

INFLUENCE OF WATER TABLE FLUCTUATION ON NATURAL SOURCE ZONE DEPLETION IN HYDROCARBON CONTAMINATED SUBSURFACE ENVIRONMENTS

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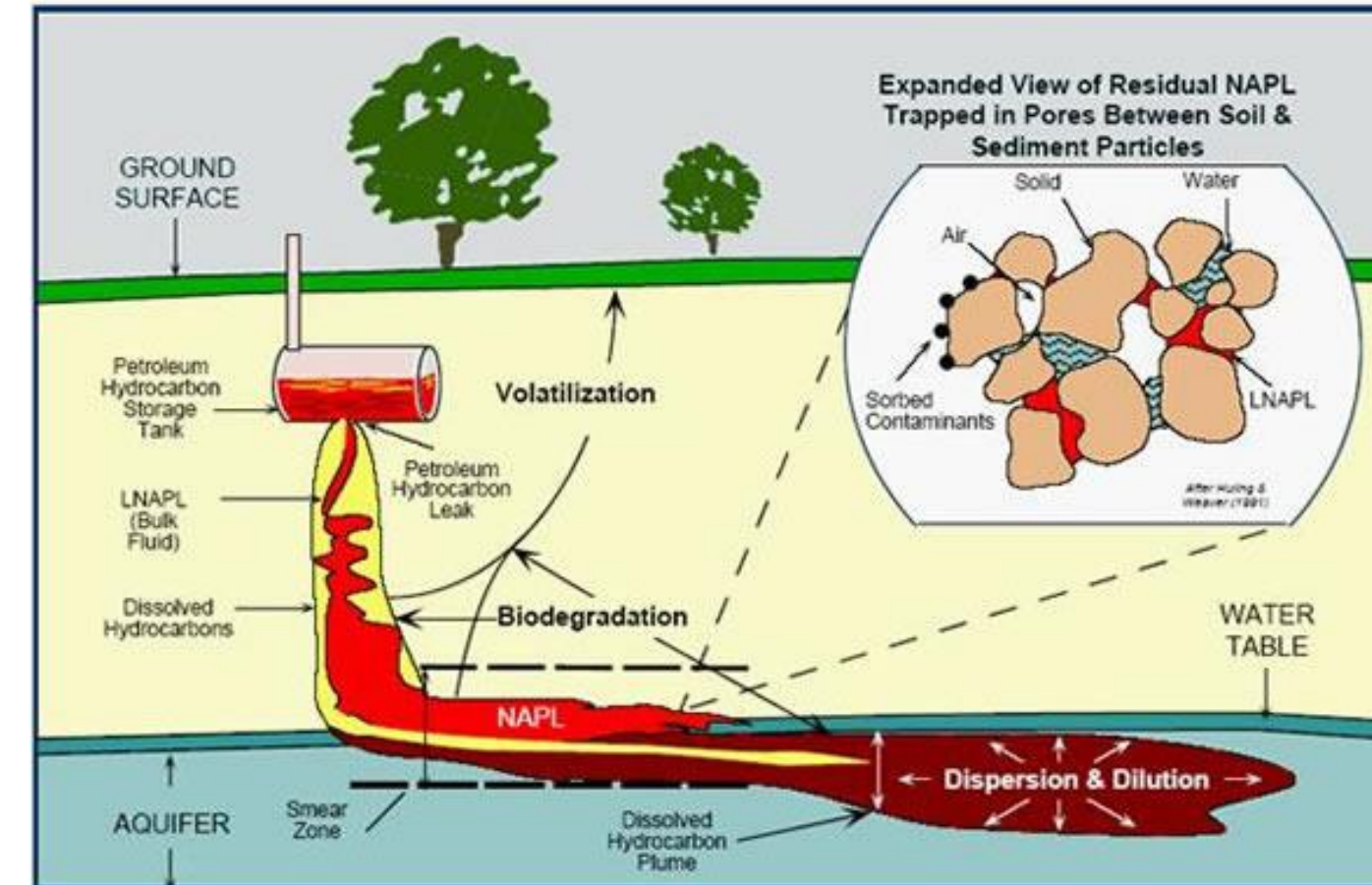
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Background and Hypothesis

- Accidental spills of petroleum hydrocarbons (PHCs) are common source of soil and groundwater contamination in coastal environments that distribute in the subsurface systems as a non-aqueous phase liquid (NAPL).
- Natural source zone depletion (NSZD) processes (including dissolution, volatilization, and biodegradation) and smearing due to water table fluctuations.
- The water table fluctuation enhances the mass transfer of oxygen from the atmosphere to the groundwater which results in spatial gradient as well as temporal variation in local redox condition

- We hypothesize that water table fluctuation under sulfate reducing bacteria will enhance the biodegradation of Toluene and Naphthalene compared to non-fluctuating water table.

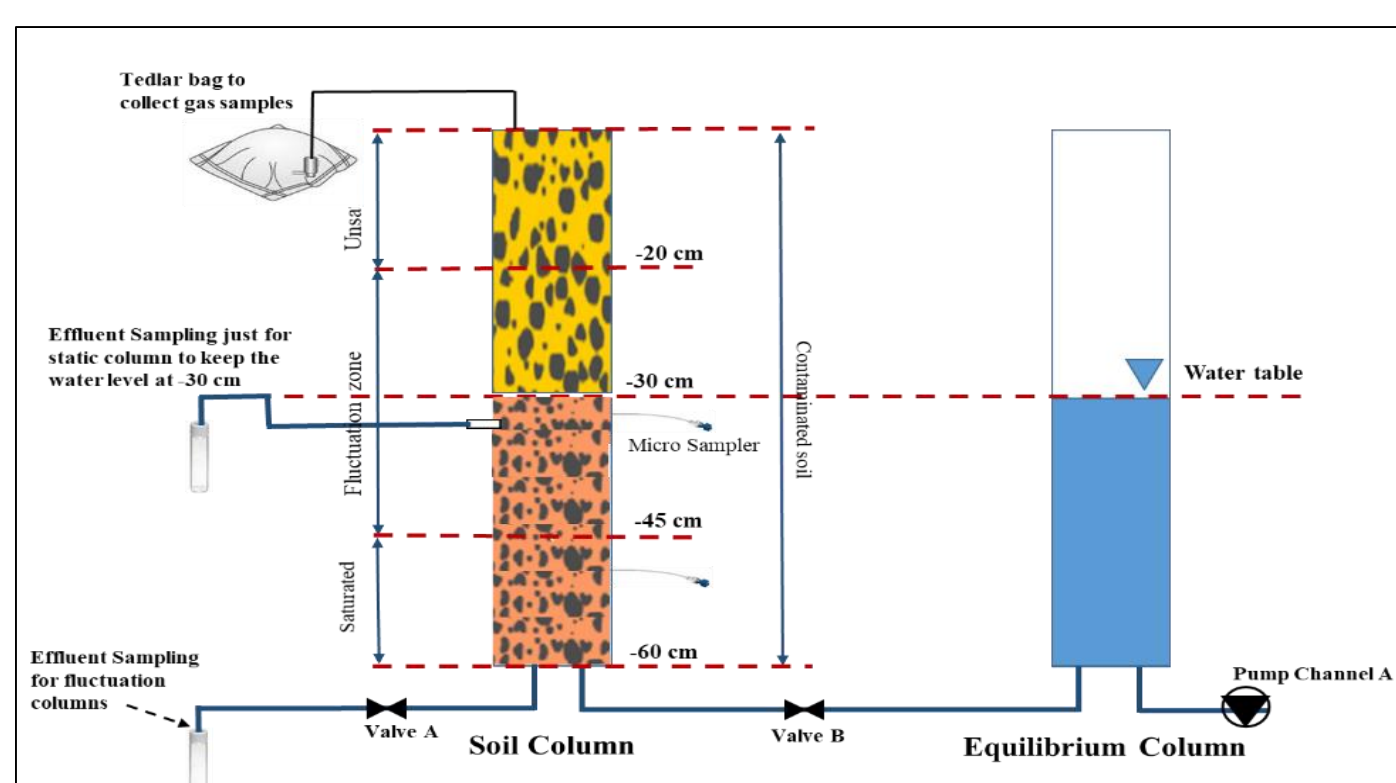


Experimental Methodology

- An experiment of two columns operated under static condition, and two columns operated under fluctuating condition ran for 5 months

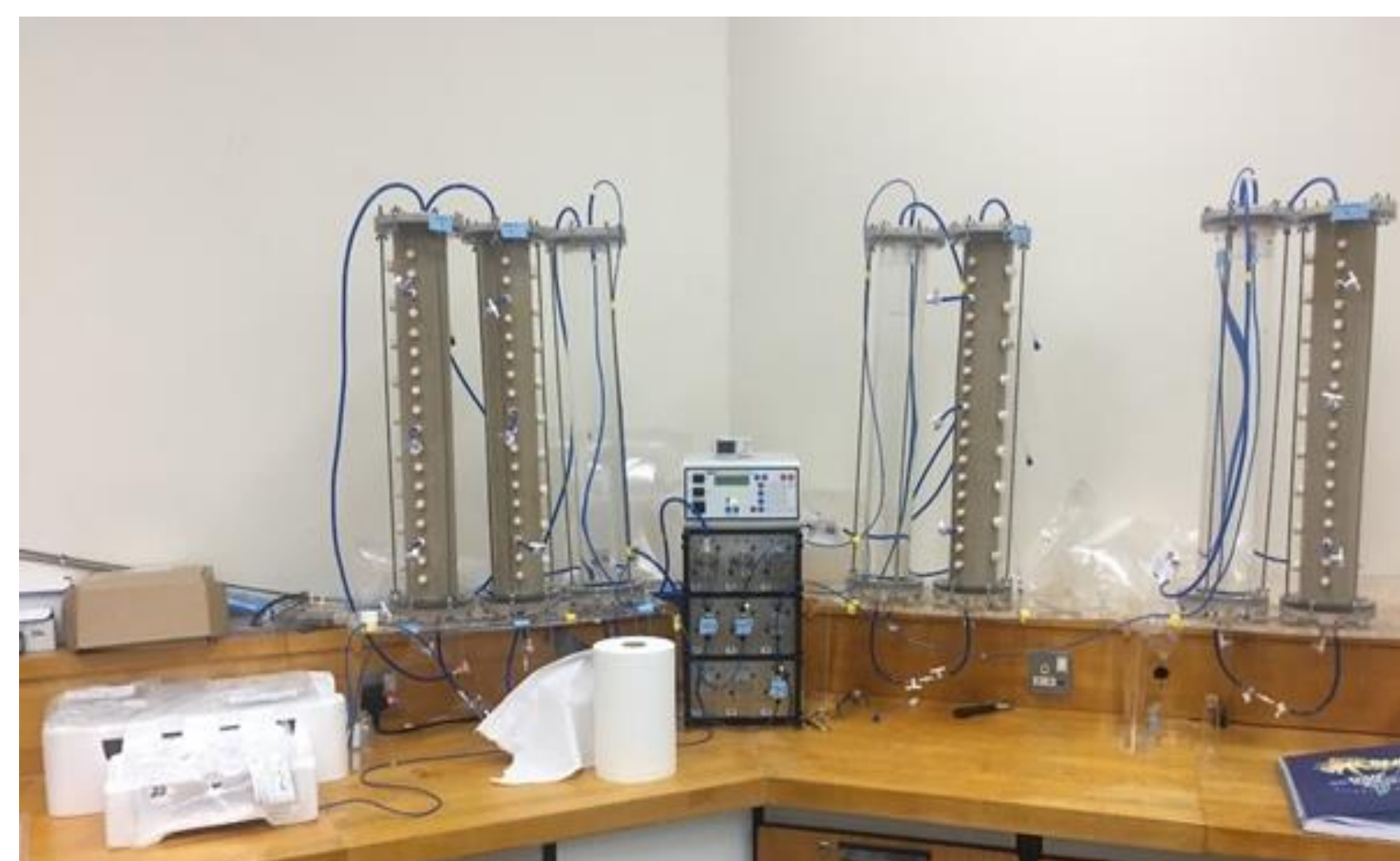
Soil Preparation:

5 kg of uncontaminated soil was used for each column after removing large size particles. 25% of the soil was taken and spiked by toluene and Naphthalene and mixed gently to provide a homogenized spiked soil sample.



- Synthetic groundwater:** Prepared by argon-purged deoxygenated water ($DO < 0.8 \text{ mg}^{-1} \text{ L}$) based on groundwater analyses containing background nutrients.

- Two static columns connected to one equilibrium column – columns were always saturated
- Two fluctuating columns, each one was connected to one equilibrium water column. They were fluctuating between top and -40 cm.

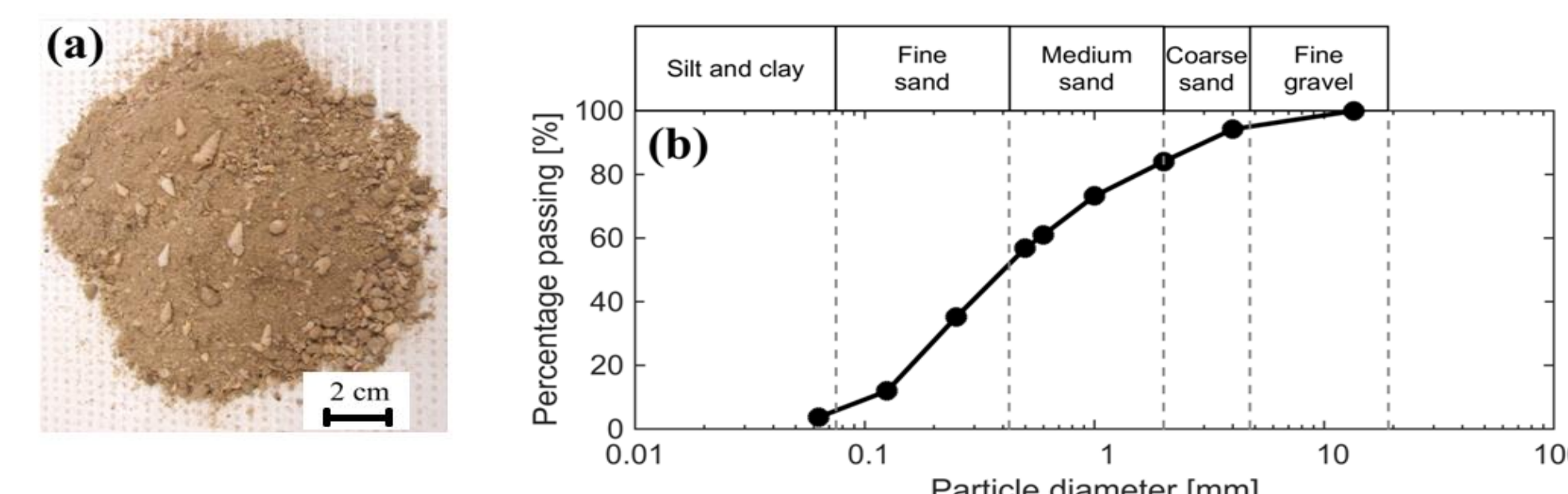
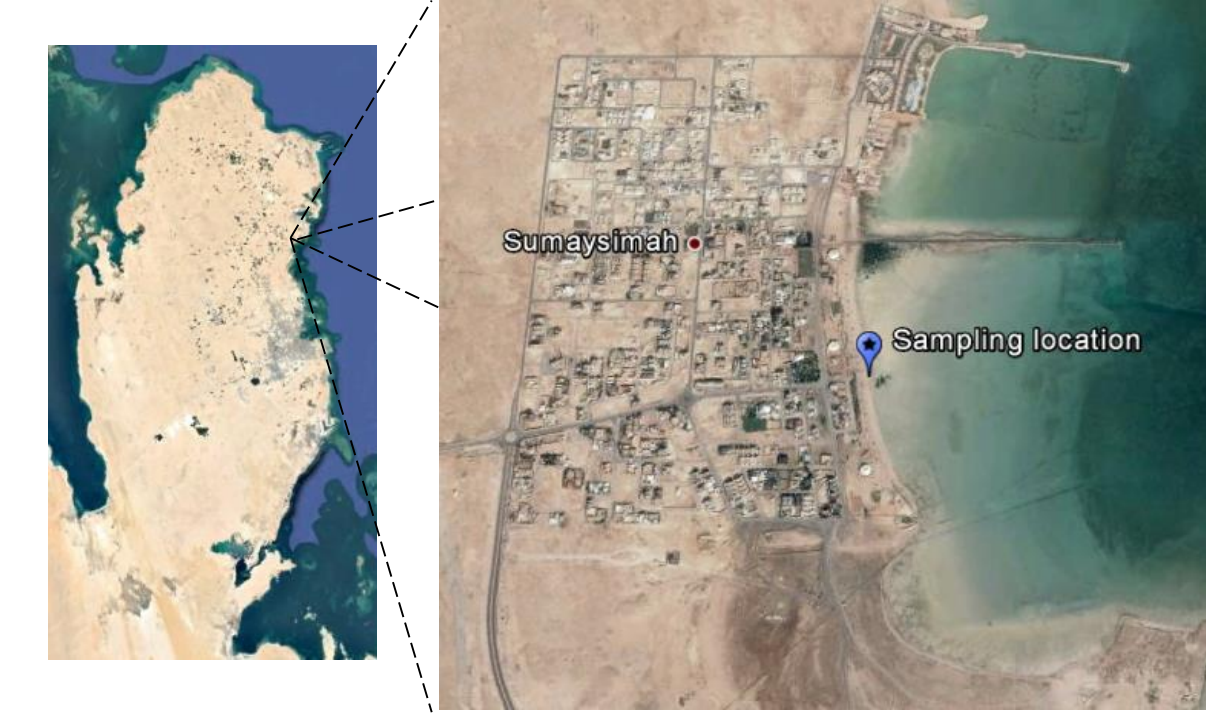


- For fluctuating columns, Each week one drainage-saturation cycle.

- Two effluent aqueous samples collected each week at -30 and -50 ports
- Analysis include pH, DO, EC, ORP, DOC, DIC.
- sulfate/nitrate concentration.
- Organic concentration in effluent samples (GC)
- Soil initial & final organic concentration (GC).

Field Site and Soil Characterizations

The soil was a sand with the texture class of sabkhas and saline beach sandy soils. It had elevated concentrations of soluble calcium, sodium, sulfur, chloride and sulfate.



(a) Photograph of the soil and (b) the particle size distribution including seashells and using the Unified Soil Classification System (USCS).

Soil samples were collected from a (semi)-arid brackish coastal site at the eastern side of town of Sumaysimah, on the eastern coast of Qatar. The site provides an ideal setting to study the fate of PHCs under extreme environmental conditions (e.g., variable salinity and temperature, and tidally-driven water table fluctuations).

Objectives

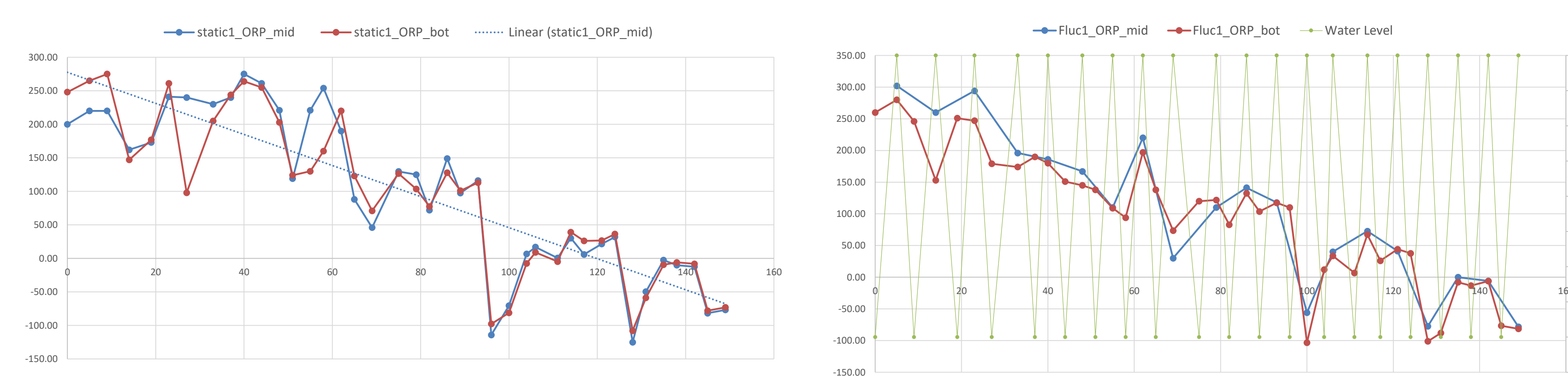
The evaluation of the movement of petroleum hydrocarbons under the conditions of groundwater table fluctuations

Understand the effect of water table fluctuation and PHC-contamination of soil geochemical properties

The comparison of the organic mass removal between the static conditions and water fluctuation in the subsurface

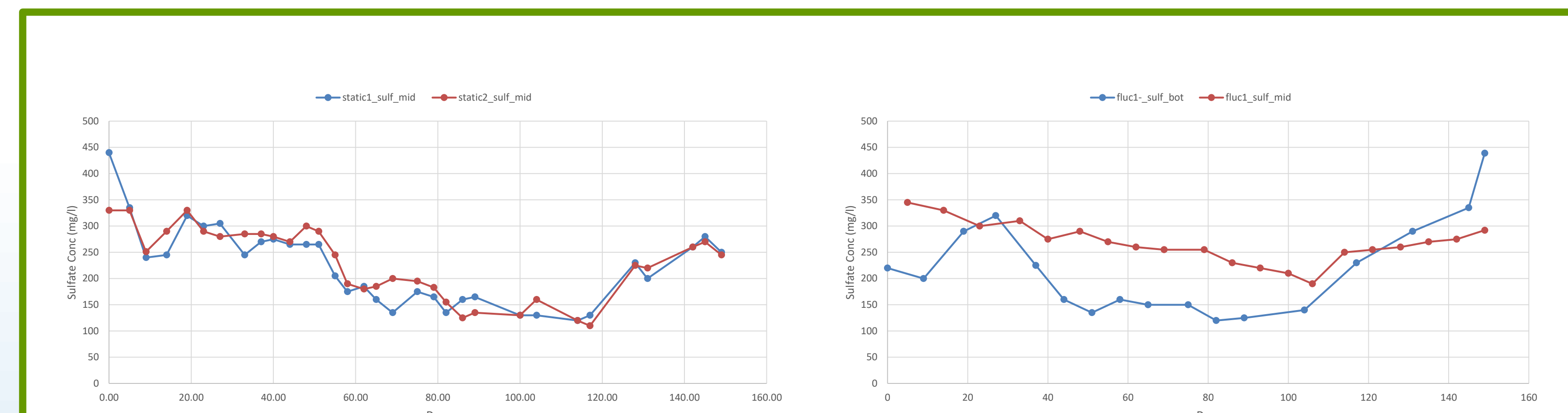
Results

The aerobic and anaerobic degradation of PHCs under static and water table fluctuations



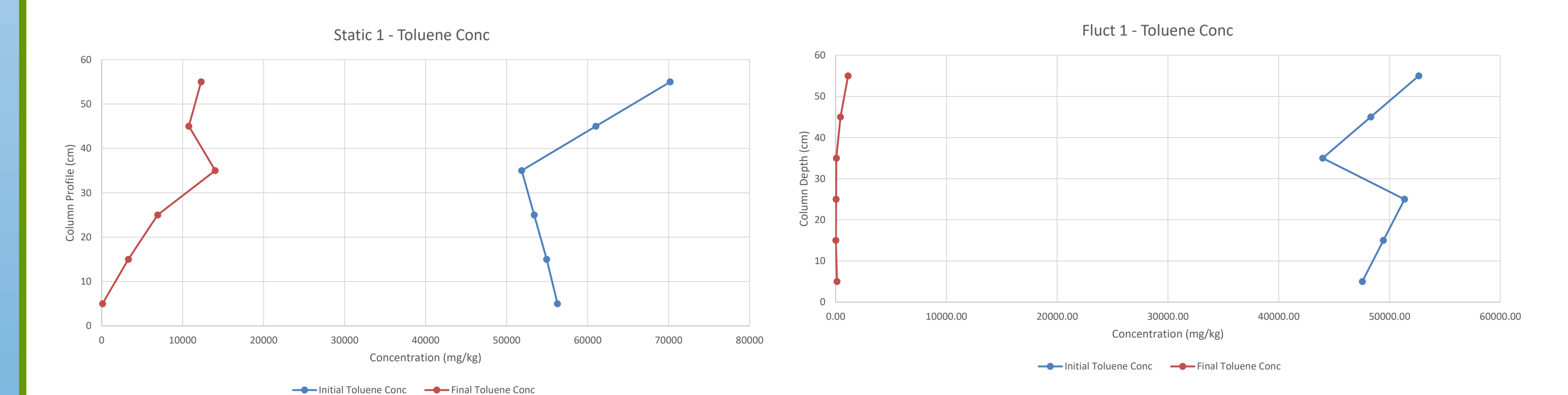
Left: Oxidation-reduction potential (ORP) for static 1 at -30 and -50 cm. right: ORP in Fluctuation 1 at -30 and -50 cm.

- Pore water ORP values were $\sim 250 \text{ mV}$ and gradually decreased to $< 100 \text{ mV}$ after 65 days indicating the development of reducing conditions and enhancement of anaerobic microbial community. Reducing condition was more significant in the stable water table columns.
- Reducing condition during the drainage periods in the fluctuating water table columns is clear, while during the water rise oxidizing condition gradually changed to reducing conditions. Sodium sulfite was added as an important oxygen scavenger after 95 days, DO decreased very fast during water rise and ORP at both depths in all columns suddenly dropped to -100 mV and fluctuated in the range of -50 to -100 mV until the end of experimental period.



Left: the effluent sulfate concentration for static 1 & 2 columns, right: the effluent sulfate concentration in Fluctuation 1 at -30 and -50 cm.

- At the beginning of the experiment, and when the columns still under aerobic condition, sulfate concentration at -30 cm of static columns was at around 400 mg/l . after 65 days, when most of DO is consumed and anaerobic condition was developed, sulfate concentration dropped to less than 200 mg/l and it continued to reduce until 120.
- the concentration of sulfate at -50 cm is following the same pattern of static columns. The concentration of sulfate started at 220 mg/l to and increased to 320 mg/l at 35 days reaching the concentration at -30 cm and then continued to decrease until 120 days.



Left: Soil initial & final toluene concentrations along the static 1 column right: Soil initial & final toluene concentrations along the Fluctuating 1 column

- Around 94% of toluene concentration was degraded in the upper part of static 1, while for the bottom part it was 78%.
- Around 99% of toluene concentration was degraded in the upper part of Fluctuating 1, while for the bottom part it was 98%

Conclusions

- The fluctuation of water table fluctuation can influence and enhance PHCs mass transfer and microbial activities, and hence, result in their removal and biodegradation.
- The rate of degradation in static columns was less than the one in the fluctuating columns.
- The anaerobic condition by sulfate reducing bacteria was achieved after oxygen depletion.

Acknowledgments

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