Evaluation of a Continuous Sediment Ebullition Monitor

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Introduction: Understanding occurrence, frequency and distribution of gasses released from subaqueous sediments into the overlying water column (ebullition) can play an important role in contaminant flux and transport to the surface. Gasses are produced by microorganisms decomposing organic matter under anoxic conditions in the sediment. These processes occur naturally in the environment, in addition to contributions from degradation of organic contaminants that may contribute to the overall gas release from aquatic ecosystems. Hydrophobic contaminants located within the sediment bed can adhere to the surface of the gas bubble and may result in transport and redistribution to the surface water column. Accurate monitoring of gas flux from the sediments is used to support risk evaluations, remedy decisions and remedy design. Various methods have been employed to monitor this phenomenon, each with unique advantages and limitations. As the production and ebullition of gasses is driven by many dynamic factors, a continuous in-situ method is ideal for developing a process-based understanding of ebullition to be included in site-specific or global models. An autonomous sediment ebullition monitor was developed by Eosense, designed to continuously monitor gas flux from sediment and capture temporal variability.

Methods: The sediment ebullition monitor was designed and developed based on previous work by Varadharajan et.al.[1]. The main instrument components consist of an inverted funnel and gas collection column, stabilized by a tripod system that rests on the sediment bed. There is an auto-siphon in the gas column to allow for continuous operation of the instrument. Sensors to measure the gas volume inside the chamber are included along the length of the column, along with peripheral sensors to measure water temperature and water depth. The system is supported by a datalogger and solar power at the water's surface. Two different iterations of the design were deployed as pilot projects in diverse environments, including 1) a rain basin located within an industrial facility, and 2) a publicly owned waterway. The pilots were designed to test the operation and instrument performance over a continuous and extended monitoring duration, and to evaluate variable influences (such as air temperature, water temperature, barometric pressure, water levels) on measured ebullition rates.

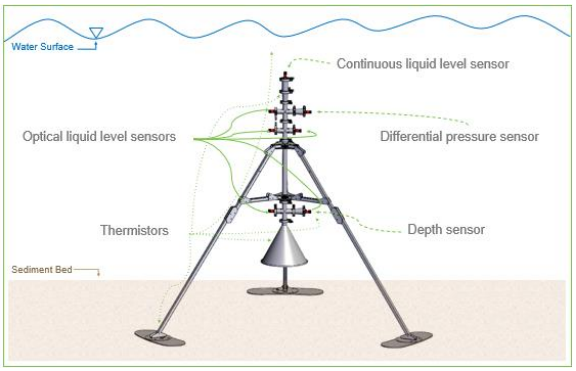

Fig. 1: *Schematic of the sediment ebullition monitor*

Results: The performance of the sediment ebullition monitors for each field pilot will be presented. Design improvements that were made from the first iteration to the second, based on challenges encountered in the pilots will be reviewed for efficacy. A continuous ebullition flux dataset will be presented, and a comparison of ebullition fluxes measured by the instrument over an extended period relative to historical manual short-term measurements. These data will be compared to previous flux data from similar waterways, as an alternative approach to traditional ebullition measurement tools and practices. Recommendations will be given for best practices in continuous sediment ebullition monitoring.

References: [1] Varadharajan C, Hermosillo R, Hemond HF. 2010. A low-cost automated trap to measure bubbling gas fluxes. Limnology and Oceanography-Methods 8:363-75.

On-site sediment toxicity monitoring using a field operable biosensor (SUNDANSE)

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Introduction: In light of the fact that sediments can be a critical source of bioavailable toxic contaminants affecting both the environmental biogeochemical of water bodies, as well as its biodiversity. Their remediation can have a detrimental effect on aquatic life when dredging or other techniques are used. The present study thrives to provide policy makers with hard data in terms of providing a picture over the course of a river such as the Danube in terms of its toxic potential. For this we propose a field-enabled biosensor.

Methods: Genetically engineered E. coli cells were im-mobilized on a fiber optic tip using a calcium alginate matrix. This method enhances detection sensitivity by placing the bacterial cells in direct contact with the fiber optic surface, maximizing the bioluminescent signal in response to genotoxicants[1, 2]. Sediment samples were collected from six different sites around Israel, that are suspected to be contaminated. The sediments were placed in Eppendorf tubes containinSg DDW. Alginate immobilized tip of a multimode optical fibres, SFS400/440 (Fibreguide Industries, Inc., USA), was placed inside the sediment suspention, while the other tip of the fiber was connected to a photon-counting PMT detector HC135-01 Hamamatsu Photonics, Japan). The PMT detector was interfaced with an in-house developed board for signal acquisition. This setup was placed in a light-proof case, that was sealed during measurements.

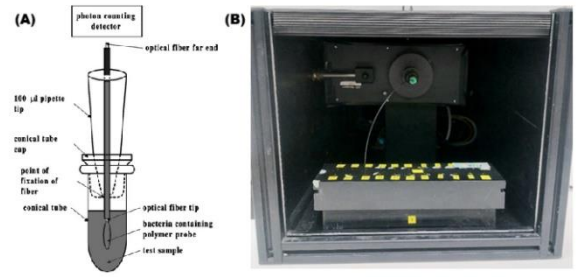

Figure 1: *(A) Instrument set-up demonstrating the components used in the experiments for the bioluminescent measurements using the optical fiber tip optrode whole-cell biosensor (B) A photo of the biosensor system.*

Results:

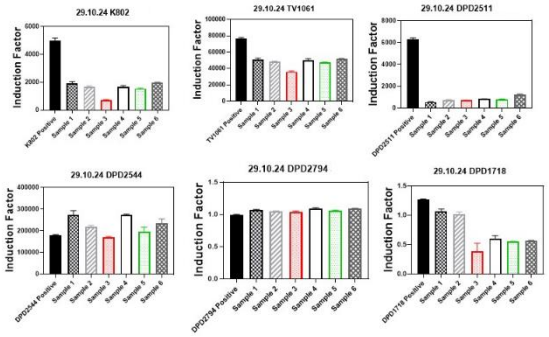

Figure 2: *Bioluminescent response of six bacterial strains (DPD2794, TV1061, DPD2544, DPD1718, K802NR, DPD2511) to sediment samples from six different sites measured using the biosensor system.*

Discussion: The results demonstrate the effectiveness of the fiber optic-based bioluminescent biosensor in detecting sediment toxicity across multiple sites, with variations in bacterial strain responses indicating differing sensitivities to specific toxins. Spatial variability in toxicity likely stems from diverse pollution sources, sediment composition, and hydrodynamic conditions. These findings align with previous studies, reinforcing the utility of bacterial bioreporters as a rapid and reliable tool for environmental toxicity assessment[1-4].

References:[1] B. Polyak, E. Bassis, A. Novodvorets, S. Belkin, R.S. Marks, Sensors and Actuators B: Chemical, 74 (2001) 18-26.
[2] B. Polyak, E. Bassis, A. Novodvorets, S. Belkin, R.S. Marks, Water Science and Technology, 42 (2000) 305-311.
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Enhancing Harmful Heavy Metal Contamination Profiling in Coastal Sediments: A Modified Geochemical Index Approach

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Introduction: Sediment contamination by harmful heavy metals (HHMs) poses significant risk to ecosystems and human health. Historical mercury (Hg) data from Cartagena Bay (CB), Colombia (1996-2024) were analyzed. A modified geochemical index (mP_d) is proposed for improving sediment vertical contamination profiling for a more accurate sediment contamination than traditional approaches, surface-level assessments. Numerical results suggest its potential applicability to various coastal areas.

Methods: The proposed index builds on existing geochemical indices: pollution degree (P_d) [1], contamination factor (CF_n) and geo-accumulation index (I_{geo}) [2]. Empirical Hg data from CB validated the approach. Hg was selected as target HHMs due to its persistent impact on CB over the last three decades. The existing indices P_d and CF_n are mathematically equivalent since $P_d = CF_n - 1$. I_{geo}, a logarithmic scale of CF_n, aligns with P_d and CF_n, but with a rescaled value:

$$I_{geo} = \ln\left[\frac{C_n}{B_n}\right] / \ln(2), \quad (1)$$

where I_{geo} ln(2)=Dh, D being diffusion in a sediment layer of thickness h. The vertical concentration profile is $C_n(z)=B_n\ exp(Dz)$ for $z \in [0,h)$; with $h(t) = b_0 + wt$, where b_0 is the initial thickness and w the sediment accumulation rate. Using the molecular diffusion equation:

$$\frac{\partial C}{\partial t} = D\frac{\partial^2 C}{\partial z^2}. \quad (2)$$

where porosity and tortuosity limit diffusion, the boundary conditions are defined as:

$$C(z=0) = B_n \text{ and } C(z = b_0 + wt) = C_n. \quad (3)$$

Solving (2) and (3) yields:

$$C(z,t) = B_n + (C_n - B_n)\left[1 + \text{erf}\left(\frac{z - wt - b_0}{2\sqrt{Dt}}\right)\right]. \quad (4)$$

Integrating over z from 0 to h(t) normalizing by h and B_n, gives the modified pollution index:

$$mP_d = P_d[1 + F/h]. \quad (5)$$

where F is the integral of the solution. As t→∞, F/h=1/2, and mP_d varies from P_d to 1.5 P_d.

Results: Hg contamination of CB varied significantly from 1996 to 2024. The highest index values were near urban areas in regions influenced by the Dique Channel, reflecting significant anthropogenic inputs from industrial discharges. The central and southern regions had much lower index values indicating less Hg contamination. Results highlight the importance of including sediment transport processes in future studies to better understand Hg distribution and long-term effects in this ecosystem.

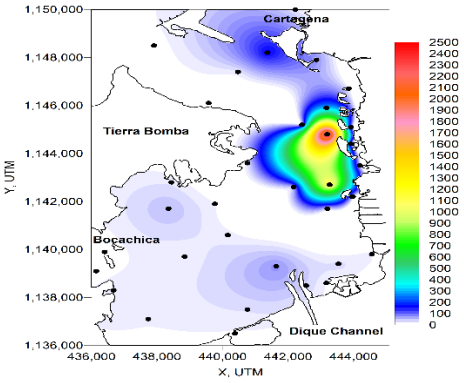

Fig. 1: Results of the mP_d in sediments of CB.

Discussion: Hg concentrations decrease from the industrial zone toward Bocachica and Tierra Bomba, influenced by suspended sediment transport driven by a pycnocline and bedload transport, which redistributes sediments and supports pro-delta growth near the levee channel. The sediment dynamics and release of particulate Hg obscure the link between proximity to the Dique Channel and contamination levels. By accounting for processes like diffusion and sediment interactions, this approach provides an accurate assessment of HHM distribution, overcoming limitations of traditional geochemical indices and aiding environmental remediation. The mP_d reliably evaluates HHM in vertical sediment profiles.

Additional sediment quality issues in CB will be presented during the 2025 SedNet conference.

References: [1] M. Fukue et al. (1999) *Eng. Geol.* **53**: 131-137. [2] L. Hakanson (1980) *Water Res.* **14**:975-1001. [3] W.T. González Cano, K. Kim (2022) *Sustain.* **14**: 14821.

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