77 and 0.93 for linear regression and random forest, respectively. The analysis of features importance indicated the most important features to be the pipe's slope, number of residents that contribute wastewater to a pipe and the pipes located upstream, and the stream order (indicating the relative location of a pipe in the network). The high accuracy of the model's predictions indicates that locations of solids accumulation in sewer pipes, due to the implementation of water efficient solutions, can be predicted using simplified models. Using such models spares the need to set up a complicated detail hydrodynamic model. In future research, the ML models predictive accuracy will be examined while removing some of the features, to evaluate to what extent these models can be simplified. In addition, a biochemical transformation model will be integrated to include the prediction of hydrogen sulphide from the accumulated sediments.

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Utilization of Network Sub-Systems for Optimization of Water Distribution Systems

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In this paper, a methodology that incorporates system reliability in the optimal design of water distribution system is proposed. The methodology is developed by treating the system reliability problem in terms of an explicit level of system redundancy (both hydraulic and topologic redundancy of the network are considered). Due to complex nature of optimizing a looped network with some level of system redundancy, the optimization problem is solved by decomposing the system into subsystem networks using graph theory. Each sub-system is generated in such a way in case a failure occurred in one link, all the demand nodes will remain connected with the source through the other intact links. Thereafter, in the design stage, the components of the network are designed to operate without inferring consumers' demand under normal and abnormal constraints.

The Effect of Meteorological and Air Quality Parameters on the Chemical Characteristics of Water Produced from the Atmosphere

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Water scarcity around the world is enforcing and encouraging humans to seek for alternative out-of-the-box technologies to produce drinking water. Atmospheric dew water is a potential source of potable water as the earth's atmosphere is a huge and renewable water resource. It contains approximately 12,900 billion tons of fresh water, 98% is in a vapor state. Atmospheric Water Generators (AWG), a device that converts water vapor into liquid water, is a promising alternative technology to overcome the global water scarcity. AWG does not require any water transport infrastructure since it can be placed almost anywhere and even can use solar as an energy source.

In this research, the influence of meteorological and air quality parameters on the chemical characteristics of water produced from the atmosphere was studied. A unique AWG which can be programmed to produce water at a specific time throughout the day was used. The machine that was placed in Tel-Aviv (TAU campus), contains only water-production generator and does not have any air/water filtration systems and water treatment technologies.

The results demonstrated that the origin of different chemical compounds in atmospheric water (dew water) can be difficult to trace because aerosols and atmospheric gases can be transported over large distances, or due to chemical reactions after the dew water has been generated. This research uses different tools to determine the influence of atmospheric components on the generated water.

Various Metals, Ions, Volatile Organic Compounds (VOCs), and Semi-Volatile Organic Compounds (SVOCs) were analyzed in the dew water. Nearly always (day and night in different seasons), the water meets the WHO and Israeli water standards. The main elements found in dew water are ammonium, calcium, sulfate, and nitrate. Moreover, it was found that the regional and local atmospheric conditions have a clear influence on the dew water. Several essential minerals were found in low concentrations in dew water. The location of the sampling site (Tel-Aviv) in an urban area, between major traffic routes, affects the chemical composition of the produced dew water. On a regional scale, the trajectory that the air passes in the days before arrival to the water production site influences the chemical properties of dew water. South and east trajectories carry desert derived elements, while western trajectory is characterized by marine elements. In addition, it was indicated that the time of day when the dew is produced does not significantly affect its composition.

Overall, the production of dew water by AWG in a large urban area, such as in Tel Aviv, can provide safe drinking water at day and night throughout the year.

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A New Fixed-Bed Desupersaturation Concept for Reducing Chemical Scaling Propensity in Membrane Systems

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A new concept for reducing supersaturation levels of process streams undergoing reverse osmosis (RO), nanofiltration (NF) or electrodialysis (ED) is suggested herein. The method is aimed at preventing inorganic fouling, thus allowing for increased recovery ratio, e.g. >95% in effluent nanofiltration. Unlike common methods for scaling prevention, (acid/antiscalant addition, precipitation ponds, or fluidized bed reactor), our approach is fast, simple, with close-to-zero chemical input and minimal footprint. The de-supersaturation unit is a packed bed reactor that can be placed, for example, between two consecutive RO/NF stages. The supersaturated concentrate leaving the first RO/NF stage, flows through the reactor to induce rapid precipitation, which significantly reduce scaling tendency in the subsequent RO/NF stage. We measured Calcite precipitation, a major scaling agent in wastewater RO/NF, as well as other membrane processes [1]. Our experimental setup included a fixed-bed column system, testing two grain size calcite particles (1-2 mm, and 0.15-0.3 mm in diameter), and a filter cake module (Ca. 15 µm $CaCO_3$ powder). In order to extract the kinetic constant of the precipitation reaction, and to predict the performance of the system in different conditions (solution composition, reactor parameters, etc.), a chemical equilibrium-kinetics hybrid model was developed and is described in Figure 1. A. To evaluate the unit performances, we streamed solutions supersaturated with $CaCO_3$ and measured Ca^{2+} concentration and pH before and after the de-supersaturation unit. We tested the process in varying flow rates (retention times), and sampled from several bed depths during the fixed bed column experiments. Using the geochemical software PHREEQC, we calculated that 20-30%, and 50-70% of the calcium carbonate precipitation potential (CCPP) was realized, for the fixed bed 1-2 mm (empty bed HRT: 0.6-1.4 min) and 0.15-0.3 mm (empty bed HRT: 0.7-1.8 min) grain size respectively, and 40-70% in the filter cake experiments (empty bed HRT: 0.13-0.6 min). The fixed bed experimental results are in close agreement to the model simulation (Figure 1. B), and exhibit the trend which we expected to see for the reaction along the column. The high precipitation rate recorded in the filter cake experiments, indicate that the reaction is surface dependent (low amount of CaCO3 powder, high effective surface area), as was found for similar reaction in the past [2-3]. Our results indicate that the process is feasible, and with further analysis of bed/cake resistance we plan to further test the process stability with synthetic and real wastewater effluent.

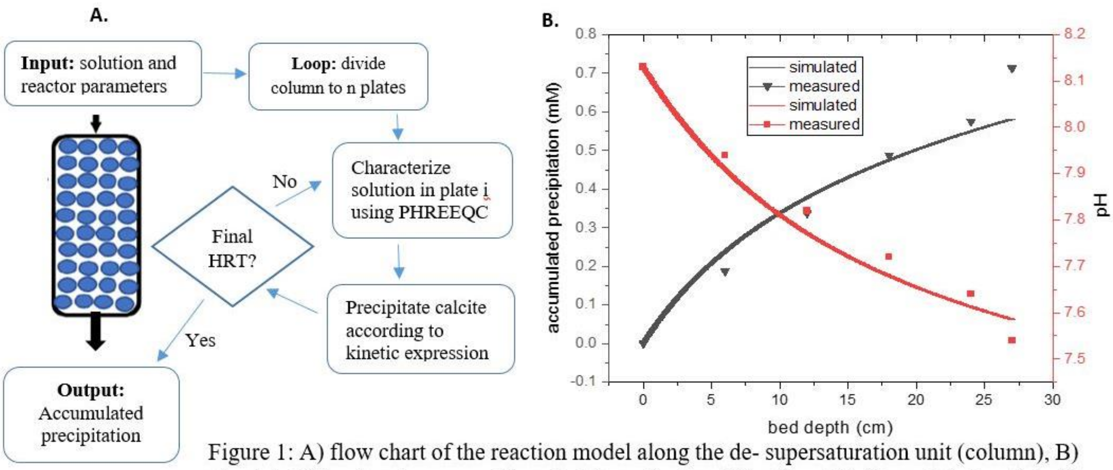

Figure 1: A) flow chart of the reaction model along the de- supersaturation unit (column), B) simulated (lines) and measured (symbols) results for pH (red) and Ca^{2+} precipitation (black) for 1-2 mm grain size, at 765 ml/min flow rate.

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Optimal Treatment Plant Design for Water Distribution Network Considering Uncertainty in Mixing at Cross Junctions

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Around the world there has been an increase in potential point and non-point source contaminations of water sources. The increasing contaminant concentrations of existing water supply reservoirs and other sources are being potential treat to public health. This led to an increase in development of huge treatment plants at the water supply reservoirs. The treatment cost increases exponentially with increase in the level of treatment needed, this problem requires an optimal treatment level needed at the sources which will be robust enough to meet the quality standards at the outlet of the water distribution network (WDN). The movement and distributions of contaminants in the WDN are largely dependent on the level of mixing at the cross junctions. The concentration levels attained due to various mixing levels at the cross junctions is modeled using bulk-advective mixing (BAM) model. Current work aims at providing the optimal treatment levels at the source locations which will satisfy the concentration constraints at the outlet demands for an existing WDN. The uncertainty in the level of mixing is also handled though robust optimization concepts. Due to high complexity of BAM model equations, a data driven linear surrogate model is approximated. This surrogate model is further used in a combined linear programing and a meta-heuristic optimization algorithm framework to find the optimal treatment levels. The framework is tested on a small 16 node grid network with 8 cross Junctions.

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Considering COVID-19 Pandemic Reaction and Response Analogies in an Agent Based Modelling Framework for Water Distribution System Contamination Response

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Hazardous events such as contamination events in water distribution systems (WDS), similar to other natural or man-made disasters can cause distress in the affected population and requires fast handling of authorities and the respective water utility manager. While numerous studies have been conducted on the reactions of various stakeholders during disastrous events using agent based modelling, the social background and related psychological states of different society groups have not been considered. This study utilizes recent observations during the COVID-19 pandemic from social science and psychology and implements them in an agent based modelling framework. Furthermore, various analogies are drawn between the global pandemic and a deterioration of water quality in a water network and the reaction of consumers and the response of the utility manager are explored and investigated. A hydraulic and water quality model is established and coupled with an agent based model to explore the consumers reactions to the event based on their social backgrounds, location in the water network and symptoms from possibly consuming contaminated water by utilizing fuzzy logic. The utility manager agent has various possibilities of reacting to the event e.g. placing mobile equipment to monitor the water quality, warning consumers via social media and declaring endangered and contamination free zones in the network. This clustering of the network is conducted utilizing graph theory while considering various flow directions and patterns and inspired by "contact tracing" which is an efficient method to curb the spread of corona virus used by many health authorities. First results suggest that considering the social background of consumers is significant regarding their reaction to a water quality event and that the timely spread of information about contaminated and danger-free parts of the network can help preventing distress amongst the population and locate the source of the contamination more quickly.

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Pressure-Wave Driven Wetting and Solute Transport in the Vadose Zone

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Soil degradation by salinity is a major problem that affects agriculture worldwide, gradually depleting soil fertility. The traditional practices for leaching accumulated salts from the root zone are by adding water amounts to the irrigation dose and by occasional irrigation events that are specifically objected for leaching purpose and rely on flushing the entire soil profile. Evidently, however, the leaching efficiency of these practices is relatively low, as they demand significant water amounts and are limited in their ability to transport solutes. Salt leaching by flushing occurs in relatively short time scales, as it relies on advection dominant transport. Consequently, adsorbed ions and solutes in diffusive sites weakly participate in these short-duration rapid-flowing events.

Theoretical investigations verified by experiments suggest that altering the water flow regime between a creep (Darcy) type flow and a pressure impulse thrust flow driven by pressure-waves, enhances water and solute displacement in porous media.

In this work, the flow in soil is manipulated by the creation of pressure waves in the water phase using a simple setup, constructed from a solenoid valve and a pressured water line, providing an irrigation mechanism for enhancing solute mobilization from water-stagnant locations to locations that are accessible for leaching.

We report on a Hele-Shaw cell experiment in which the efficiency of solute displacement from a saline fine-textured soil region was compared between two leaching treatments: (1) constant flux entering the soil at atmospheric pressure (drip-irrigation conditions), and (2) burst injections of water (50 milliseconds each) entering the soil through the custom-made pressurized pulse setup (at pressure higher than atmospheric).

In-situ measurements indicate that, under these conditions, the amount of solutes leached down from the fine-textured region per volume of water was significantly larger when the pressure pulses were applied (approximately two times more than the constant flux). Furthermore, the water distribution differed significantly between the constant flux and the pressure–pulse driven flow that displayed a higher water content behind the wetting front which was smoother and less inclined to preferential flow.

Nutrient (N&P) Containing Aerogel for Hydrocarbons Adsorption and Biodegradation in Marine Environment

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Oil and Petroleum spills are considered to be destructive environmental hazards contaminating water or soil and damaging the ecological balance of these environments. This research focuses on the aquatic environment, concentrating on water – hydrocarbon interactions. A novel method for the removal of hydrocarbons that contaminate aquatic environments using aerogels, i.e. carbon based sorbents, is proposed. The aerogel is characterized by high hydrophobicity, high porosity, low density, and has a high adsorption capacity for hydrocarbons. It is prepared from paper through a short and simple production method. Preliminary results demonstrated that physical adsorption can be combined with biodegradation of crude oil using microorganisms. The microbial biodegradation process is enhanced by supplementation of phosphorous and nitrogen which is present in minute concentrations in the ocean. These basic concepts may enable incorporation of unique bio-materials during the various stages of oil isolation-separation-concentration, and thus enhances simultaneous biodegradation of oil constituents. Preliminary results show greater bacterial growth in media in which nutrient carrying aerogels are the single source for N and P when compared to N and P free growth media.

Spatial and Temporal Variability of Gas Content in Sediment of Lake Kinneret, North of Israel

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Shallow gassy aquatic sediments, abundantly found in Israel and worldwide, are a source of major concern for their contribution to destabilization of coastal and marine infrastructure, ecological balance, air pollutions, and global warming. Gas bubbles within sediment change effective sediment properties, including also its geo-acoustic characteristics. Among other characteristics, sound speed is the most sensitive parameters to presence of gas. This study proposes a novel methodology for acoustic sediment characterization. Behavior of reflection coefficient is used for estimations of gas content along off-shore transect and thickness of gassy sediment layer. Study was carried out in the North-Western part of Lake Kinneret, North of Israel. Variations in the free gas content in sediments with water depth obtained using the proposed method shows an agreement with the distribution of organic matter content in and methane fluxes from sediment, both revealed by the preceding studies. Study of seasonal variability of the free gas content shows an agreement in changes in hydrostatic pressure, caused by variations of lake water level. Proposed in this study non-invasive, cost-effective methodology allows a rapid scanning over large areas of aquatic sediments. This method is especially suitable for characterizing gassy sediments and highlighting locations of potential methane emissions. This, in turn, allows a better understanding of methane gas distribution in the upper sediment layer and can be used in monitoring of ecological balance of the region.

Modeling Risks of Salt-Induced Irreversible Soil Degradation

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Degradation of soil hydraulic conductivity resulting from the use of saline and sodic irrigation waters is a major environmental danger, especially in dry areas. Limited water resources in these regions encourages the use of low-quality irrigation water — often high in salt content — for agriculture. While the mechanisms of how salinity and sodicity lead to reductions in hydraulic conductivity (e.g., slaking, swelling, clay dispersion) are the focus of a vast body of scientific literature, the rehabilitation process is far less understood. Existing models treat degradation and rehabilitation in the hydraulic conductivity as reversible. The scant experimental evidence that exists, however, suggests that these processes feature hysteresis, i.e., the system follows different paths for degradation and rehabilitation. We introduce the SOTE model (Kramer & Mau, 2020), a minimalistic model designed to study the long-term dynamics of soil water content, salinity, and sodicity, as driven by irrigation practices and climatic conditions. We integrate the SOTE model with a novel framework in which a soil's history of degradation and rehabilitation are used to assess future response (see Yair Mau's presentation for discussion of the framework and Taiwo Adeyemo's for an overview of the experimental procedure underlying the framework). We use the integrated version of the SOTE model to explore the effect of irreversibility on the risk of soil degradation. When the potential for hysteresis is taken into account, risk of long-term degradation from a typical irrigation regime and climate conditions in Israel increases from 20% to 35% in a span of 10 years. When comparing current climate conditions to expected shorter rainfall seasons, irreversible degradation risk increases by 25% over 10 years. Our results emphasize the importance of considering irreversibility when assessing salinity and sodicity induced degradation risks.

Isaac Kramer and Yair Mau. Soil degradation risks assessed by the SOTE model for salinity and sodicity. Water Resources Research, 2020. https://doi.org/10.1029/2020WR027456

Three Dimensional Configuration and Dynamics of the Fresh-Saline Water Interface Near Two Saline Lakes with Different Levels

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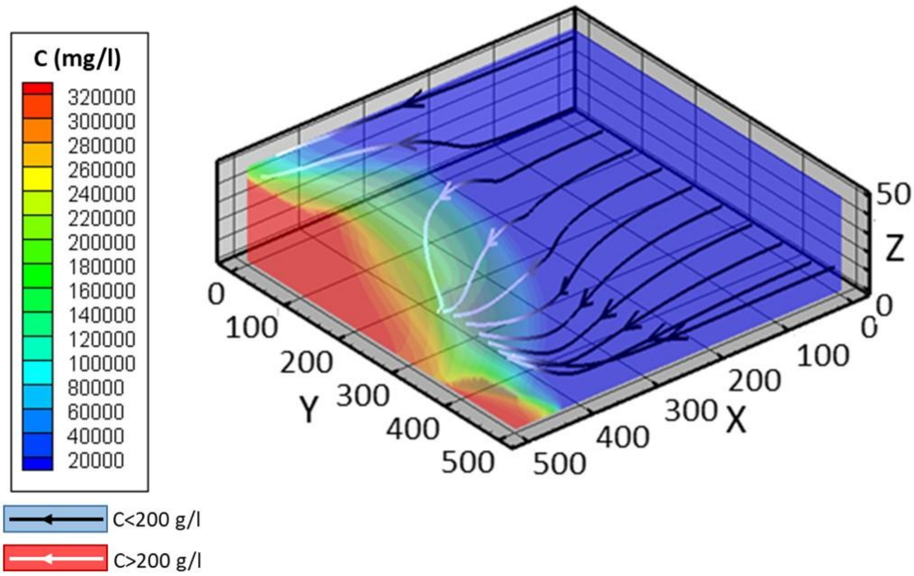
A typical fresh-saline water interface in a coastal aquifer is characterized by saline-water circulation below the interface and fresh-water flow above the interface. Both flows are perpendicular to the interface. The configuration and flow patterns adjacent to two separate saline lakes are more complicated. For example, the Dead Sea northern basin and the evaporation ponds of the Dead Sea Works separated during the 1980s into two adjacent lakes. The northern basin water level is dropping by 1.1 m/yr and the southern evaporation ponds level is increasing by 0.2 m/yr as a result of anthropogenic operations of the Dead Sea works. In this study, we numerically simulate the dynamics of the fresh-saline water interface in a coastal aquifer of a lake that is divided due to its water level drop into two adjacent lakes with different water levels. Streamlines parallel or semi-parallel to the interface are significant. Due to this flow field, the fresh-saline water interface intrudes landward adjacent to the high water level saline lake (evaporation ponds) and is pushed lakeward adjacent to the lower saline lake (Dead Sea). Electrical conductivity monitored in boreholes located close to the water bodies show this behavior in the Dead Sea coastal aquifer.



Deep Learning-Based Estimation of Actual Evapotranspiration to Support Irrigation Management

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Water demand is expected to increase by 55% globally between 2000 and 2050, mainly for manufacturing, electricity, and domestic use (OECD, 2012). This change will leave a small scope for increasing water for agricultural use, and therefore, it is imperative to improve agricultural water use efficiency. A precise, yet affordable, method to estimate crop water consumption, or crop evapotranspiration (ETc), throughout the growing season will contribute to improving irrigation management and water use efficiency. One such common method, used by farmers for day-to-day irrigation management, is the FAO-56 Penman-Monteith equation (FAO-56; Allen et al., 1998). FAO-56 requires basic meteorological and vegetation variables and can then be validated and calibrated against actual ETc measurement using the Eddy Covariance (EC) method. Recent technological developments have led to widespread adoption of EC systems that provide accurate, rich, and high-temporal resolution ETc data. Parallelly, intense research in machine learning has led to the creation of advanced models that can exploit such data and derive a precise estimation of ETc using standard meteorological and vegetation variables.

The aim of the study was, in the first phase, to develop an algorithm to fill gaps of several days in EC measurements given meteorological variables and the ETc values of neighboring days, to tackle malfunction of EC sensors, which leads to data gaps. In the second phase, the goal was to create a generalized model to estimate ETc in a specific crop and region based on EC measurements from previous years, for irrigation purposes.

For the first phase, we compiled a database consisting of EC measurements of various crops (tomato, cotton, and wheat) in different places in Israel, along with meteorological variables. A unique Deep Learning (DL) technique was developed and trained on the database (Richard et al., 2020). The DL method showed a significant 13.5% decrease in RMSE (root mean square error) and a smaller standard deviation compared with the prevalent gap-filling method (Fine et al., under review), indicating that it could be helpful for research scientists using EC systems. For the second phase, multi-layer perceptron neural networks were trained on EC measurements of two fields of processing tomato in Hula Valley, from 2019, along with meteorological variables taken from a nearby meteorological station. During 2020, our daily ETc models showed better performance compared with FAO-56 (RMSE of 0.68 mm vs. 0.9 mm, relative to EC). Concurrently, an irrigation experiment was conducted, where a mobile application, embedded with our models, was used by the farmer. Our irrigation method was compared with the 'gold standard' irrigation practice (i.e., guided by an irrigation expert and soil sensors for feedback). Both techniques resulted in similar yield and water use efficiency.

These results are encouraging given the high availability and ease of use of our suggested tool. This study demonstrates the potential of using advanced DL techniques, together with high-quality data acquired from agricultural fields, to better quantify crop water consumption and perhaps save water.

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MOF/GO Nanohybrid Incorporated Polymeric Hollow Fiber Mixed Matrix Membranes Demonstrating Efficient Removal of Heavy Metals from Contaminated Lake Water

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The rapid industrialization has resulted in the contamination of water bodies with toxic heavy metals, such as copper, arsenic, and lead. It has become a significant concern because the contaminated water, if consumed leads to several diseases, particularly organ disorders. Therefore, there is a need to treat these polluted water sources. In this regard, the removal of toxic heavy metals from water sources using membrane technology has been an attractive research area in recent years. In particular, the one-step adsorption-ultrafiltration membrane separation process is presently preferred water purification method since it is cost-effective, efficient and less prone to fouling. In this process, the polluted water is passed through the adsorptive ultrafiltration membranes, which perform the adsorption and filtration in a single step. In the present study, novel MOF/GO nanohybrid incorporated polyethersulfone (PES) hollow fiber mixed matrix membranes were prepared, which showed favorable surface morphology, functionalization with oxygen-enriched surface groups, improved hydrophilicity, and negatively charged surface. The adsorptive membranes showed remarkably high pure water flux (346.4 ± 11.2 $L/m^2/h$) and flux recovery (95.7%) for the HFMs embedded with 0.5 wt. % MOF/GO nanohybrid. The adsorption capacity of these HFMs was 66.4 ± 3.2 mg/g and 86.4 ± 4.3 mg/g for copper and lead, respectively. Significantly, high removal of copper (94.5 ± 1.2%) and lead (97.8 ± 1.1%) was also observed. These novel adsorptive HFMs were easily regenerated to reuse them for 5 filtration cycles. These HFMs showed preferential removal (>50 %) of these heavy metal ions from the mixture of different ions. Therefore, with these results, this study presented a novel and potential hollow fiber membrane material for the efficient separation of heavy metals from water bodies.

A Two-Point Titration Method for Determining the VFA Concentration Trend in Anaerobic Digestion

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A new analytic approach is presented for determining the total volatile fatty acids (VFAT) concentration in anaerobic reactors. The approach relies on external determination of the inorganic carbon concentration (CT) in the analyzed solution, along with two strong-acid titration points. The CT concentration can be determined by either a direct analysis (e.g. by using a TOC device) or by estimating it from the recorded partial pressure of CO_2(g) in the biogas (often a routine analysis in anaerobic digesters). The titration is carried out to pH~5.25 and then to pH~4.25. The two titration results are plugged into an alkalinity-mass-based equation and then the two terms are subtracted from each other to yield an equation in which VFAT is the sole unknown (since CT is known and the effect of the total orthophosphate and ammonia concentrations is shown to be small at this pH range). The development of the algorithm and its verification on four anaerobic reactor liquors is presented, on both the raw water and on acetic acid-spiked samples. The results show the method to be both very accurate (±~1% of the expected value) and repetitive when the total orthophosphate and ammonia concentrations are known, and fairly accurate (±~5% for VFAT>5 mM) when these are completely neglected. PHREEQC-assisted computation of CT from the knowledge of the partial pressure of CO_2(g) in the biogas (and pH, EC and temperature in the liquor) resulted in a very good estimation of the CT value (±3%), indicating that this technique is adequate for the purpose of determining VFAT for alarming operators in case of process deterioration and imminent failure.

The Influence of Surfactant-Application Method on Remediating Treated Wastewater Induced Soil Water Repellency

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Soil water repellency is a common feature of dry soils under permanent vegetation and drought conditions. Soil-water hydrology is markedly affected by soil-water repellency as it hinders infiltration, leading to enhanced surface runoff and soil erosion. Although this phenomenon was primarily ascribed to sandy soils, it has been observed in loam, clay, and peat soils in dry and humid regions. One detrimental effect of soil water repellency on plants is the reduction of soil water availability that stems from the non-uniform water retention and flow in preferential pathways (gravity-induced fingers) with relatively dry soil volume among these paths. It was recently discovered that prolonged irrigation with treated wastewater, a widely used alternative in Israel and other Mediterranean countries due to the limited freshwater, triggers soil water repellency which invariably resulted in preferential flow development in the field. Due to climate change events, the use of treated wastewater for irrigation as a means of freshwater conservation is expected to widen, including in countries that are not considered dry.

While most research efforts have been devoted to characterizing various aspects of water repellent soils, their alleviation, using surfactants particularly, was less studied under wastewater irrigation. Results of laboratory and field studies on the effect of nonionic surfactant application to water repellent soils showed that the surfactant application method can either enhance or extenuate the occurrence of preferential flow pathways and non-uniform moisture distribution. We investigated the efficacy of two surfactants application to remediate hydrophobic sandy soils. We found that the application of aqueous surfactant solution to the surface of water-repellent soil, the commonly used remediation method, formed finger-like plumes similar to those obtained for water application to water repellent soils. Bulbous-like plumes were formed when the soil was premixed with the aqueous surfactant solution before water application. These findings from both lab and ongoing field studies will be presented and discussed at the conference.

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Electrochemical Biosensor for Rapid Detection and Quantification of Microcystins in Surface Waters

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Microcystins are a group of toxic cyclic heptapeptides produced by common cyanobacteria. The accumulation of microcystins in water reservoirs is an emerging worldwide problem. Exposure to microcystins is mainly associated with hepatotoxicity and carcinogenesis and leads to both acute and chronic damages. Microcystin-LR (MC-LR), the most common microcystin, accounts for most of the reported poisonings and is considered an imminent threat to human and animal health. Consequently, stringent regulation has recently been imposed by the World Health Organization (WHO) limiting the allowed MC-LR concentration in drinking water to <1 µg/L and a maximal daily intake of 0.04 µg/kg body weight. Current methods for MC-LR detection generally rely on chromatography coupled with mass spectrometry requiring bulky and expensive equipment, highly trained personnel and labor-intensive preparation steps. Therefore, there is an urgent need for an affordable, on-site diagnostic tool providing a rapid quantitative determination of MC-LR in surface waters.

We have developed an electrochemical biosensor for MC-LR detection that is based on the transduction of bimolecular binding into an electrochemical signal using specific antibodies as biorecognition elements and an electrochemical (EC) cell as the transducing element. We have developed a biochip to be used as an EC cell with a chamber for biosensing measurements, using low cost, and routinely employed microfabrication techniques. We have demonstrated the feasibility to specifically detect low MC-LR concentrations by applying a highly sensitive electrochemical impedance spectroscopy (EIS). Herein we present preliminary measurements of MC-LR electrochemical detection demonstrating a LOD of 3 ppt (parts-per-trillion) and a linear range between 0.1 µg/L to 3 µg/L MC-LR. We further characterize the electrochemical response of the different sensor components and generate a calibration curve for the impedimetric immunosensor.

Arrhenius Energy Barriers and Pre-Exponential Factors for the Transport of Monovalent Anions Through Dense Polyamide Membranes

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Eyring's transition state theory can be applied to describe ion transport through dense polymeric membranes using an Arrhenius-type equation for the ion permeability. In this work, we used a custom-made diffusion cell to measure the permeability of five monovalent anions (i.e., fluoride, chloride, bromide, iodide, and nitrate as sodium salts) at four different temperatures (25, 30, 35, and 40°C) in order to extract the energy barrier and pre-exponential factors for the anion transport from a linearized Arrhenius plot. These parameters can elucidate molecular-level mechanisms that underlie the transport. Our results show a good correlation between the Stokes radii of the anions and the Arrhenius parameters (Figure 1). As the Stokes radii reflect the actual hydrated size of the anions in solution, we relate our obtained correlation to the ability of the anions to undergo partial dehydration during their transport. More specifically, an anion with larger hydrated size is expected to face a higher energy barrier when penetrating through pores of similar dimensions due to the energy required to adjust the hydration shell. Our measured pre-exponential factors, which describe the theoretical maximum permeability of the anions, indicate that this permeability is independent of the ion hydrated size, supporting the notion that ions penetrate the dense membrane in a partially dehydrated form.

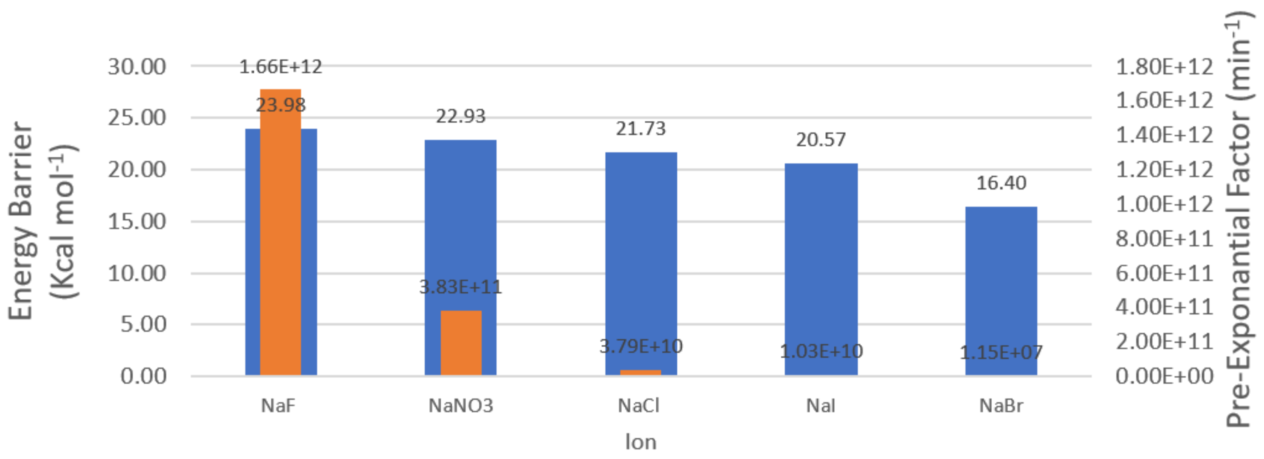

Figure 1. Energy barriers (Blue bars) and pre-exponential factors (orange bars) for the transport of different sodium salts (i.e., fluoride, nitrate, chloride, iodide, and bromide).

Effect of UV-LED Wavelength and Intensity on *E. coli* Inactivation Kinetics

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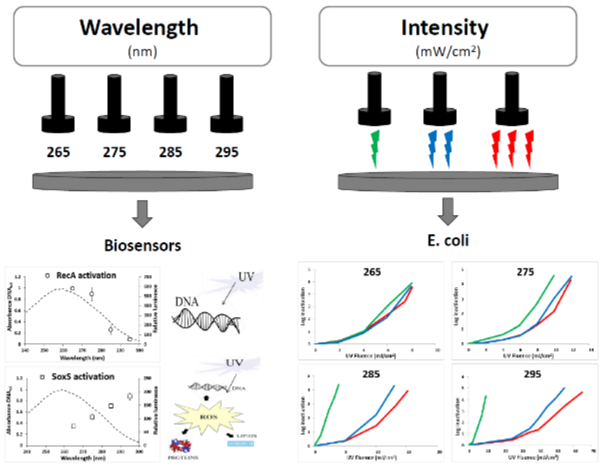
UV disinfection efficiency depends on the UV dose, which is defined as the product of the incident irradiance (fluence rate) and exposure time, corrected by factors such as water absorbance and reflection. It has been reported that the same time-dose reciprocity may not apply to microorganisms when exposed to different light intensities. For example, *E. coli* showed higher UV inactivation when exposed to a higher UV intensity over a shorter exposure time, for a traditional LP mercury lamp (Sommer et al. 1996). This effect was attributed to repair enzymes in the cell that were impaired more severely by the high average incident irradiance.

UV-LEDs, as a new technology, have some limitations, such as low power and energy efficiencies. Its low irradiances might affect the expected time-dose reciprocity as described above. Furthermore, LEDs enable tuning the wavelengths, with each wavelength possibly exhibiting a different time-dose reciprocity. Each wavelength might also affect the overall metabolic mechanisms of microorganisms differently. For example, Song et al. 2016 showed that different wavelengths can induce different stress mechanisms due to direct or indirect damage to cell components.

This research focused on two aspects; first to examine the time-dose reciprocity on *E. coli* inactivation using four different wavelengths (LED_{265}, LED_{275} LED_{285}, and LED_{295}) under different average incident irradiances. Our research implies that the microbial inactivation kinetics determined at LED_{265} is not influenced by fluence rate and exposure time for a given UV fluence. Meaning that LED_{265} does not follow the time dose reciprocity law in contrast to LP; where higher inactivation has been observed when achieving a UV fluence using a high irradiance and low exposure time combination. Moreover, when wavelength increased to LED_{275}, LED_{285}, and LED_{295} high microbial inactivation kinetics has been observed for a given UV fluence when using a low fluence rate coupled with a high exposure time. This trend is generally the opposite trend that has been observed for LP (254 nm).

Since the literature does not provide any explanation for the inactivation kinetic differences between the wavelengths and the intensities, a second aspect was examined; to investigate the UV intracellular damage mechanisms for each LED wavelength by using bioreporters. RecA was used as an indicator for bacterial DNA damage and SoxS used as an indicator for oxidative stress. For shorter wavelengths (LED_{265}) higher DNA damage was observed, more intensive DNA damage caused by activation of the RecA promoter, and prolonged expression of RecA. For long wavelengths (LED_{285} and LED_{295}) higher oxidative stress was observed. These microbial damage mechanisms can shed light on the differences between the *E. coli* inactivation under different average incident irradiances.



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Fate and Toxicity of Micro- and Nano-Plastic in the Aquatic Environment

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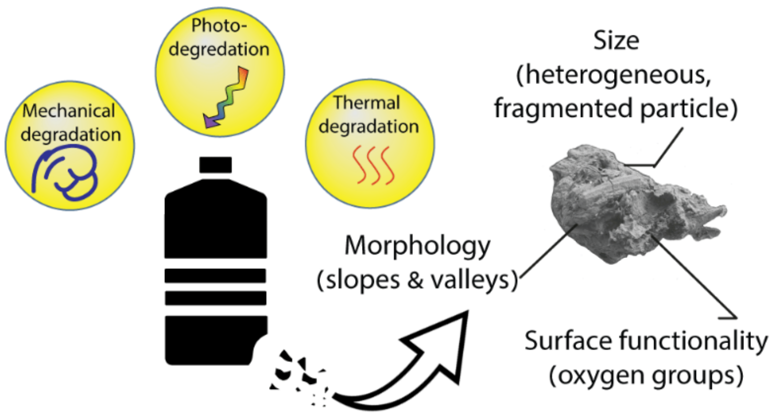
Presence of micro- (<5 mm) and nano- (<100 nm) plastic (MPs and NPs) is increasingly reported all around us: in tap and bottled water, food and air - form the Arctic to the deep ocean.[1,2] Continual environmental weathering, shapes the MP and NP into unique particles with shredded, oxidized surface area and change their initial nature as a pristine plastics (Figure 1). According to the abundance in the environments, scientist investigating a great effort to evaluate potential exposure and co-responding toxicity of plastics for the environment and human health.

Studies on MP and NP focuses on their fate, transport, and toxicity in the environment usually use a spherical polymeric beads[3] which poorly represent environment plastics which mostly appear as shredded and oxidized fibers and fragments[4–6]. Using a beads model, we may draw a wrong conclusions regarding the potential risk of MPs and NPs. Therefore, an improved model for MPs and NPs for fate, transport, and toxicity studies is needed.

Due to their unique surface chemistry, MP's and NP's can adsorb dissolved hydrophobic molecules from the environment and act as vector of environmental pollutants into our body. Despite the increasing concern, there is no solid evidence show the potential harm of environmentally - relevant MP's and NP's to our health.

In our study, we demonstrate the first steps toward the development of engineered MPs and NPs with high environmental-relevancy, which can be used by researchers around the globe. Specifically, we use a top-down, accelerated lab approach to imitate typical environmental conditions of plastics. Additional step of the study is to assess their adsorption potential toward target organic micropollutants such as Triclosan (commonly use chemical can be detected in the environment), and test their toxicity using a human colon cell line (Caco2) in the presence and absence of adsorbed pollutants.

We find that the surface morphology and surface chemistry of environmental plastic can by mimicked in lab conditions to create environmentally relevant MP's. Also, we show that surface functionality, in particularly Carboxyl groups, drives interaction and increase adsorption capacity. Then, we also find that Caco2 cells been highly effected by joining effect of MP with adsorbed Triclosan. To sum up, our holistic approach includes degradation, adsorption, and toxicity of human cells indicate the importance of the plastic life cycle when accounting for environmental risks and can significantly bridge the knowledge gap of the hidden risks of MPs and NPs to humans.



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Quantifying Sources of Uncertainty of Managed Aquifer Recharge with Desalinated Seawater via Stochastic Numerical Modelling of Flow and Transport

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In the last decade seawater desalination has become an important practice in (semi-) arid regions. It aims to close the annual gap between water demand of a constantly growing population and the supply-capacity of the natural water resources in a region/country. An example of such natural resources are coastal aquifers, which in many countries (e.g. Israel) maintain an important water source due to its relatively low production price. However, aquifer production has its limitations as sustainable annual production depend on recharge volumes of previous years, which depend on climate variability (e.g annual rainfall).

In order to account for the above-mentioned limitation, managed aquifer recharge (MAR) sites have been developed in the last century all across the globe. An example of a successful one, is the Menashe-Streams MAR site in Israel, in which an average of 10 million m^3 of runoff water are recharged annually since the late 60s.

In 2015, a new source of recharge water appeared in the Menashe MAR site: a certain volume of water is injected (disposed) from the Hadera desalination plant into one of the infiltration ponds in the Menashe MAR site mainly due to maintenance campaigns in the National Water Carrier. These disposal events and following recharge processes have been monitored and investigated by Ganot et al (2017). Ganot et al (2018) modelled groundwater flow and transport, using stable water isotopes of the reverse-osmosis desalinated seawater (DSW), as conservative tracers, to show the propagation of the DSW plume through the aquifer.

The growing availability of DSW in the last decade in Israel, created circumstances for "returning water back to nature" in order to revive streams and ecosystems that have been neglected and dried out continuously during the pre-desalination years. One of possible methods is the introduction of access DSW as a source for MAR site. In order to assess such schemes, there is a need for deeper investigation of the mixing mechanisms and the chemical reactions involved.

In order to design a comprehensive MAR scheme there is a need for predictive numerical modelling that would account for the uncertainty involved in such modelling. The two main sources of uncertainty in predictive modelling of MAR scenarios: (1) the variability of annual climate scenarios (2) the heterogeneity of the subsurface structure. In this work, we investigate and evaluate the importance of those uncertainty sources.

We use Menashe as our case study. Following Ganot et al. (2018), update and validate an existing deterministic flow model (with daily head, recharge and production data) and use stable water isotopes of the DSW as a tracer in the mixing model (with isotope fraction data from a biannual sampling campaign). We run and compare 4 modelling approaches, which are the possible combinations of deterministic or stochastic (geostatistical) subsurface realizations combined with deterministic or stochastic future runoff-recharge scenario. Annual recharge from runoff in prediction years is randomised and based on historical recharge values. Recharge of DWS is, however assumed constant in all prediction years in order reduce uncertainty. Prior to that, the characteristics for geostatistical realizations of the subsurface have to be established, mainly the horizontal correlation length of the least permeable material (i.e. clay), this is done via calibration process. The results of this work can give an indication of what characteristics should be more heavily regarded by planning teams of future sites.

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Developing a Tool for the Site-Independent Assessment of the Water Quality at the Extraction Element for Potential Soil Aquifer Treatment Sites

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With the PRAMOSAT tool, a practical and fast method for the assessment of operation of any potential soil aquifer treatment (SAT) site is presented. A simplified Hydrus 1D hydraulic and biogeochemical model is employed and coupled to Microsoft Excel to make an easy-to-use tool. The tool provides an easy Excel-interface for input and output control; the GUI of Hydrus 1D doesn't have to be used. Moreover, the output control allows the user to view the data with the help of interactive diagrams for both time- and location-based analysis. Additionally, overall performance criteria are calculated. In the model, first order reactions of nitrification, de-nitrification and DOC-oxidation are assumed as well as nonlinear adsorption of the relevant species. Because the dynamics of the soil gas phase - and therefore the oxygen availability for different reactions - could not be modelled directly, another method was developed to account for the influence of oxygen availability on reaction rates or reaction rate constants, respectively. Several aspects that may influence the overall reaction rate constants were accounted for. Chemical parameters (e.g. raw water quality, treatment level), geo-hydraulic parameters and operational variables (wetting / drying cycles, ponding depth) are used as input for an adapted multiple linear regression to compute reaction rate constants before the simulation. This allows for a site independent assessment of the treatment performance, which is typically only possible by extensive modelling or laboratory experiments. The calibration of the adapted multiple linear regression was done by utilizing data from five different laboratory experiments. By calibrating the tool on different datasets, the applicability for any potential SAT-site is given. It could be seen that the tool performs well, especially for the assessment of the quasi-steady state. In addition to the prediction of water quality at the capillary fringe, a simple mixing calculation can be conducted with the tool to assess the water quality at the extraction element.

A Novel Method for Dynamic Control of the Trade-Off Between Ionic Perm-Selectivity and Solvent-Permeability in Microfluidic Devices

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The ion-permselectivity of a medium (e.g., membrane, nanochannels) to the transport of ions of a given charge sign is an intriguing physical phenomenon. Its potential applications in lab-on-a-chip devices include electrochemical separation, e.g., direct seawater desalination and purification [1], energy harvesting, e.g., reverse electrodialysis and streaming current/potential [2], as well as biomolecule preconcentration for enhanced biosensing in lab-on-a-chip format [3]. Interestingly, a medium with a pore size of several orders of magnitude larger than the ions becomes ion-permselective due to ion interaction with the pore surface charges. Reduction of the pore size to similar dimensions as the Debye length, cause an overlap of the electric-double layers, which leads to the exclusion effect of co-ions and the preferential permeability of counter-ions (i.e., ions of a charge opposite that of the surface) and gives rise to a Donnan potential within the pore. However, all ion-permselective mediums exhibit a trade-off between ionic-selectivity (i.e., which molecules can pass through) and solvent-permeability (i.e., hydrodynamic resistance and throughput) [4]. Herein, we studied the performance (i.e., ion perm-selectivity, solvent-permeability) of a single tunable nanochannel (made of soft deformable elastomer) by varying the channel cross-sectional dimension from micro-to nano meter scale in a continuous manner, thereby, enabling its optimization and dynamic operation [5]. We investigated the nanochannel integration within a single microfluidic main channel by examining the concentration-polarization phenomenon, and in particular the corresponding limiting current. An extension to an array of such tunable nanochannels connected in series was also investigated and demonstrated the ability to control the location of preconcentrated plugs of bioparticles (e.g. biomolecules, bacteria) as well as to enhance the parallelization of diagnosis.

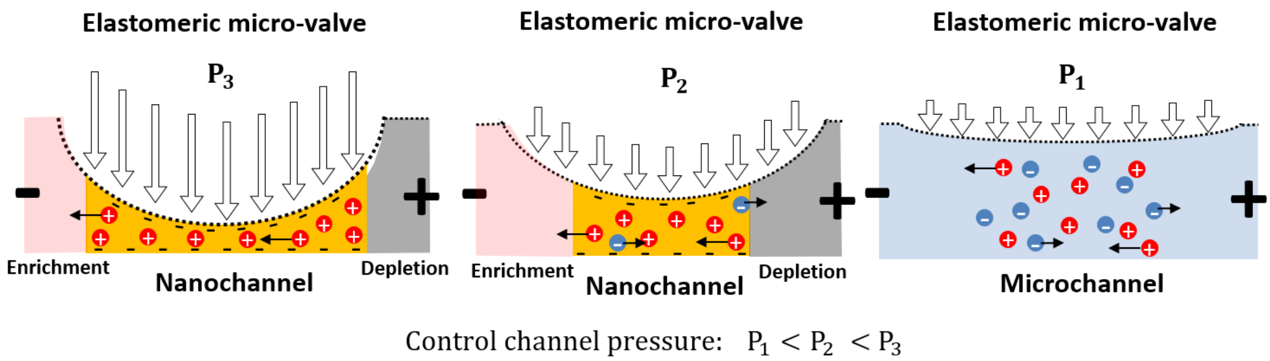

Figure 1: schematic description of the concentration-polarization phenomenon for three different applied control channel pressures on an elastomeric micro-valve.

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Interaction of Graphene Oxide with Cell Membrane Models: Effect of Membrane Properties

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Carbon-based nanomaterials (CBNs) hold great interest in many industrial applications not only due to their unique physical and electrical properties but also for their high biocompatibility compared to other engineered nanomaterials (ENMs). One of the highly investigated CBNs is graphene oxide (GO); a two-dimensional (2D) nanomaterial with exceptional surface area to volume ratio, high thermal and electron conductivity and mechanical strength. Not only for its extraordinary properties is GO sought after; stable in aqueous solutions, GO is an ideal precursor for graphene which in turn is a precursor for many other CBNs such as carbon nanotubes and fullerenes. This combination of stand-alone desirable properties alongside being the main starting point in the production of other CBNs results in the high probability for environmental presence and possible contamination of GO. The wide use in GO raises the need to examine its interaction with living cells that may occur in biotechnological applications or once GO is leached out to the environment following use.

Over the past couple decades, liposomes—or lipid bilayer bound spherical vesicles—have proven to be an effective model for cell membranes, mimicking not only the biological membrane structure and composition, but also the shape and curvature of the biological cell. Since liposomes are soft matter by definition, they possess a fragile nature, threatened by mechanical or physical impact induced by environmental conditions or by interacting with other materials, or GO nanomaterial in our case. However, physical interaction of liposomes (and real cells) with surrounding constitutes is highly dependent on its own physicochemical properties. For example, larger liposomes may internalize small nanomaterials, while smaller one may experience loss of membrane integrity.

Our work focuses on liposome-nanomaterial interactions and the role of nanomaterial properties[1,2] and more over the properties of the liposome itself. Specifically, we find that nanomaterial shape and surface chemistry highly affecting the interaction. Furthermore, we find that liposome size changes the kinetics of interaction, but not the overall loss of membrane integrity. Liposome charge highly affects the extent of interaction, but the nature of interaction (liposome adsorption onto the GO surface) remains. By investigating the interaction of liposomes with GO, this fundamental study can bridge the knowledge gaps of GO environmental impact and identify of critical liposome properties that govern the extent of this highly probable interaction.

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Multifunctional MoS_2-Supported Nanocomposites for Water Decontamination

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Pollution of drinking water sources by a variety of inorganic compounds has created a need to develop more efficacious removal technologies to ensure contaminant-free and clean water. Conventional methods for water decontamination involve physicochemical separation and chemical oxidation. Yet, physicochemical separation lacks pollutant selectivity and produces toxic waste streams,[1] while chemical oxidation requires intensive energy and chemical inputs and may form transformation byproducts.[2]

Nanotechnology-based approaches are increasingly explored as an alternative for decontamination methods. Many new technologies leverage the reactive and tunable properties of nanomaterials for increased cost-efficiency, selectivity toward priority pollutants and energy/chemical sustainability.[3] Through manipulation of material size, morphology, and chemical structure, nanomaterials can have exceptional adsorptive and catalytic properties for water decontamination.

Molybdenum disulfide (MoS_2) 2D nanosheets stand out as a promising advanced-material for water decontamination. MoS_2 act as an efficient and selective adsorbent for the removal of heavy metal ions (e.g., Hg^{2+} and Ag^{+}) through strong Lewis acid and base soft−soft interactions with sulfur atoms in the MoS_2. Affixing MoS_2 nanosheets onto a platform is essential to minimize the risk of nanomaterial release into the environment. In the context of nano-assisted water treatment technologies, affixing nanomaterials onto active platforms such as granular activated carbon media may enable multifunctional decontamination. Activated carbon is the predominant adsorbent used widely in water treatment today, due to its high affinity for organic pollutant adsorption, but lack affinity to inorganics. MoS_2 affixed onto activated carbon, enhances overall decontamination performance by enabling simultaneous adsorption of organic and inorganic pollutants.

In this research, we examined the tunable water decontamination capabilities of MoS_2 nanosheets grown on activated carbon (MoS_2@AC) in a hydrothermal method for the adsorption of organic (methylene blue) and inorganic (mercury) contamination from water. In a batch experiments, we demonstrated the high mercuric adsorption potential of MoS_2@AC (~2000 mg Hg/g MoS_2) in the absence and presence of methylene blue. Furthermore, methylene blue was removed in similar rates by MoS_2@AC and pristine AC. These results suggest that while MoS_2 is active and enable the removal of mercury, its presence does not interrupt the activated carbon activity. Moreover, we will investigate the practical application of this nanocomposite by evaluating the effect of background ions on the mercuric adsorption capacity. We also assess the nanomaterial leaching during operation in various conditions to demonstrate the reuse capabilities and to assure safe and durable use, in a lab-scale reactor. Overall, results from this study will provide a proof-of-concept for water treatment enhancement by 2D nanomaterials.

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Applying Transition-State Theory to Explain Water-Ion and Ion-Ion Selectivity in Polyamide Membranes

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Polyamide reverse osmosis (RO) and nanofiltration (NF) membranes are at the core of water purification and desalination processes. While these membrane processes have achieved substantial industrial success, the fundamentals underlying molecular transport in these membranes are not well established. The conventional solution-diffusion model, frequently used to describe transport in dense polymeric membranes, has limited capability to elucidate molecular-level phenomena that govern water and solute permeation in these membranes. Instead, the transition-state theory (TST), which is rarely used to describe transport in synthetic membranes, can highlight important features of molecular diffusion under confinement. More specifically, experimental energy barriers and pre-exponential factors from Arrhenius-type equation can provide molecular-level interpretation of solute transport through these membranes in terms of enthalpy and entropy changes, respectively, that occur during the transport. In this work, we explore energy barriers and pre-exponential factors for ion and water transport in dense NF and RO membranes and show correlations between these parameters and inherent properties of different ions (i.e., ion bare size and Stocks radius) and water (i.e., size), highlighting molecular mechanisms that govern water-ion and ion-ion selectivity. Notably, we demonstrate that the membrane water-ion and ion-ion selectivity are governed by entropic (steric effects, Figure 1a) and enthalpic changes (ion dehydration, Figure 1b).

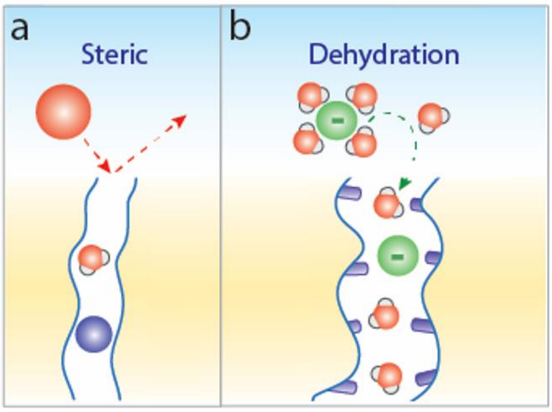

Figure 1. Illustration of two governing mechanisms that affect the Arrhenius parameters for solute transport in membranes: (a) Steric effect- based on molecular size and shape, and (b) dehydration- detachment from all or part of the hydration shell

Natural Electron Mediators Induce Current in Micro Photobiological Fuel Cells

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One of the promising green energy solutions is the usage of microbiological fuel cells (MFCs). MFCs are composed of bacteria which produce electrical current by reducing the anode in bio electrochemical cells. This reduction can be done directly by natural redox active proteins and/or by pili in the outer membrane. Addition of external electron mediators such as ferricyanide, quinones or phenazines can assist in increasing the current. Although MFCs seem to be a cheap promising solution, their large-scale cultivation requires large amounts of sugar sources and may be considered as environmental pollution themselves. Photo-microbiological fuel cells (PMFCs) use cyanobacteria or other photosynthetic systems. In addition to electron transport mechanisms that exist in bacteria, cyanobacteria can also produce electricity based on their photosynthetic pathway as electron source. Since they can produce glucose doing photosynthesis, they are cheaper to grow. They can also be found in nature in very high quantities in oceans and lakes.

Most of the PMFCs are based on the model species Synechocystis. This raised the question whether other cyanobacteria can be exploited? Addition of Ferricyanide as electron mediator managed to induce the photocurrent. However, it is toxic to the cells and decrease their viability.

In our work, we produced photocurrent from various cyanobacterial cells which grow in fresh and sea waters. We have also found that addition of the natural non – toxic electron mediators NAD^+ and $NADP^+$ increase the photocurrent in PMFCs. Quantification of this effect was done using screen printed electrodes.

Green Roof Stormwater Mitigation Efficiency Under Mediterranean Climate Conditions

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As global population is becoming more and more urbanized, built impervious surfaces continue to increase, irreversibly changing the natural hydrological cycle. As a consequence, rainfall events turn into heavy surface runoff that can overwhelm existing city infrastructure and its receiving waters. Green roofs, a vegetated roof cover, are emerging as a new simple and efficient tool to tackle the challenge of rapid urbanization. This is an important component of the water sensitive urban design initiative, recognizing stormwater as an urban resource and aiming to restore natural flow patterns. Extensive experimental data confirm that green roofs are able to significantly mitigate urban stormwater. By turning rooftops into pervious areas, green roofs are able to drain, detain and slowly release stormwater, reducing existing stress on local man-made hydrological systems. However, recent research efforts concentrate mainly on temperate climates where precipitation is distributed along the year, while research considering Mediterranean climate regions is mostly limited. As green roofs systems are implemented more and more, the need for a thorough understanding of the climate specific hydrological responses is imminent. This research aims to develop a temporal model to examine the different factors affecting the hydrological balance of green roofs and the way to mitigate them (e.g. vegetation, evaporation and evapotranspiration, substrate, long dry summers). The model will be developed with a final aim to simulate runoff dynamics from green roof systems under Mediterranean conditions. The local green roof model to be developed is envisaged to allow for better understanding of the benefits and limitations of utilizing this tool locally.

Simulating Accumulation of Low-Conductivity Layer in Streambeds Under Moving-Bedform Conditions

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Ben-Gurion University of the Negev

Recent studies have shown that under moving-bedform conditions in streams, a low-conductivity layer is formed below and within the region of bedform scour near the surface of the stream bed. This clogging layer is the result of the combination of fine-particle deposition due to hyporheic exchange flux (HEF) and erosion due to bedform scour. The layer accumulates over time as a result of the passage of many bedforms. Previous modeling studies of bedform-induced HEF have used a frame of reference that moves downstream with the bedform. This approach can be useful when studying the porewater flow induced by a bedform and the transport of solutes due to this flow. However, by definition it cannot simulate the accumulation of fine particles at a given location over time as a modeling outcome. Moreover, the above approach implies that the domain shape imposes a constant flow field on every point in the domain, while in reality each point is subject to a flow field that changes with the shape of the bed. In order to address these gaps, a simulation is presented which captures these factors using a stationary frame of reference. Passage of successive bedforms is represented by varying the shape of the top boundary of the domain. To our knowledge, this is the first simulation of bedform-induced HEF to use a stationary reference frame with a domain that considers bedform shape. Simulation results successfully reproduce experimental observations of the development of the low-conductivity layer near the scour zone.

A Numerical Study of the Role of Aquifer Flow in the Dissolution of CO_2

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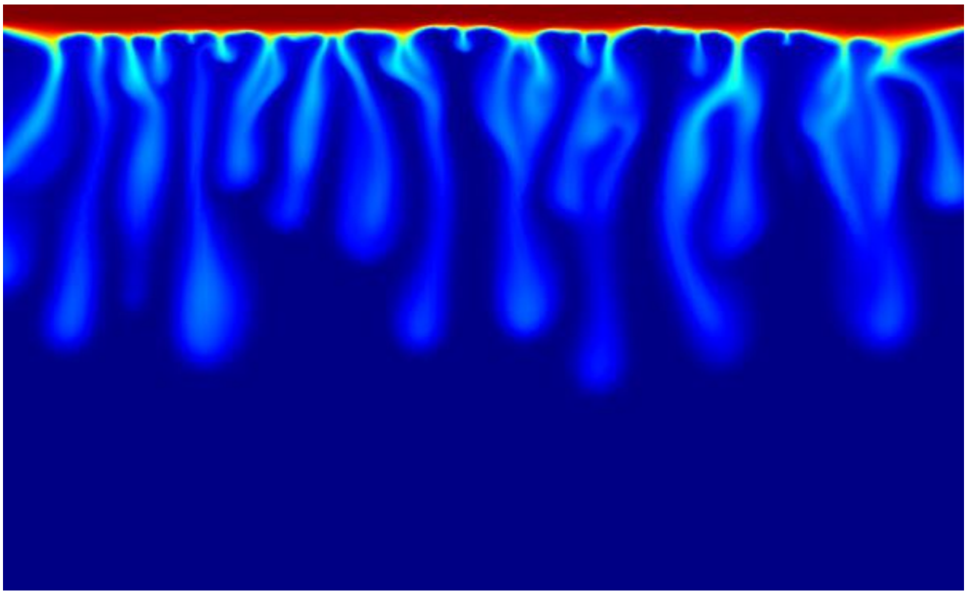
The storage of carbon dioxide (CO_2) in deep saline aquifers is regarded as a promising technology for the reduction of greenhouse gas emissions. One of the most important mechanisms immobilizing the CO_2 is its dissolution in the aquifer's brine. When the CO_2 is dissolved into the brine, it slightly increases the density of the brine which results in unstable conditions that leads to the development of dense fingers. In the vast majority of previous studies that investigated the processes of convective dissolution of CO_2, natural groundwater flow and the associated hydrodynamic dispersion were neglected. Analytical and numerical studies suggest that hydrodynamic dispersion and groundwater flow decrease the CO_2 dissolution rate [1]. A recent study, done by our research group, involved a series of experiments in a quasi-two-dimensional bead pack with horizontal flow, using a CO_2 analogue [2]. The study results display a good agreement with previous studies regarding the effect of horizontal flow on finger morphology. However, in contradiction to findings of the former studies, results suggest no significant dependence of the dissolution rate on the horizontal flow velocity. The main objective of the presented study is to explain the discrepancies between the literature and the experimental study by providing insight into the dissolution mechanisms via numerical simulations. To do so, a representative numerical model was set up and the two-component analogue-water system of equations was solved. The simulations were able to reproduce the convective fingers observed in the experiments and displayed the same trends found in the experimentally-measured dissolution flux.



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Seawater Flow Patterns in Coastal Aquifers: Nitzanim (Israel) Case Study

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Israel coastal aquifer is a significant source of freshwater as it supplies more than 15% of the nation's water consumption and has the ability to collect more than 350 million cubic meters of meteoric water each year [Gvirtzman, 2002]. Extensive pumping and sea-level rise expose the coastal aquifer to seawater intrusion (salinization) and may impair groundwater utilization for drinking and irrigation [Vengosh et al., 1993]. Moreover, groundwater discharge from the aquifer into the sea is a major component of nutrient and element fluxes [Moore., 2010]. Knowing the hydrological mechanisms of seawater intrusion and its circulation in the aquifer will allow predicting the sustainability of groundwater production before being overexploited ,nutrient and water flux into the sea, the flow regime of contaminates, and the movement of the fresh-saline interface into the mainland [Vengosh et al., 1999]. Our research aims to identify these mechanisms and their time scale using detailed chemical analyses of major and trace elements and radiogenic isotopes ($^{87}Sr/^{86}Sr$, $^{234}U/^{238}U$). This study may improve policymaking with respect to water resources management and add an alternative perspective regarding water-rock interaction along the coastal aquifers. The study area is in Nitzanim nature reserve, located in the south part of Israel's coastal aquifer. Samples were taken from Nitzanim shoreline and from three monitoring wells that belong to Israel Water Authority. The wells are perpendicular to the shoreline and stretch up to 500m inland. The sampling depth range was between 0 and 70 meters below the aquifer water table to provide a chemical profile of major and trace elements.

Our preliminary results show that the same elements (major and trace) can display conservative and non-conservative behavior depend on the geochemical processes. We hypothesize that this reflects the period of the interaction between the circulated seawater and the aquifer sediments. i.e., groundwater samples that correlate linearly on the mixing line present a short-time scale of water-rock interaction, while samples that lie below or above reflect longer time scales. Another assumption that we aim to prove is the dominant mechanism that governs during seawater intrusion. Previous studies showed that enrichment of some elements could be explained as a result of salinization, which monovalent cations (Na+/K+) replace adsorbed divalent ions (Ca^{2+}/Sr^{2+}) in sediments via cation exchange [Russak et al. 2010, Sivan et al. 2005]. However, the high concentration of uranium and strontium may suggest that carbonate dissolution is responsible for the enrichment of Ca, Sr, and U. In sedimentary rocks strontium predominantly found in carbonate rocks composed of calcite, aragonite or dolomite and may substitute for Ca in the $CaCO_3$ lattice. For that reason strontium, acts as chemical analog for calcium. In addition, uranium weight in carbonate rocks and specifically sand stone can be at least 0.0001% (>100 ppm) [Klepper.et al. 1959]. i.e. uranium enrichment can be explained as the chemical weathering of these minerals. Our results displays a conservative behavior of strontium near the shoreline and non-conservative (enrichment) behavior far from shore. Whereas uranium displays non-conservative behavior in all sites (enrichment). Uranium and strontium concentration in the aquifer rocks are in the same range (100-600 ppm) [Karl et a.1956] , but in groundwater, the strontium concentration is three orders of magnitude greater than uranium. Thus, any minor change of uranium concentration near the shore might look as a non-conservative behavior. The behavior of Sr and U shows that these elements respond at a different rate to water-rock interaction and can be used to track the flow paths and mixing with freshwater in the aquifer.

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The Rejection Peak Imposed by Concentration-Polarization: Theoretical Analysis and Practical Implications for Micropollutants Removal by Nanofiltration

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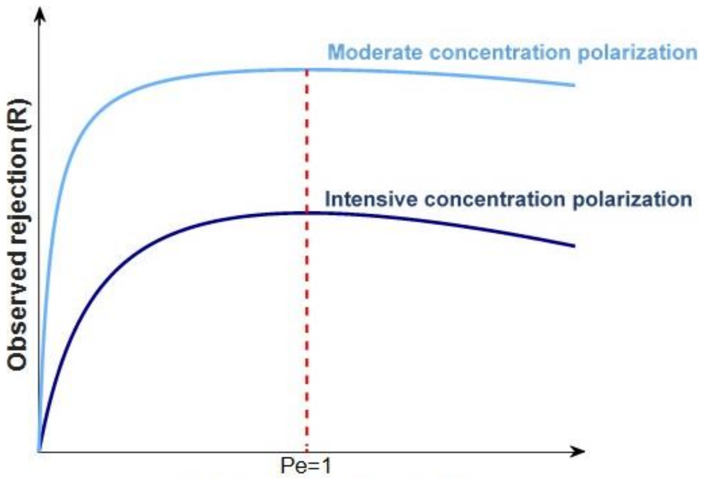
Concentration polarization (CP) is a well-known phenomenon, which adversely affect the efficiency of membrane-based separation processes. Here we studied a feature of CP that were largely overlooked thus far, revealing interesting theoretical aspects with industrial implications. We addressed the peak in the observed rejection of neutral solute, and its subsequent decline, appearing with the increase in permeate flux. Although this phenomenon was previously reported (however scarcely), a theoretical analysis focusing on the rejection peak was not performed yet, nor the phenomenon practical implications were discussed. Here, we present a simple, yet fundamental analysis of the film-model, revealing that the flux corresponding to the rejection peak equals to the mass-transfer coefficient characterizing the system. Subsequently, we indicate that the ratio of flux to mass-transfer coefficient – a non-dimensional Péclet number – emerges as a useful design criterion for pinpointing the rejection peak.

We applied this criterion in evaluating the practical implications of CP induced peak rejection for the case of organic micropollutants removal by nanofiltration membranes. The results indicated that a decline in micropollutants rejection could occur even when operating at typical operating conditions, especially when CP is enhanced by particulate fouling. In light of these findings, we discussed the effects that different operation conditions or membrane properties night induce on system design and scale-up. We tested our analysis by performing CFD simulations of pressure-driven filtration in COMSOL Multiphysics, which couples fluid-flow and solute transport physics. In addition, we simulated cake-enhanced-concentration-polarization by integrating porous-media flow physics into the CFD model. The elaborated numerical simulations agreed with the simple theoretical model and supported our predictions regarding the peak solute rejection. Subsequentially, we examined the model validity by performing a set of rejection experiments by NF membranes. First, we tested the removal of a divalent salt similar to prevalent organic micropollutants in its diffusion coefficient value, where we found an excellent agreement between theoretical and experimental results. Next, we tested the removal of Carbamazepine, and found a general agreement with the model, with a low statistical significance. The experimental results join to the numerical analysis to corroborate the ability of our analysis to predict and characterize the peak rejection, demonstrating its importance in designing NF processes for micropollutants removal.



Is It Worthwhile Using Ozone in In-Situ Groundwater Remediation? Fundamental Study on Ozone Consumption by Israeli Soils

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Groundwater pollution caused by petroleum products is one of the main water challenges in Israel. In-situ chemical ozonation (ISCO3) is a promising method for effective removal of organic contamination from groundwater. The injected ozone can directly react with pollutants in the contaminated area. As a reactive substance and strong oxidant, ozone also interacts with surrounding compounds (other than the target pollutant), resulting in accelerated consumption of ozone and lower availability for remediation. However, such reactions may lead to formation of hydroxyl radicals, which are stronger and more effective in petroleum-product degradation.

The complex, multi-phase environment of saturated zone to be treated may adversely affect the treatment efficiency, especially interaction with soil media. On the one hand, the presence of soil will directly lead to the ozone attenuation and affect the removal efficiency of target containments. On the other hand, the organic matter and metal oxides in soils will promote ozone decomposition to produce more hydroxyl radicals which improve the contaminant removal. Although the effect of soil specific parameters on ozone consumption has been studied, the interactions with the complex environment are not fully understood. This study aims to determine the main ozone consumers in soils and to estimate the minimal applied ozone dose to be delivered, which takes into account side reactions with soil, for effective design of an in-situ ozone treatment.

Three different types of soil were collected from Israel costal aquifer. Batch experiments were conducted to explain the ozone decay trend in different soils. Due to the interaction of soil components with the reactive ozone molecules, ozone consumption of different soils was found in the range of 1.5-5.6 $1/s \cdot 10^3$, higher than ozone decay in the absence of soils (0.9 $1/s \cdot 10^3$). The most active soil, Hamra, was pre-treated to account for the role of its chemical composition on the nature and extent of reaction. Pre-ozonated soil showed much less content of instantaneous ozone demand (IOD) and lower ozone consumption compared to the pristine soil, which indicated that instantaneous consumption occurred by finite consumers while the slower ozone decay might due to the catalytic reactions. We also selectively removed fractions of soil constitutes, and showed that organic matter and iron oxide highly affecting the ozone attenuation. Although presence of soil organic matter had a more significant impact on ozone decay, more hydroxyl radicals were formed during the reaction between ozone and soils' iron oxides. The effect of soil particle size was studied as well, where fine particles below 100 µm were found to be the major contributors to ozone consumption.

Column experiments were also conducted to simulate the ozone migration process in the aquifer, to estimate the amount of ozone consumed by soil, and to provide a reference ozone dosage range for the application of the ISCO3 method. Because of the high content of iron oxides in Hamra soils, the catalytic consumption of ozone in the soil column resulted in steady-dtate decomposition of 80% of applied ozone, which illustrated the necessity to characterize ozone consumption by soils in the area to be treated as a preliminary stage of in-situ ozonation processes.

Employing Transient Wall Shear Stress for Biofilm Separation in Water Distribution Systems

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Biofilms are composed of complex microflora coated with an extracellular protective matrix (EPM) made of various types of biopolymers which can form on a variety of surfaces. Biofilms are ubiquitous in drinking water systems, either in the form of thin and patchy colonies or as surface-covering multiple layers. Besides causing water taste and odor problems, it can lead to chlorine demand increase, coliform growth, pipes corrosion, and increase maintenance costs. Moreover, biofilms provide a possible habitat for hygienically relevant microbes in which they can persist and even multiply. Furthermore, when organized into biofilms after maturation, bacteria are resistant to many forms of stress, since the EPM is designed to protect the embedded bacteria from antibiotics, disinfectants, and environmental insults.

Biofilms cleaning is a complex task whose efficiency depends, besides other phenomena, on hydrodynamic effects. Researchers have shown that removal kinetics are functions of the fluid detergent velocity and of the mean wall shear stress. Moreover, other studies demonstrated a clear positive effect of an increase of the fluid shear stress fluctuation rate on the spore detachment. Therefore, in addition to providing disinfectants into the system, there is a need to disrupt the biofilm architecture, allowing more efficient delivery of the disinfectants to the cell membrane of the embedded bacteria.

In this work, an unprecedented approach is introduced for controlling biofilm growth in pipe systems. This is achieved by stimulating controlled transient waves (CTW), which introduce sudden disturbances into the system (e.g., rapid valve closure). Subsequently, intense fluid shear stresses with high fluctuation rates are generated which, in turn, induce biofilm breakage and biofilm deformation.

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השבת יסודות הזנה חיוניים מבוצה עירונית באמצעות תהליך הידרותרמי

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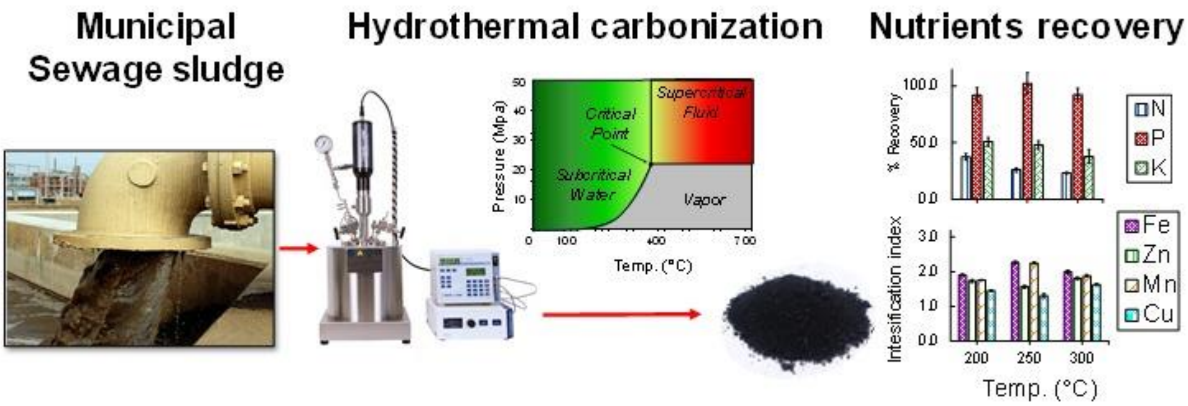
2. המחלקה למדעי הקרקע והמים, הפקולטה לחקלאות, מזון וסביבה ע"ש ר. ה. סמית, האוניברסיטה העברית בירושלים, רחובות

הגידול באוכלוסיית העולם מעלה שאלות מהותיות בגין היכולת של החקלאות לענות על הצרכים הקיומיים של החברה. חקלאות אינטנסיבית מחייבת הזנה ביסודות מאקרו (חנקן, זרחן, אשלגן, מגנזיום וסידן) לצד יסודות קורט, כגון ברזל, מנגן, אבץ ונחושת. בעוד חנקן הינו יסוד הניתן לקיבוע מהאטמוספירה, המקור העיקרי של זרחן, ברזל ושאר יסודות קורט הוא על ידי כרייה וחציבה מסלעים. הזרחן נחשב למאקרו יסוד עיקרי, מאחר והוא משתתף בהרבה תהליכים ביוכימיים בצמחים, רוב הזרחן בחקלאות מגיע לצמחים ע"י שימוש בדשנים כימיים. יצור מוגבר של הדשנים תורם יותר למחסור הגלובלי בזרחן וגורם לצמצום בעתודות הזרחן שעתידם להיעלם תוך100-400 שנה. מאחר ובמדינות מפותחות מרבית הפסולת האנושית עוברת טיפול במכונים לטיפול בשפכים (מט"ש) בתהליך המבוסס על בוצה משופעלת, רוב יסודות ההזנה שוקעים בבוצה, שמהווה אם כך משאב מרכזי למיחזור אותם יסודות. למשל, 80–90% מהזרחן הנכנס למט"ש נותר כמשקע בבוצה בריכוז משקלי של 1–5% (על בסיס משקל יבש). עדיין, השימוש בבוצת מט"ש לא מטופלת עשוי להוות בעיה ונתקל בחסמים רגולטוריים, בעיקר בשל סוגיות של בריאות הציבור. במחקר זה אנו בוחנים את יעילות התהליך ההידרותרמי, המבוסס על שימוש במים במצב תת-קריטי כמדיום לפירוק ביומסה, כטכנולוגיה להשבת יסודות הזנה שונים מבוצת מט"ש. הנחת המחקר היא שלאחר התהליך ההידרותרמי מרבית יסודות ההזנה ששקעו בבוצה יימצאו בפאזה המוצקה (הידרוצ'אר). בסדרה של ניסויים מבוקרים, בדקנו בוצת מט"ש שניונית (ממט"ש כרמיאל) בריאקטור הידרותרמי מעבדתי (500 מ"ל) ביחס מים:מוצקים 1:10 בתנאי הפעלה שונים הכוללים שלוש טמפרטורות (200, 250 ו-300 מ"צ) ושלושה זמני שהייה (30, 60 ו-120 דקות).

ממצאי המחקר מלמדים על ניצולת מוצקים גבוהה יחסית (61-74%) מבוצת מט"ש לאחר טיפול הידרותרמי בזמן הרצה של 60 דקות בשלוש הטמפרטורות. תכולת החומר האורגני בהידרוצ'אר הייתה בין 53 ל-58%. בדיקת אלמנטים עיקריים הראתה שריכוז הפחמן בהידרוצ'אר נשאר דומה לריכוזו בבוצה הגולמית (~40%) בעוד שריכוז החמצן ירד מ-19% בבוצה ל-12.0% בהידרוצ'אר בטמפרטורת הרצה של 200 מ"צ, ולכ-6% בהידרוצ'אר בטמפרטורות הרצה של 250 ו- 300 מ"צ. דפוס זה מצביע על תהליך פיחום של החומר האורגני המבוסס בעיקר על מנגנון דה-קרבוקסילציה במהלך הריאקציה ההידרותרמית. מאזני מסה לזרחן, מגנזיום, סידן, נחושת ואבץ הראו אחוזי השבה גבוהים מ-80%, בעוד אלו של ברזל ומנגן היו גבוהים מ- 94%. אחוזי ההשבה של חנקן, אשלגן, ונתרן היו נמוכים מ-50%, ככל הנראה בשל מסיסותם הגבוהה בפאזה המימית של התהליך. מלבד מאזני מסה, נמצא שהריכוז של יסודות קורט כגון ברזל, אבץ, מנגן ונחושת היה גבוה פי 1.5–2.5 בהידרוצ'אר ביחס לריכוזם בבוצה.

לסיכום, המחקר מדגים את הפוטנציאל של הטכנולוגיה ההידרותרמית לטיפול בבוצת מט"ש לטובת הפקת הידרוצ'אר והשבה יעילה של יסודות ההזנה החיוניים להתפתחות הצמח, תוך הגדלת סל החלופות לזרחן ממקורות מתחדשים שתיתן פתרון לבעיית הזרחן הגלובלית. מלבד אחוזי השבה גבוהים של יסודות מאקרו נמצא כי התהליך עשוי להיות יעיל בהעשרה של הריכוז היחסי של יסודות קורט. נקודה זו עשויה להיות משמעותית בעיקר בשל המחסור הצפוי ביסודות קורט בקרקעות חקלאיות והצורך במציאת פתרונות להבטחת המשך חקלאות אינטנסיבית. המאמץ העתידי יתמקד באופטימיזציה של התהליך לטובת השבה מקסימלית של כל יסודות ההזנה והגדלת הזמינות שלהם. הצלחת המחקר תאפשר יישום בטוח של תוצרי התהליך ההידרותרמי בחקלאות לצד פתרון הנדסי לבעיית הבוצה במט"שים.



ניתוח מצבו הטרופי של אגמון החולה בעזרת משוואות מבניות בדגש על הביוגיאוכימיה של זרחן

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רקע. שפע חומרי הזנה, בעיקר זרחן וחנקן, במי אגם עלול לגרום לפריחת פיטופלנקטון תהליך הנקרא הַעֲתָרָה (Eutrophication) שאינו רצוי כיוון שעלול להביא לאי יציבות של המערכת האקולוגית ולפגיעה באיכות המים. אגמון החולה הינו אגם רדוד ששטחו כ- 820 דונם ועומקו הממוצע כ- 0.2 מטר. מאז הקמת אגמון החולה, מספר העגורים (Grus grus) החורפים עלה מאלפים בודדים ל- 57,000 בחורף 2018-19. העגורים ניזונים מזרעים בשדות ולנים במי האגמון הרדוד וכך מייבאים זרחן (מיקוד מחקר זה) מהשדות לאגמון בהפרשותיהם. הגידול במספר העגורים הביא לגידול בתיירות לאגמון החולה (כחצי מיליון תיירים בשנה) מחד ומאידך מעלה את החשש לתהליך העתרה באגמון עקב תוספת הנוטריינטים. משקעי הקרקעית מהווים מאגר זרחן משמעותי ביותר לכן תהליכי שחרור ושקיעת זרחן חשובים ביותר במאזן הזרחן באגמים. כדי לבחון תופעה מורכבת זו יושמה מערכת משוואות מבניות. SEM (Structural Equation Modeling - SEM) הינו ניתוח נתונים רב-משתני, שמיועד לאמוד מערכת קשרים מורכבת ולכן יכול להתאים לבחינת התהליכים המורכבים של הזרחן באגמון. השיטה משלבת השערה על סיבתיות במערכת וניתוח סטטיסטי של מדידות. השערות המחקר הן: (1) הזרחן באגמון הוא גורם המגביל את פריחת הפיטופלנקטון. (2) החומר האורגני בקרקעית האגמון מהווה מאגר גדול של זרחן אולם קרקעית האגמון נמצאת ברוויה ביחס לזרחן. (3) לשלשת העגורים מהווה מקור משמעותי של זרחן כללי וזרחן זמין ליצרנים הראשוניים באגמון. (4) היות ויכולת הקרקעית לספוח זרחן נמוכה, תוספת זרחן גורמת לפריחת פיטופלנקטון ולתהליך העתרה של האגמון .

שיטות. מערך נתונים דו-שבועי בין השנים 2002-2019 נבנה מנתוני ניטור פרוייקט החולה - נתונים הידרו-כימיים, ריכוז כלורופיל וספירת עגורים. נתוני צפיפות כלורופיל וטמפרטורה היו חסרים וכדי להשלימם בוצע ניתוח צילומי לווין Landsat. מדידת כלורופיל וטמפרטורה מדימות לווין הראו מתאם R^2 0.7 ו- 0.94 בהתאמה. סך הכל נקבעו בתקופת המחקר 415 מדידות. שגיאות המדידה של המשתנים השונים הוערכו ושולבו במודל. ניתוח SEM בוצע בשתי סקאלות זמן: (1) מודל המבוסס על הנתונים הדו-שבועיים במשך 17.5 שנה (מודל 415) ו-(2) כיוון שהשינויים העונתיים גדולים ומקשים על הבחנה של תהליכים רב שנתיים, נותחו 2 מודלים רב-שנתיים על הנתונים החציוניים של כל שנה, סך-הכל 17 שנים) מודלים 17 .(a + 17b

תוצאות ודיון. ריכוז הזרחן הכללי היוצא מאגמון החולה ב-18 שנה האחרונות גבוה מזה הנכנס, תהליך המתגבר בקצב של כ-70 ק"ג זרחן לשנה. ריכוז כלורופיל מושפע, על-פי מודל 415, באופן כמעט בלעדי מתהליכים עונתיים ולא מזמינות הזרחן והחנקן. לעומת זאת, מודלים 17 a,bתומכים בהשערת המחקר שעליה בכמות העגורים מגדילה את ריכוז הזרחן וזה תורם לעליה בריכוז הפיטופלנקטון. הן מודלים 17 a,b והן מודל 415 מראים ש-pH, טמפרטורה וניטרט משפיעים על ריכוז הזרחן המומס, השפעות התומכות בהשערה שהקרקעית נמצאת ברוויה ביחס לספיחת זרחן וזו הסיבה להיות האגמון מקור לזרחן. חוסר היכולת של מודל 415 להראות קשר סיבתי בין הזרחן לבין כמות העגורים, לעומת קשר זה שמתגלה במודלים a,b, 17מצביע על האפשרות שזרחן הנכנס לאגמון בחורף בלשלשת העגורים, שוקע ונספח לקרקעית ומשתחרר כאשר טמפרטורת המים עולה. האגמון אינו נמצא במצב שיווי משקל ביחס לזרחן דבר העלול להגדיל את מופעי פריחת הפיטופלנקטון באגמון. כדי להבין טוב יותר את דינמיקת הזרחן באגמון מומלץ לנטר מדדים הקשורים לשחרור וספיחת זרחן מהקרקעית. למרות מגבלותיו של SEM במחקר זה עקב מיעוט יישומים לניתוח נתוני סדרת זמן וחוסר היכולת להסביר את התהליך החזוי של זרחן וחנקן בזמן, המודלים תקפים סטטיסטית, תומכים בחלק מהשערות המחקר ומבליטים שאלות לגבי השערות סיבתיות שלא נתמכו. חישה מרחוק היא כלי אטרקטיבי, זמין וזול למדידת טמפרטורת פני המים וריכוז הכלורופיל בעבר ובהווה .

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