POROUS PAVEMENTS AND GEOTECHNICAL PASSIVE INFILTRATIVE MATRICES FOR FLOOD ATTENUATION

Jacquelyn Chavez[1,2]
Advisors and Mentors: Dr. Sybil Sharvelle[2], Jumana Alja'fari[2]
Civil Engineering and Water Quality Departments

New Mexico Institute of Mining and Technology[1], Colorado State University[2]
jacquelyn.Chavez@student.nmt.edu

Abstract

According to the Census Bureau's decennial census, U.S. population is growing by approximately 3.3 million per year. This population growth puts an ever increasing strain on the sewage systems set in place to process waste water. During intense precipitation events, waste water treatment plants cannot process the waste water as fast as they receive it. As a result, waste water overflow occurs in an event called "combined sewer overflow" (CSO). CSO contains pathogens, high levels of untreated human and industrial waste, runoff from streets containing heavy metals and toxic materials, bacteria linked to cause human health problems, viruses, polycyclic aromatic hydrocarbons, chlorates, and other contaminants described by the Environmental Protection Agency. Flooding diverges CSOs into nearby receiving water bodies such as local streams or rivers. This pollutant load not only causes significant harm to river ecology, but also to humans who interact with the water. Adding permeable pavement gutters and passive filtration systems to compliment storm water control systems will reduce strain on sewers and pollutant load entering receiving river bodies, while also reducing flooding in urbanized areas. The floodwater collected can then be stored in a detention basin where passive infiltration by MnO coated sand, activated carbon, newspaper, and gravel will remove heavy metals, bacterium, pathogens, and harmful material. The exiting fluid, effluent fluid, will be comparable to treated wastewater and can be considered for green uses, non potable water supply, or can be sent to a water treatment facility and need less processing.

Introduction

Urbanization increases impervious surface area, flooding, amount of pollutants in sewers, and strain on waste water treatment plants. Storm water sewers become overwhelmed and untreated water overflows into receiving bodies of water. The storm water contains pathogens, disease causing bacteria, phosphorous, nitrates, and heavy metals from street runoff. In cases of combined sewer overflow (human and industrial waste is combined with storm water), waste is released untreated into rivers resulting in drastic ecological effects. Flood attenuation and treatment has become problematic especially in urban areas prone to heavy fluctuations of precipitation.

Storm water drain overwhelmed by debris. Causes street flooding.

Combined Sewage Overflow (CSO) into receiving water body.

Objective

- Create a flood attenuation and treatment system that requires minimum interaction and maintenance
- Create a system that treats water comparable to waste water treatment plants
- Create an economically feasible green infrastructure that is comparable to implemented hydraulic routing
- Passively treat water for non-potable water usage

Components and Materials

- Manganese oxide (MnO) coated sand: electrostatically attracts negatively charged pathogens and positively charged metal oxides
- Granular Activated Carbon (GAC): adsorption of natural organic bacteria contaminants, radiological contaminants, chemical contaminants, denitrification,
- Geo-media: prevents sand and carbon erosion
- Gravel: supportive material
- Porous Pavement (PeP): allows rapid flood attenuation while being relatively inexpensive to produce, strong
- Supportive Rocks

Figure 1 Synthesized Manganese Oxide Coated Sand (above left) and Granular Activated Carbon (above right).

Figure 2 Sample of Permeable Pavement.

Methods

- PeP was made by mixing cement and pea-gravel (*Figure 4*). A slab of PeP was placed on two layers of rocks to ensure rapid infiltration (one layer of river pebbles above a layer of river rock).
- GAC was synthesized with a –No. 13 mesh size charcoal. The charcoal was soaked in a solution of 25% $CaCl_2$ solution for 24 hours and then washed with NanoPure Water. The activated carbon filtered, and air dried for an additional 24 hours.
- MnO Sand was synthesized by adding 0.5 mol of manganese permanganate to 1.25 L of NanoPure water. This solution was boiled with the inclusion of 200 g of acid washed sand. After boiling, 1 mol of concentrated HCl was added dropwise to the boiling solution. After the last drop was added, the solution was boiled for an additional 10 minutes. The sand was thoroughly washed until the fluid ran clear.
- Varying percentages of sand and MnO sand were tested together to test for sand erosion or leaking permanganate. 50 mL of NanoPure water was ran through 10 g of GAC, each mixture of sand, and MnO coated sand. The fluid which infiltrated through the sand mix and the carbon was collected and subjected to suspended solids analysis (*Figures 3-5*). This procedure allowed the correct amount of sand to MnO sand to be chosen.
- Synthetic storm water was originally being made for this project, but several rainstorms during this project's duration allowed the opportunity to collect authentic street runoff from a cross section between Laurel and Meridian Avenue in Fort Collins, Co. This storm water was a more appropriate media as it was polluted with metals, oils from vehicles, contained runoff from lawns, and contained particles that would have been neglected in synthesizing synthetic storm water (*Figure 10*). The storm water was column filtered through the geo-media described previously and analyzed for COD, Turbidity, and MPN.

Figure 3 Results from total Suspended solids.

Figure 4 Results of total volatile suspended solids.

Figure 5 Results of total dissolved solids.

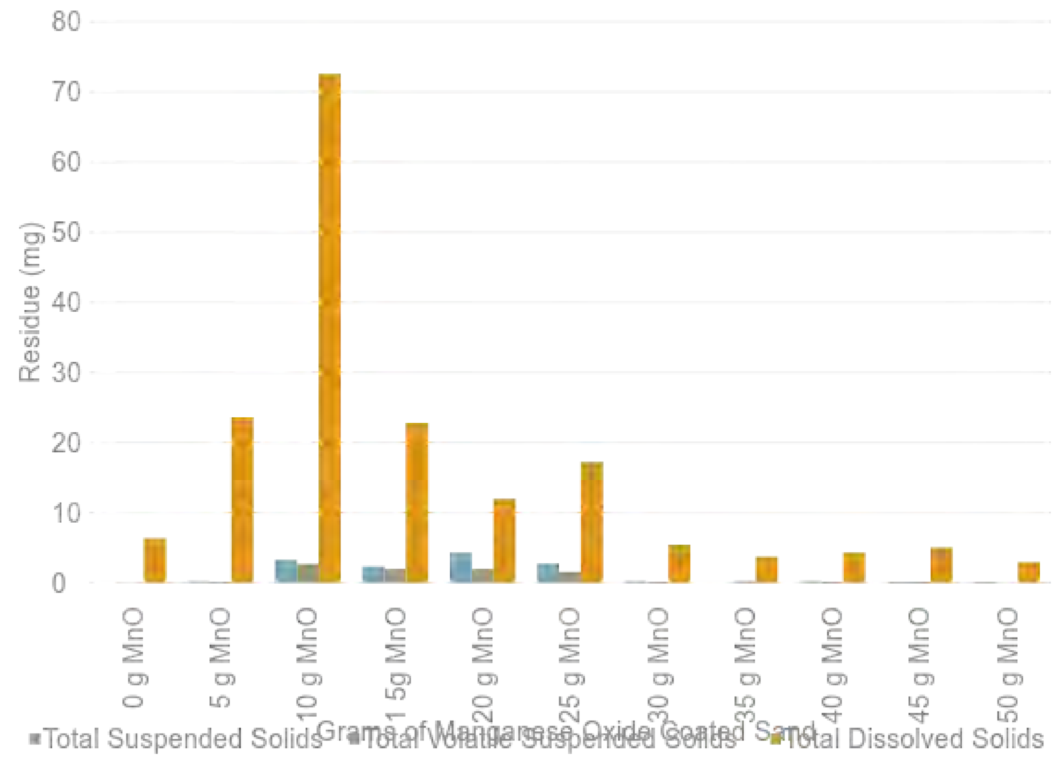
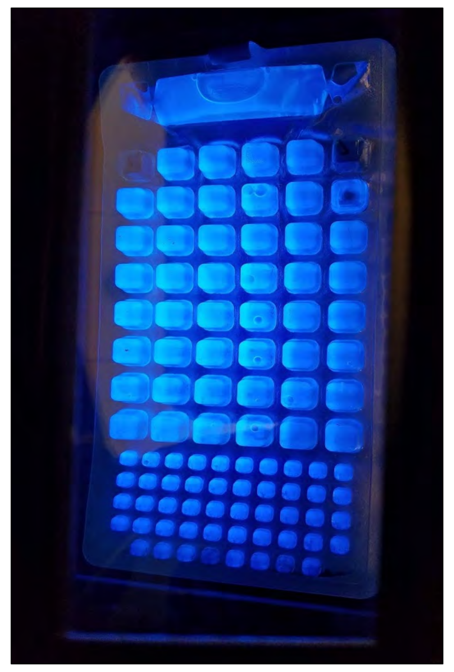


Figure 6 MnO coated sand mixtures to determine appropriate sand mixture for infiltration with minimum erosion and suspended particles.

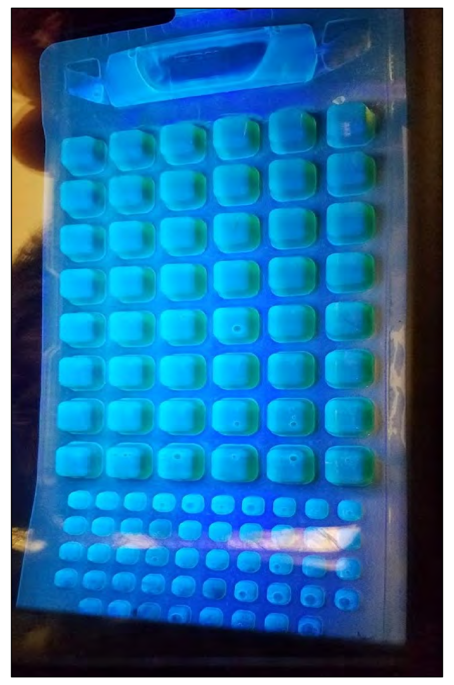
Results



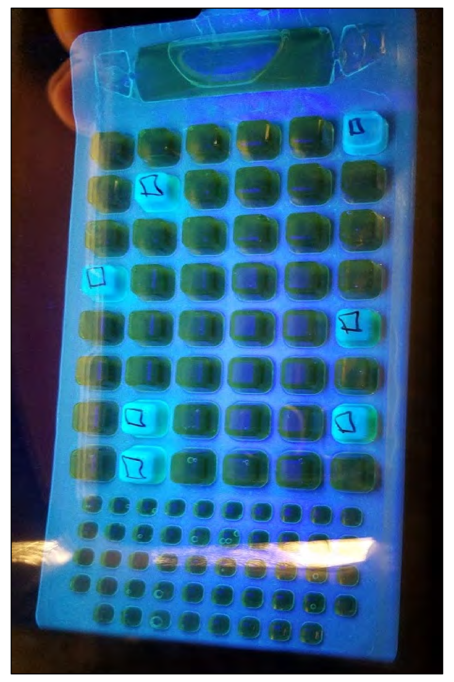
MPN (Most Probable Number Of Viable Organisms) : 961.0

MPN: 74.9

Enterococci present in untreated unfiltered street runoff before (left) and enterococci concentrations after (right) filtration through geo-filtration GAC and MnO mixed sand.



MPN: >2419.6



MPN: 7.5

E. Coli present in untreated unfiltered street runoff before (left) and E. Coli concentrations after (right) filtration through geo-filtration GAC and MnO mixed sand.

Table 1 Water quality of samples before and after geo-filtration.

Fluid	E. Coli and Total Coliform	Enterococci
Deionized Water	0	0
Unfiltered Storm Water	MPN : >2419.6	MPN: 961.0
Geo-Filtered Storm Water	MPN: 7.5	MPN: 74.9

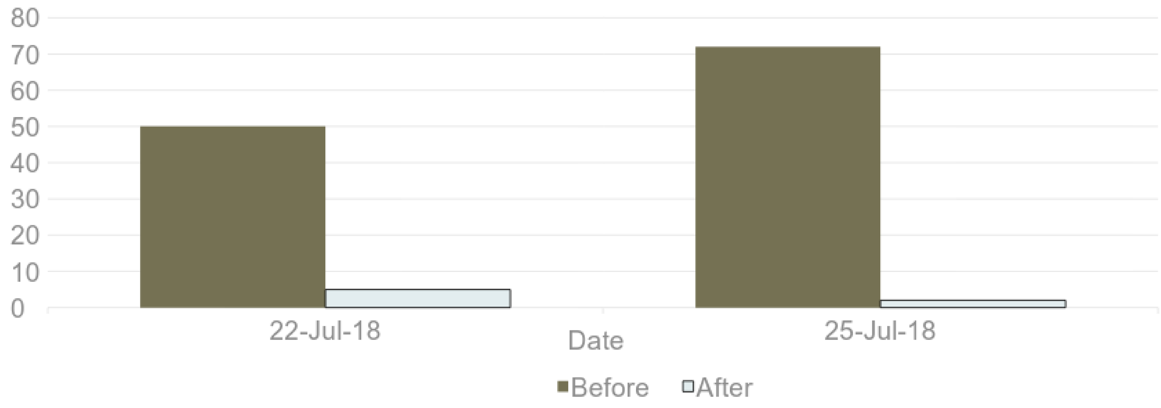


Figure 7 Turbidity (opaqueness) of water before and after geo-filtration of street runoff.

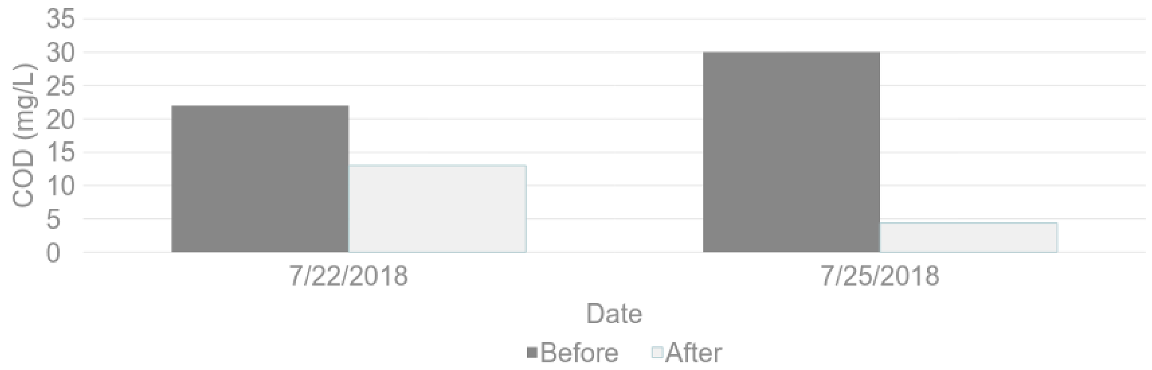


Figure 8 COD (Chemical Oxygen Demand) of water before and after geo-filtration of street runoff.

Results Cont.

Figure 9 PeP filtration (left). Tested to effectively infiltrate 5 gallons of water in 66 seconds. Measured to infiltrate at a minimum flow rate of 17.5 in^3/s. Test limited by outlet of containing bottle and effluent fluid exit area. Sand particles and debris did not affect infiltration rate. Strong thunderstorms drop 1-2" of rain. A 24 in^2 section of PeP is capable of infiltrating 2,376 in^3 volume of water in 2.26 minutes.

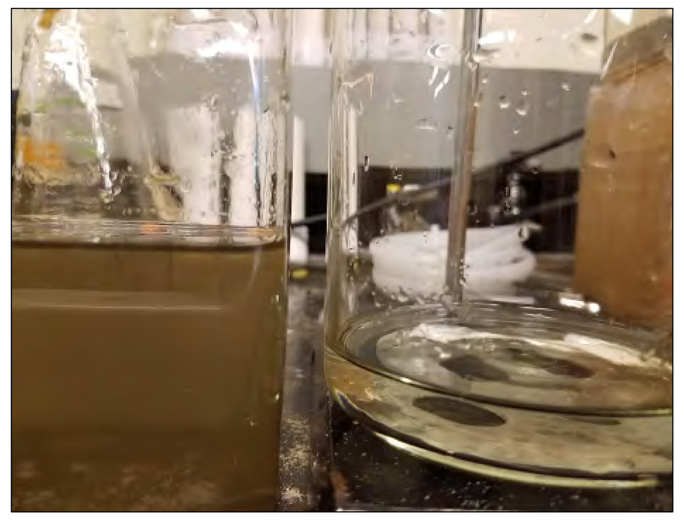


Figure 10 Raw untreated street runoff (left) and passively filtered water (right). Untreated storm water measured to have a turbidity of 50 NTU and geo-filtered storm water has a turbidity of 5 NTU. Geo-filtration layers were as follows: 25 g of MnO mixed sand, 5 g of GAC, 25 g of MnO sand, and 5 g of GAC. Columns measured 1.25" in diameter.

Findings / Discussion

- PeP measured to infiltrate 5 gallons of water in 66 seconds. Flow rate=17.5 in^3/s. Is an effective alternative to street gutters.
- 60% MnO Coated Sand to 40% untreated sand is ideal for filtration with 10 g of GAC.
- MnO mix reduces E. Coli MPN by 322x and Enterococci by 12.8x.
- GAC can be reused by heating at 550^0 C for reuse.
- Geo-Filtration drastically reduces turbidity, COD, and MPN present in street runoff.

Future Work

- Test columns of Mno, GAC, with synthetic stormwater
- Spike synthetic stormwater with Enterococci and E. Coli
- Vary inlet area to match diameter of PeP slab
- Increase effluent fluid area
- Create 5 gallon system using MnO mixture, GAC, and PeP. Test for fatigue, system breakdown, filtration erosion, performance
- Test PeP for compression and fatigue (test to see if cars can drive over slabs without deterioration)
- Test PeP for resilience against expansion and weathering due to natural elements
- Test effluent fluid for phosphorous and nitrates

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