The Living Levee: Assessment of Wetland Soil on Trace Organic Compound Removal

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Introduction: The Living Levee is a man-made subsurface flow wetland that provides tertiary treatment for wastewater effluent at the Oro Loma Sanitary District, located in San Lorenzo, California on the coast of the San Francisco Bay. The levee was constructed in conjunction with a nitrification trench and a surface flow wetland. The subsurface wetland consists of 12 cells including 4 treatments in triplicate (*Figure 1*). Each cell is approximately 1 m in depth and was built with four layers. The top layer is predominantly locally sourced Bay mud that is used to support plant development. The second layer contains sand that promotes infiltration. The third layer is gravel, which allows for drainage. Finally, the bottom layer is an impenetrable clay that ensures system isolation from groundwater.

While the original intention of the living levee was nitrate removal through denitrification, trace organic compounds (TrOCs) may also be removed. TrOCs are a class of biologically active organic chemicals whose ecological effects are unknown or poorly understood. Preliminary results suggest that all analyzed TrOCs are removed in the subsurface of the Living Levee (>80% removal). However, their fate is largely unknown. The possible fate of the TrOCs includes: discharge in the effluent, plant uptake, soil adsorption, transformation by a biological reaction, or transformation by an abiotic reaction.

This study explores soil adsorption. Soil can often act as a filter that purifies water supply. The soil's potential to adsorb TrOCs largely comes from its organic content and mineralogy. In addition, TrOC adsorption depends on the hydrology of the system. The hydraulic retention time (HRT) of the wastewater influences how much subsurface flow occurs, and thus how much contact TrOCs have with the soil. The objective of this study is to better understand the hydrology of the subsurface wetland and the adsorption capacity of the soil at various depths.

Materials and Methods: To assess the Living Levee's hydrology and sorption capacity, tracer tests, texture analyses, and isotherms were performed. This project focused on cells E, F, and G, which had the best performance and represented 2 different treatments (*Figure 1*). The tracer test used 200 g of lithium bromide introduced in a single pulse at the influent. Samples of pore water were subsequently and periodically collected at the intermediate well and the effluent. The intermediate well samples were taken manually using a peristaltic pump for a total of 6 samples over two days, while the effluent samples used an ISCO autosampler that collected 40 samples over 99 hours. The samples were then analyzed using ion chromatography (Dionex ICS 1100) to detect changes in the concentration of lithium and bromide over time.

The texture analysis required taking core samples of the soil using a 1.2 m auger with a diameter of 10 cm. For each cell, 3 cores were taken from one hole at various depths around the intermediate well. The core depths were delineated by observing differences in soil color and texture. These soil samples were then analyzed for texture per ASTM Standards method 04.08:117-127. The percent sand, silt and clay were then calculated based on the principle of sedimentation as described by Stokes' Law.

Samples were prepared for isotherm tests by autoclaving 5 g of soil for 50 minutes. A 0.01 M $CaCl_2$ solution was added to each sample and agitated for 24 hours. Afterwards, TrOCs were spiked into samples to achieve final concentrations of 0, 0.05, 0.1, 0.5, and 1 µg/L, and agitated for an additional 24 hours. Lastly, 1 ml of liquid from each sample was filtered and processed using liquid chromatography-mass spectrometry (Agilent 1200 HPLC, 6460A ESI MS-MS).

Results: The results show that the HRT is approximately 21 hours in cells F and G. Cell E exhibited some overland flow and had an HRT of 18 hours (*Figure 2)*. This signifies that there is predominantly subsurface flow occurring. Also, there is significant adsorption happening in all tested cells (fraction dissolved = 0.088, from average Kd of Carbamazepine). The compound Carbamazepine had roughly the same Kd throughout the layers (*Figure 3)*. Whereas, three compounds tested with a protonated amine group (Atenolol, Metoprolol, and Propranolol) had a significant increase in Kd at the second depth. It is believed that the Kd of Carbamazepine has little or no change with depth because its leading mechanism for adsorption is hydrophobicity. While the compounds with the amine group experience an increase in Kd possibly due to additional electrostatic interactions with minerals at this depth. Greater sorption of these protonated TrOCs also coincides with larger percentages of clay in that layer. However, it is possible that the clay content is not the only factor that is leading to this higher adsorption capacity. Other factors include minerology and organic matter deposition. Further testing will need to be done. Further testing should include more detailed trials on one cell to track spatial differences, as well as, pH dependent isotherms, and soil chemistry characterization, such as, cation exchange capacity and organic carbon- loss on ignition.

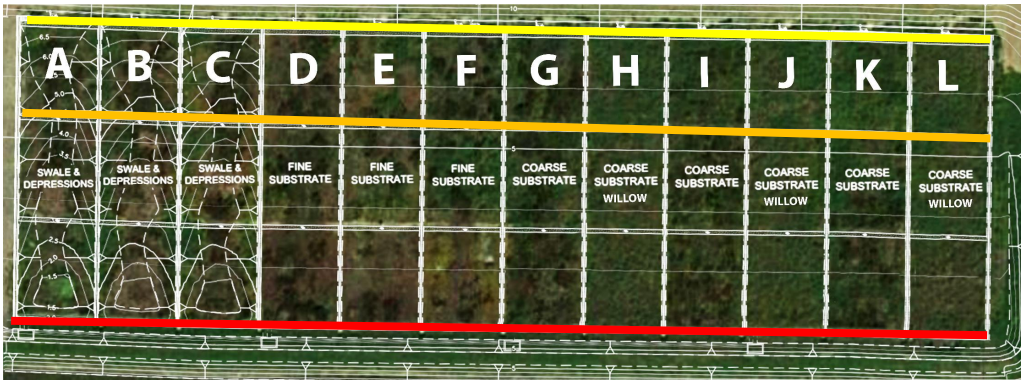

Figure 1- Overhead view of the Living Levee, overlaid with letter designations and short descriptions of each cell. The influent is marked in yellow, the intermediate well is marked in orange, and the effluent is marked in red. The flow direction is from the influent to effluent.

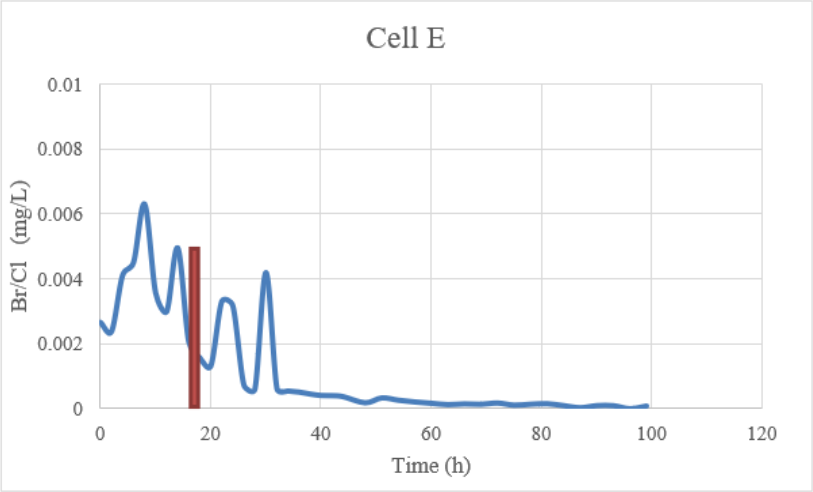

Figure 2-hydraulic retention time of Cell E

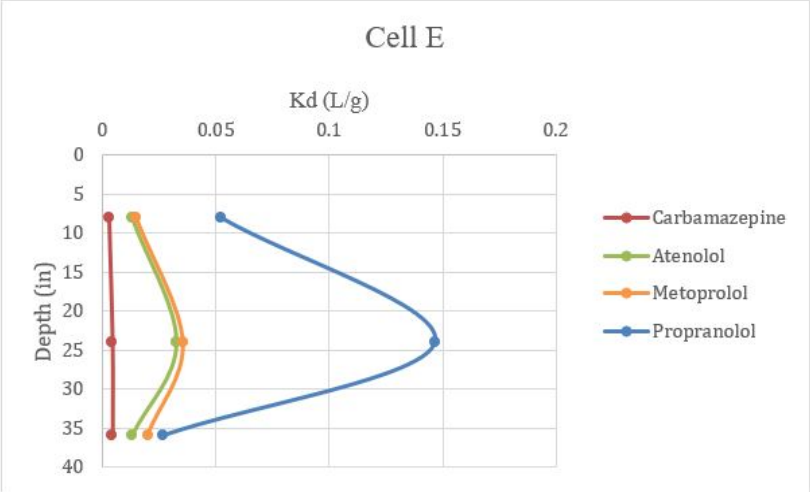

Figure 3-change in adsorption capacity with depth in Cell E

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