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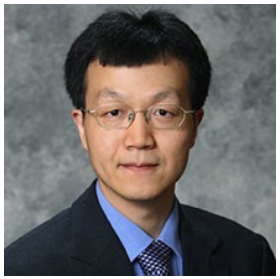
Welcome!



Removal of Escherichia Coli from Stormwater

Presented by:
Dr. Guanghui Hua

Our partners:

MOUNTAIN-PLAINS CONSORTIUM | MONTANA MDT DEPARTMENT OF TRANSPORTATION | NORTH Dakota Be Legendary. | Transportation | SD DEPARTMENT OF TRANSPORTATION | WYOMING DEPARTMENT OF TRANSPORTATION | NDSU | UPPER GREAT PLAINS TRANSPORTATION INSTITUTE TRANSPORTATION LEARNING NETWORK

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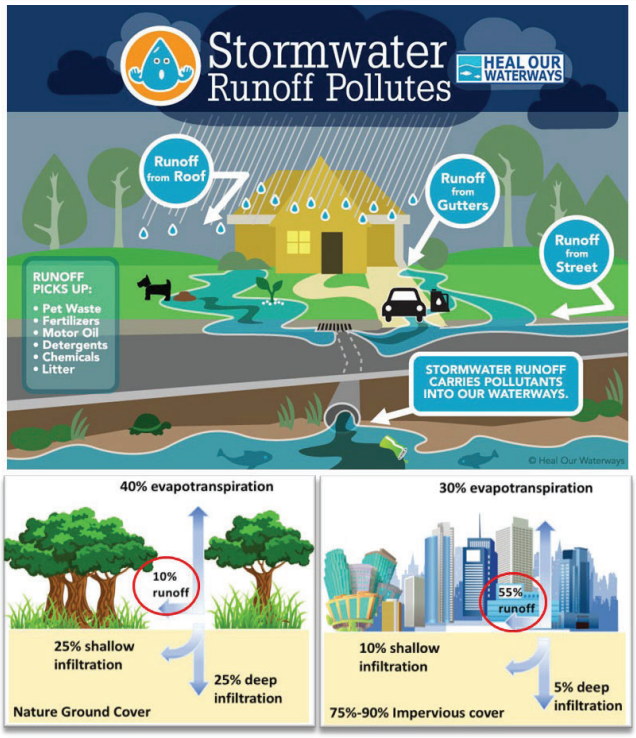
Stormwater Runoff



- Result of rain or snowmelt flowing over impervious surfaces.
- Urbanization increases area of impervious surfaces and the stormwater runoff.

Stormwater Pollution

- Nutrients (nitrate, phosphate)
- Organic chemicals
- Oil & grease
- Heavy metals (copper, zinc)
- Suspend solids
- Microorganisms (viruses, bacteria)

Stormwater Best Management Practices

1. Detention Basin (dry pond)

- Temporarily holds runoff and releases over designed time period

2. Retention Basin (wet pond)

- A permanent pool of water with vegetation around the perimeter

Stormwater volume control practices; Remove some sediments.

Stormwater Best Management Practices

3. Infiltration Basin

- Discharges stormwater into ground water. Can remove sediments.

4. Biorentention Cell

- A mix of soil and plants. Infiltrate runoff into the ground. Can remove organics and nutrients.

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Escherichia coli (E. coli) Contamination

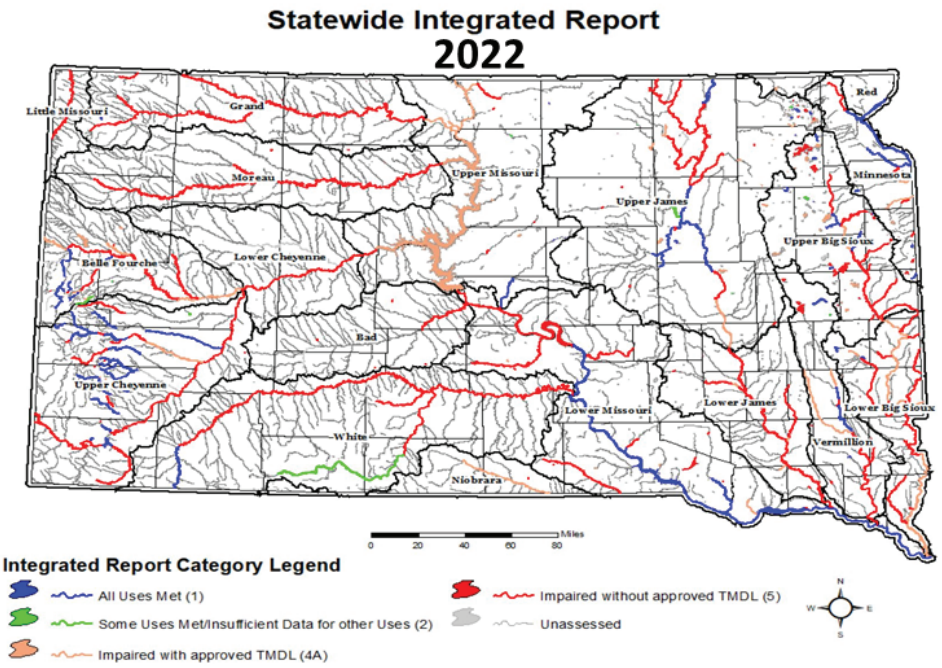
- E. coli is used an indicator of fecal contamination.
- A group of gram-negative, bacterium. Rod-shaped.
- Most types of E. coli are harmless. Some groups includes E. coli O157:H7, produce a powerful toxin.
- Symptoms of infection: diarrhea, vomiting, fever

E. Coli Recreational Water Quality Criteria

EPA's National Recommended Recreational Water Quality Criteria

Estimated Illness Rate	36 per 1000 primary contact recreators		32 per 1000 primary contact recreators	
Indicator	50th Percentile (cfu/100 mL)	90th Percentile (cfu/100 mL)	50th Percentile (cfu/100 mL)	90th Percentile (cfu/100 mL)
E. Coli	126	410	100	320

SD Surface Water Quality



78.2% of the assessed stream miles did not support one or more assigned beneficial uses

E. coli in Big Sioux River

- E. coli is a major contaminant in Big Sioux River, Eastern SD.
- Urban stormwater runoff can be a significant source of bacteria contamination. Runoff E. coli could reach 10,000 MPN/100 mL (most probable number).

New Stormwater Treatment Technology

Media Filtration Using Permeable Reactive Materials

- Low cost, low maintenance treatment technology.
- Permeable reactive materials can remove multiple contaminants: nutrients, heavy metals, bacteria, organic compounds and others.
- Zeolite, calcite, limestone, iron products, steel slags, woodchips, tire crumbles, biochar, drinking water treatment residuals etc.

Field Scale Stormwater Filters

Steel Slag Filter

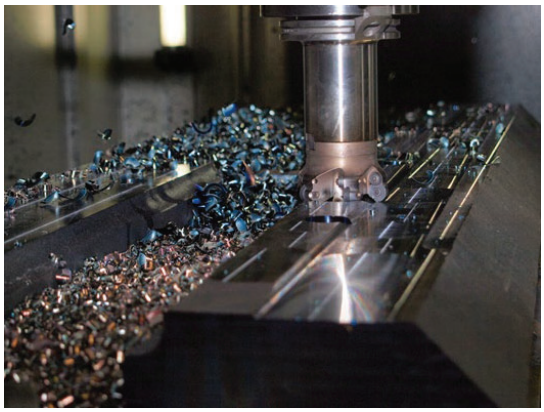
Stillwater Country Club, OK

Iron Sand Filter

Prior Lake, MN

- Reactive media filtration has been developed to remove phosphate from stormwater.

Filter Material: Recycled Steel Chips



- Steel chips and turnings: byproducts produced from steel making, machining, cutting, and grinding processes.
- Steel chips can develop iron oxides on surface for water treatment.

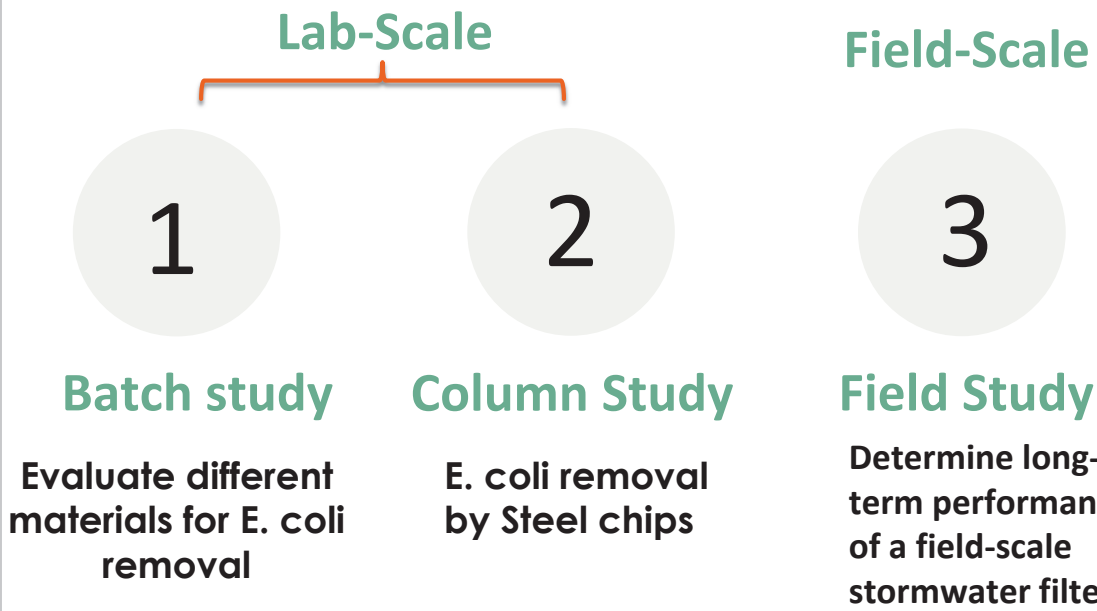
Filter Material: Steel Slag

- A by-product of steel making. Contains iron oxides and magnesium oxides.
- Produced during the separation of the molten steel from impurities in steel-making furnace.
- Good material for road construction. Good adsorption capacity for phosphate.

Project Objectives

- Develop a low-maintenance, low-cost media filtration system for stormwater treatment using recycled steel byproducts.
- Evaluate E. coli removal efficiency of recycled steel byproducts.
- Determine long-term performance of a field-scale stormwater filter.

Project Scope



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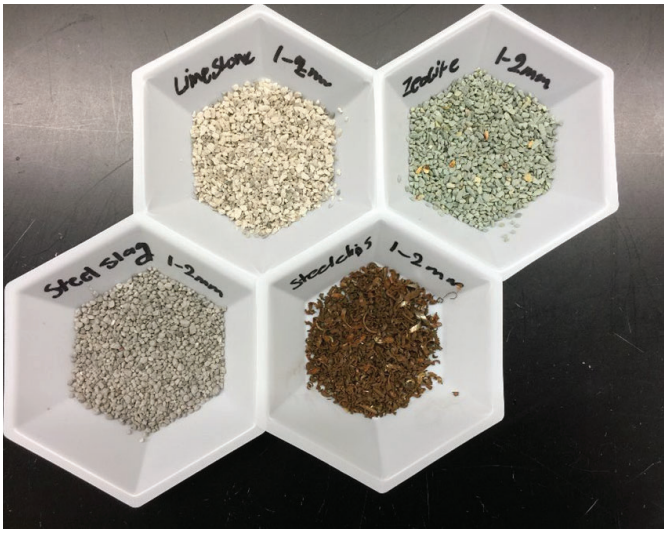
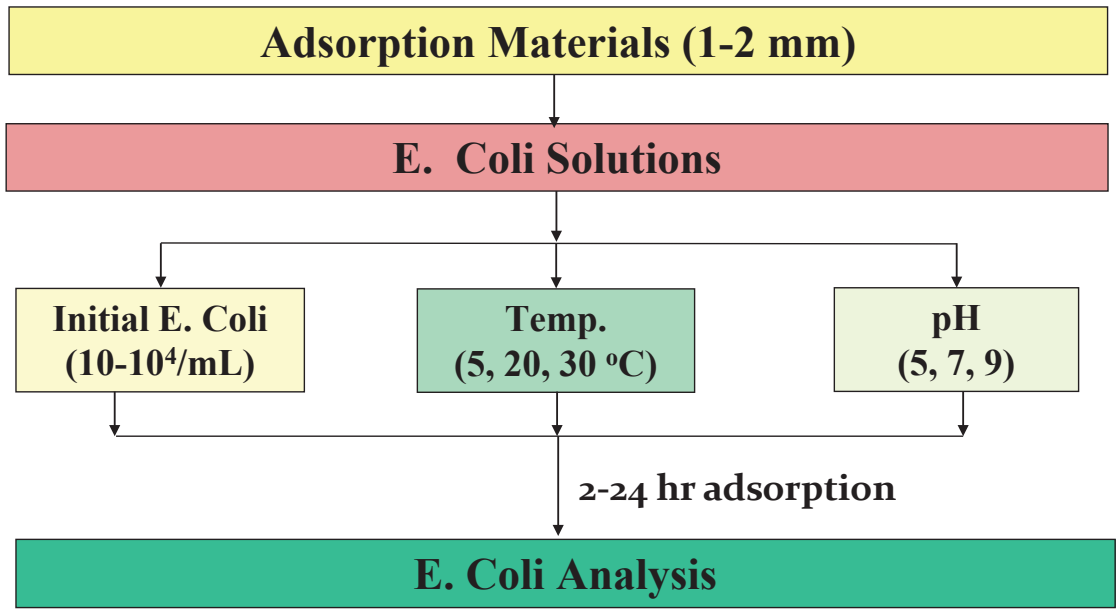
Batch Experiment Materials



Steel Chips: Sioux Falls, SD and Marshall, MN
Steel Slag: Nucor Corporation, NE
Limestone, Zeolite

Batch Experiment Design



Batch Adsorption Experiment Equipment

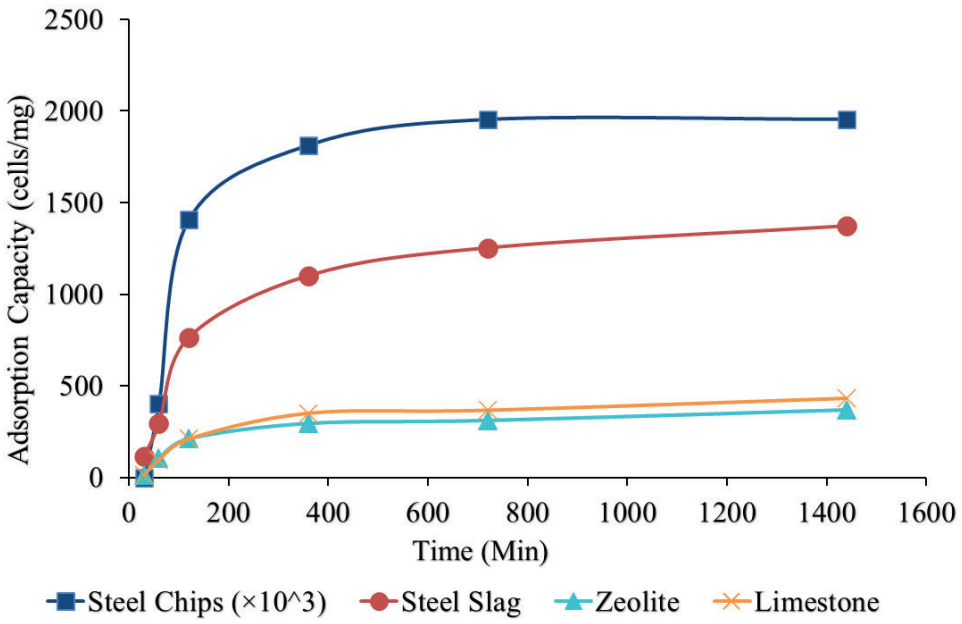
Shaker

Centrifuge

Sample Sealer

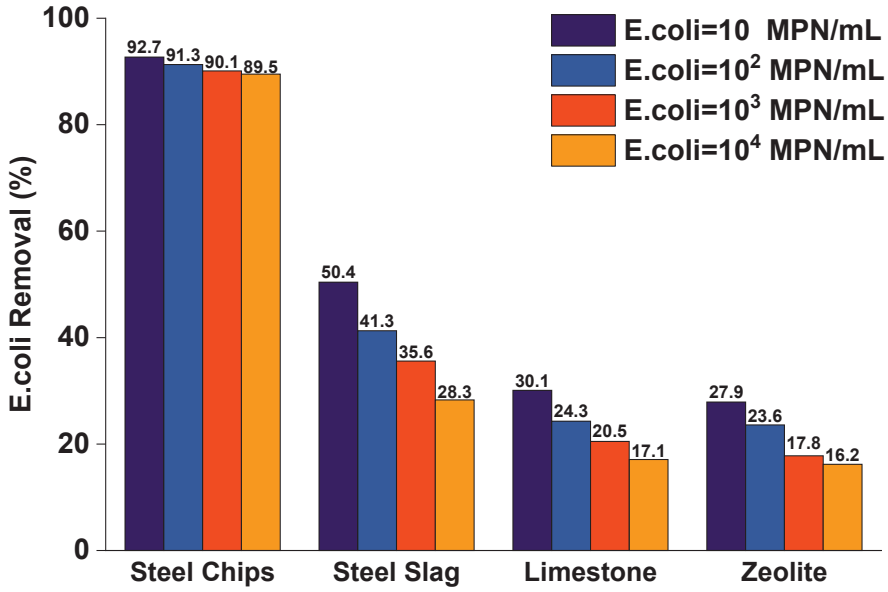
IDEXX Colilert Kit

E. coli Adsorption Kinetics



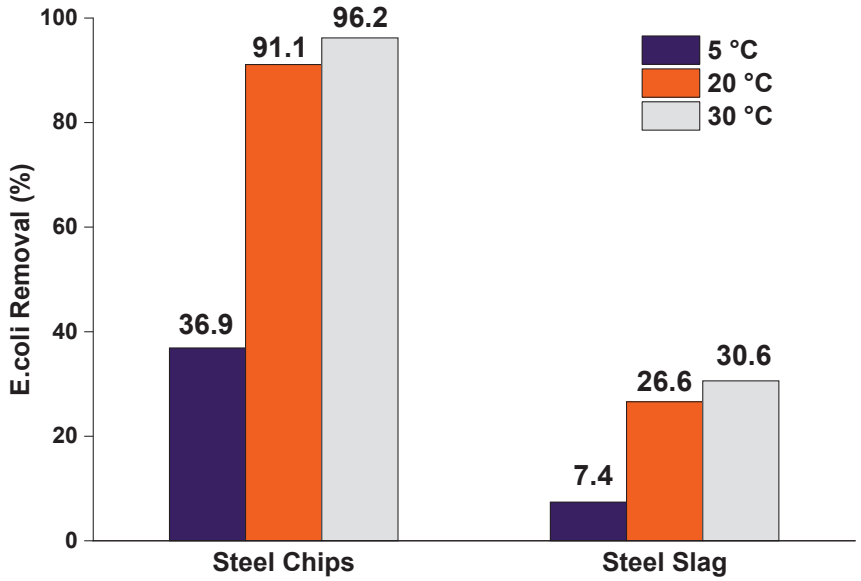
More than 80% of the 24 h adsorption completed in 6 hours.

E. coli removal: Initial Concentrations



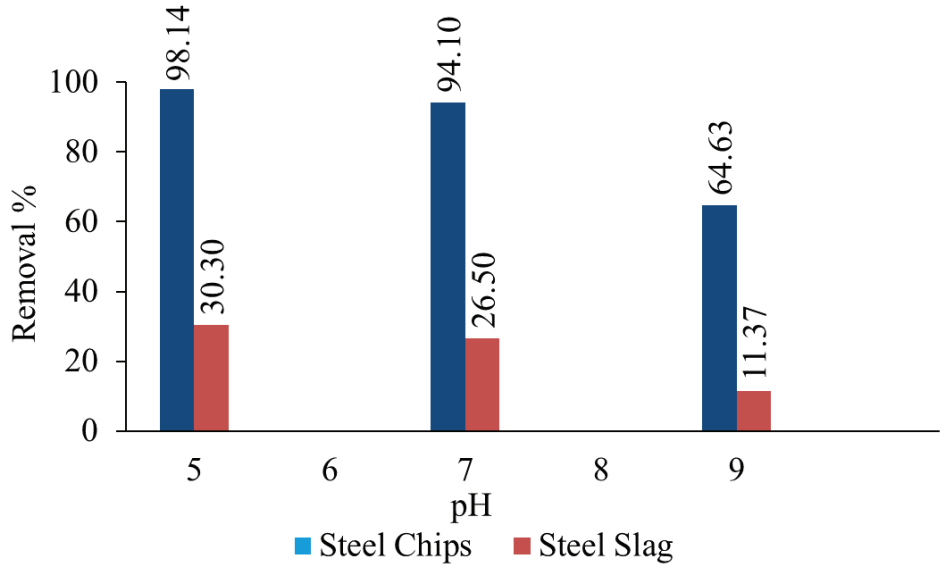
E. Coli Removal: Steel chips >> Steel slag > Limestone > Zeolite

E. coli removal: Temperature Impact



E. Coli Removal: 30 °C > 20 °C >> 5 °C

E. coli removal: pH Impact

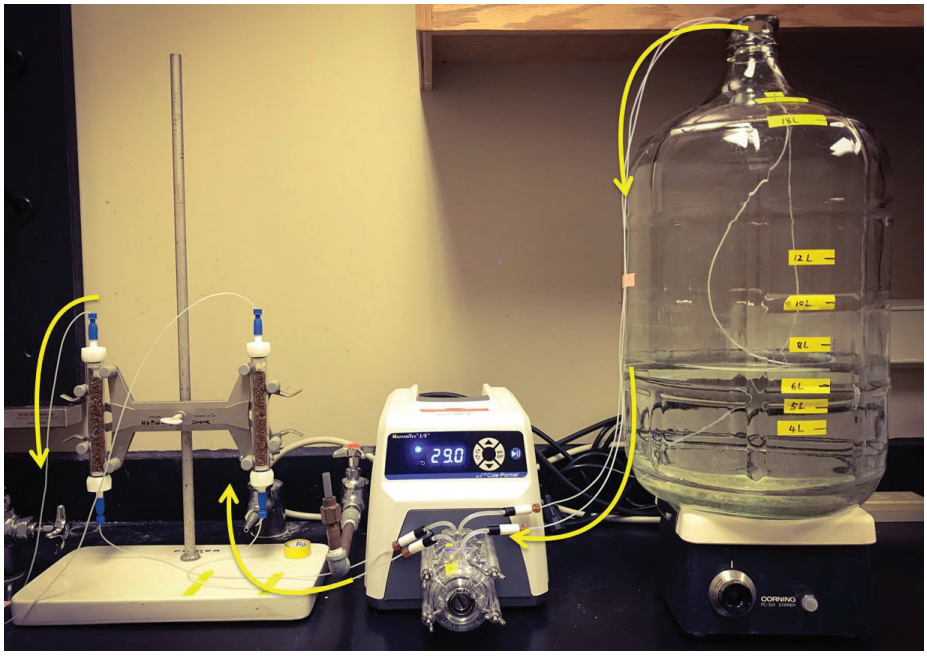


E. Coli Removal: pH 5 > pH 7 >> pH 9

Batch Experiment Summary

- E. coli adsorption capacity follows the order of Steel chips >> Steel slag > Limestone > Zeolite.
- Steel chips exhibited 1000 times higher E. coli adsorption capacity than other materials.
- E. coli adsorption by steel chips and steel slag increased with increasing temperatures but decreasing pH values.

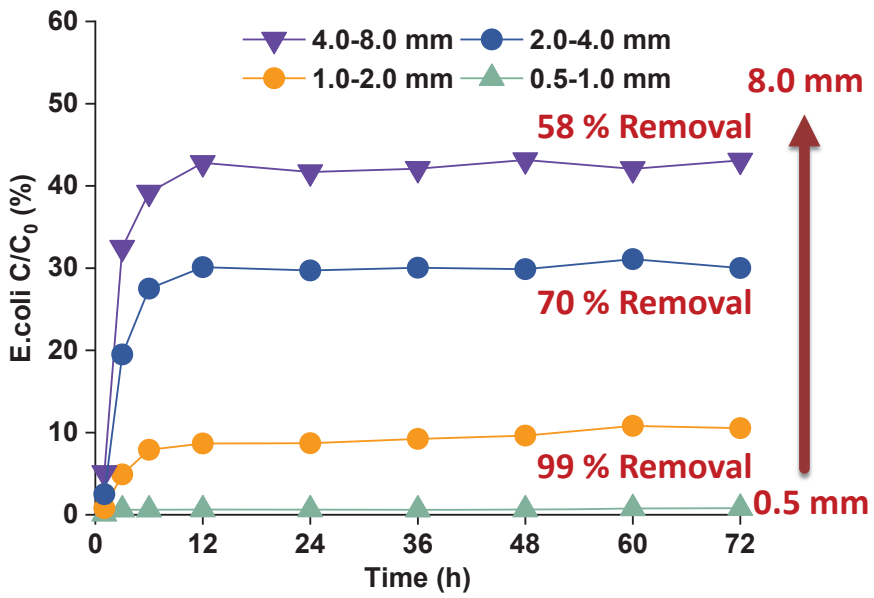
Column Adsorption Experiment



Column Experiment Materials

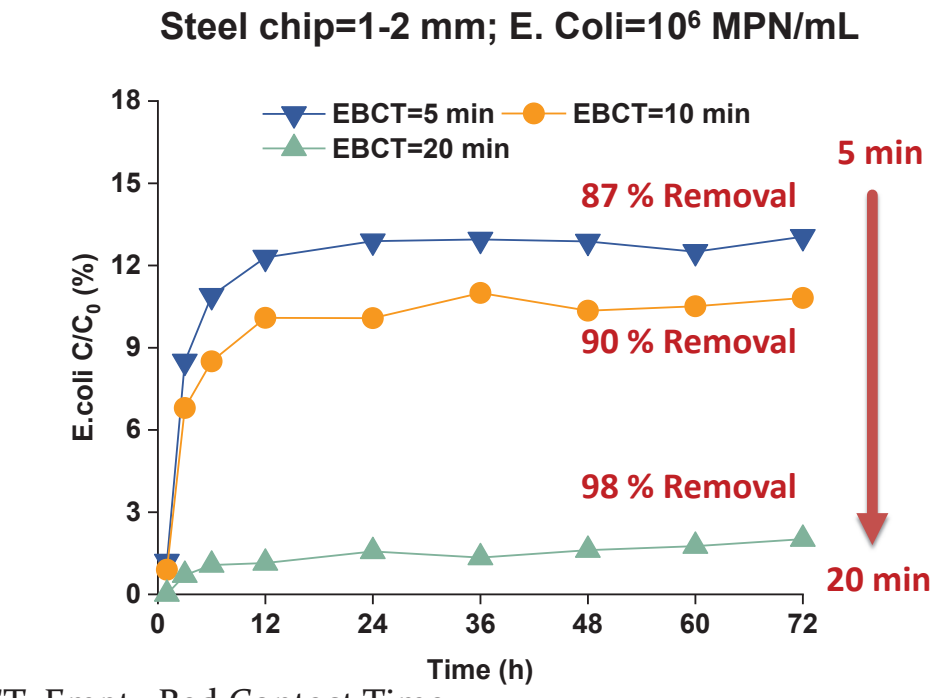
Steel Chips (0.5-1, 1-2, 2-4 and 4-8 mm)

Column Experiment: Impact of Sizes



Steel chips with smaller sizes removed more E. coli.

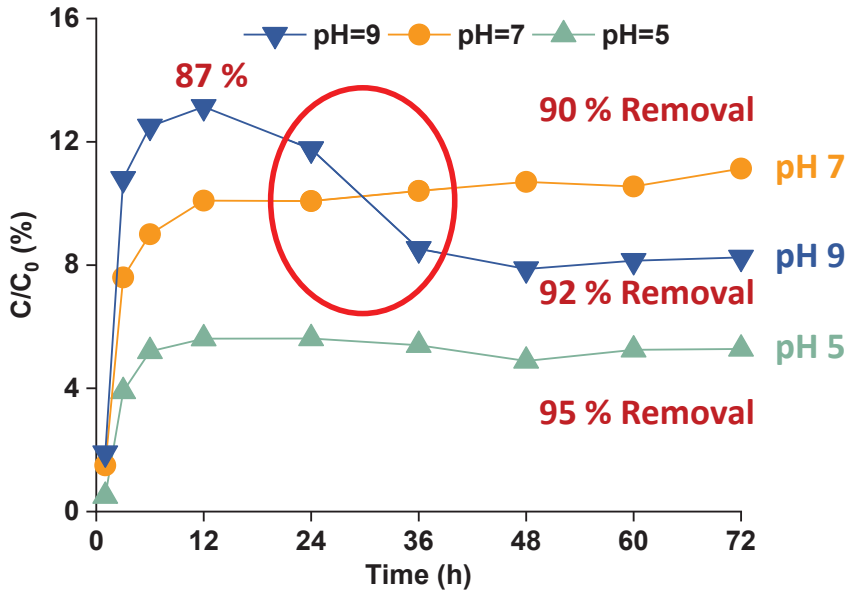
Column Experiment: Impact of Contact Time



EBCT: Empty Bed Contact Time

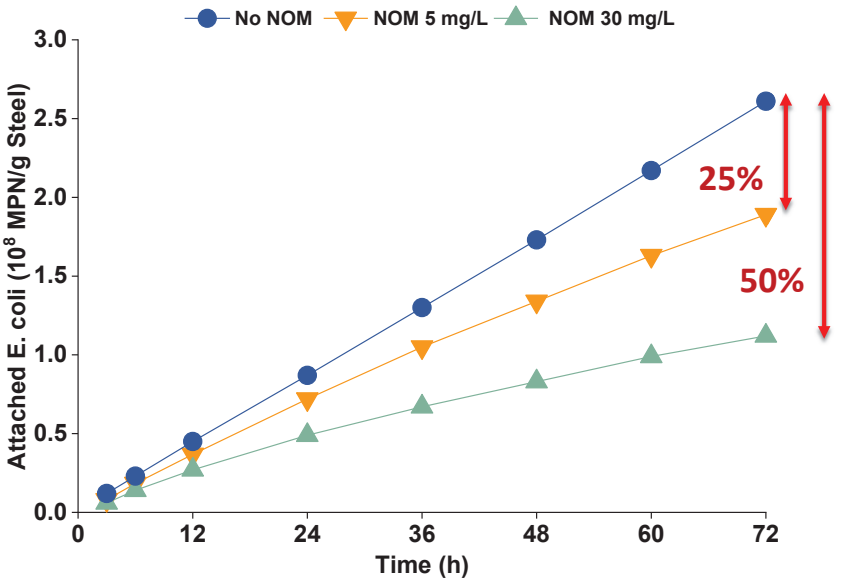
Longer contact time improved E. coli removal

Column Experiment: Impact of pH



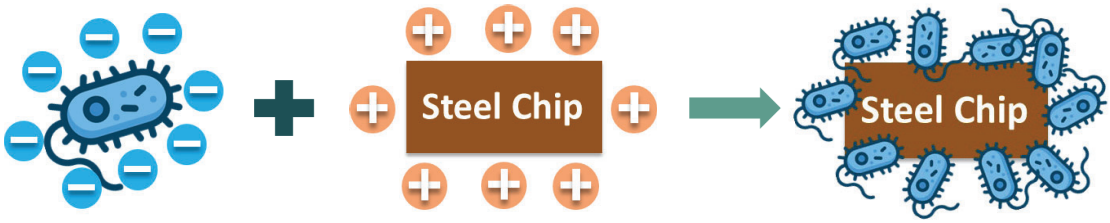
Acidity environment favored the E. coli removal.
Fe (III) coagulation at pH 9 improved E. coli removal.

Column Experiment: Impact of Natural Organic Matter (NOM)



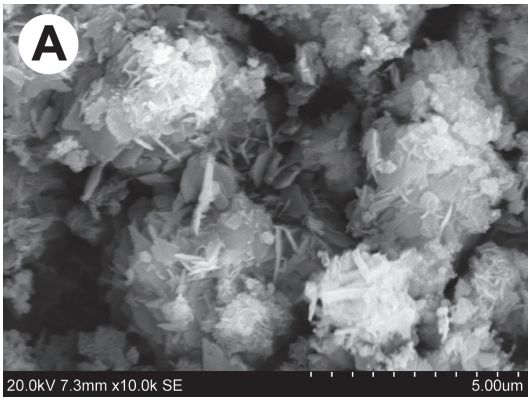
Competitive adsorption existed between E. Coli and NOM.
E. coli removal decreased by 25-50% in the presence of NOM.

E. Coli Removal Mechanism

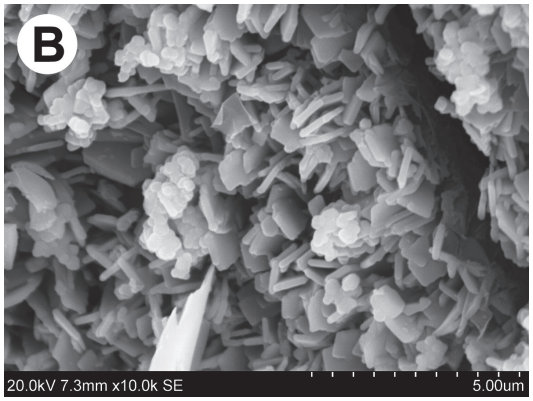


- OH^- competes for adsorption sites.
- NOM completes for adsorption sites.

Steel Chip Scanning Electron Microscopy



Steel chip surface before experiment

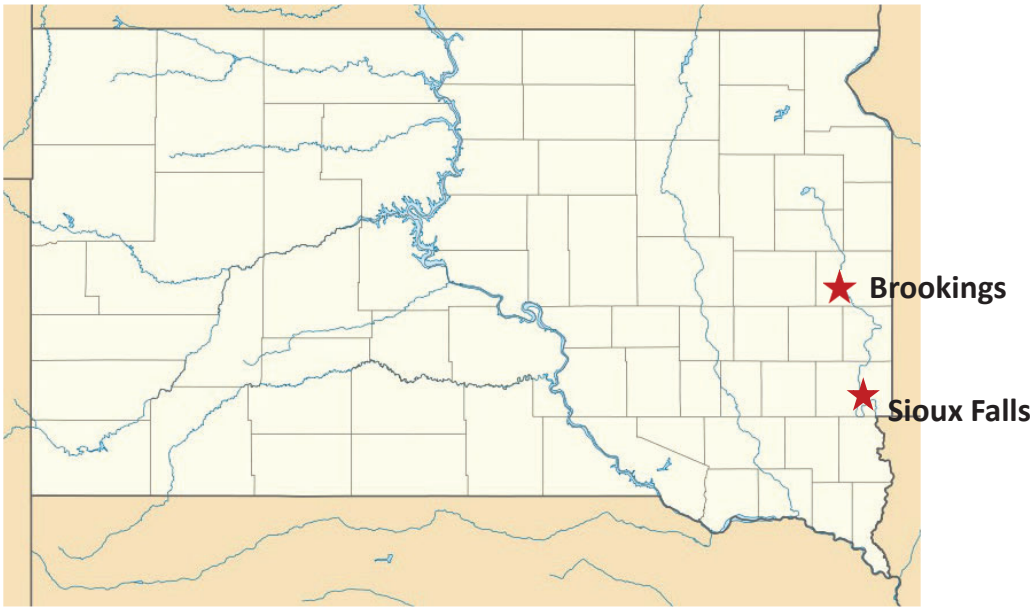


Steel chip surface after experiment

Column Experiment Summary

- Steel chip columns maintained steady E. coli removal up to 72 hours.
- Steel chip columns exhibited better E. coli adsorption under conditions of small sizes, long contact times and low pH levels.
- Organic matter negatively affected E. coli adsorption.

Field Scale Study – Brookings SD



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Field Scale Filter Installation Site

A residential detention pond that has 16-acre drainage basin.

Field Scale Filter Installation Site

Field Scale Filtration Study Materials

Field Scale Filtration Study Materials

- Steel Slag
  - Nucor Steel, Norfolk, NE.
  - Large Steel Slag (4-9.4mm)
  - Small Steel Slag (2-4mm)

- Steel Chips
  - Alter Metal Recycling, Marshall, MN.
  - Large Steel Chips (4-9.4mm)
  - Small Steel Chips (2-4mm)

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Field Scale Filter Construction

- Filter Dimensions
  - Height = 8 inches
  - Length = 6 Feet
  - Width = 5 feet
- Retention time
  - 13-50 seconds

Filter Installation

Filter in A Storm Event

Stormwater Field Filter Experiments

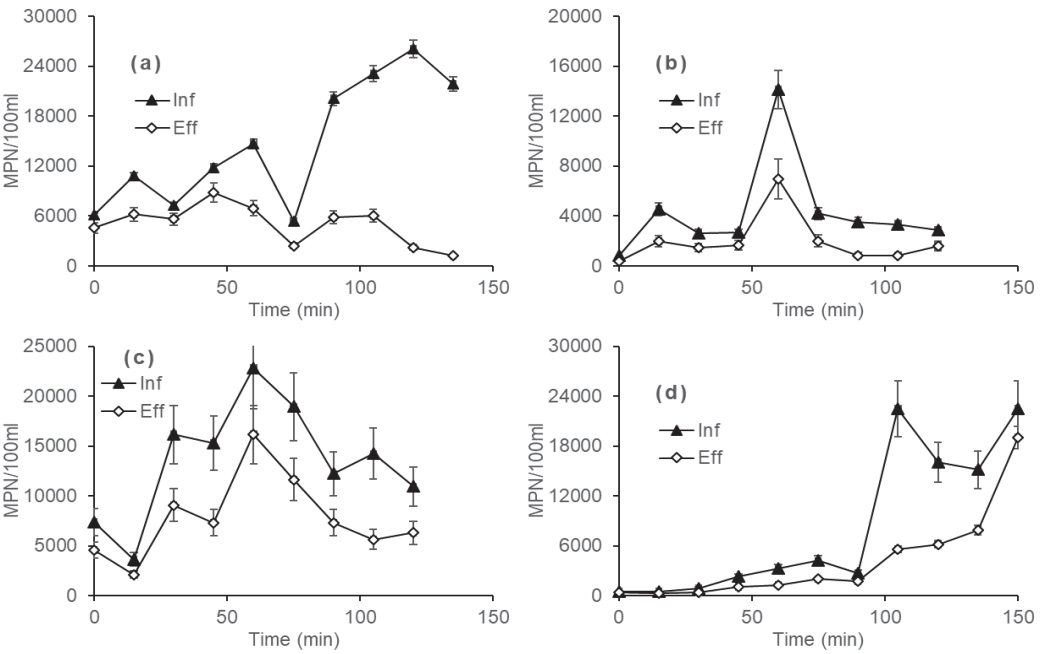
2018

Filter Materials:
70% steel chips
30% steel slag

2019-2020

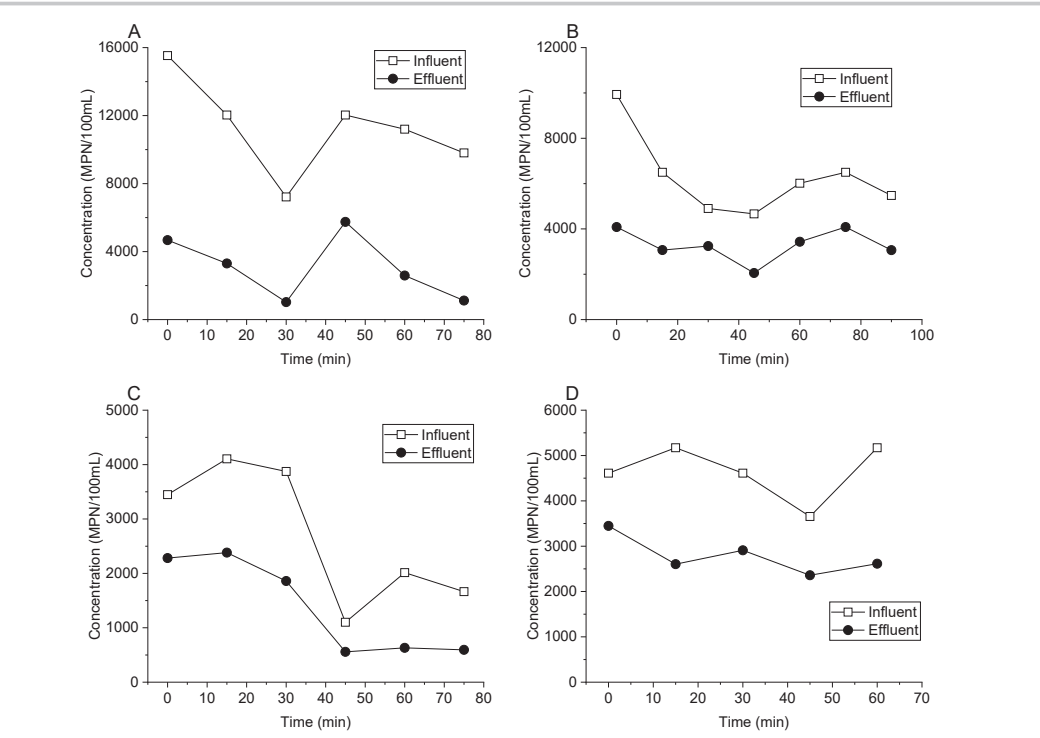
Filter Materials:
50% steel chips
50% steel slag

E. coli Removal - 2018



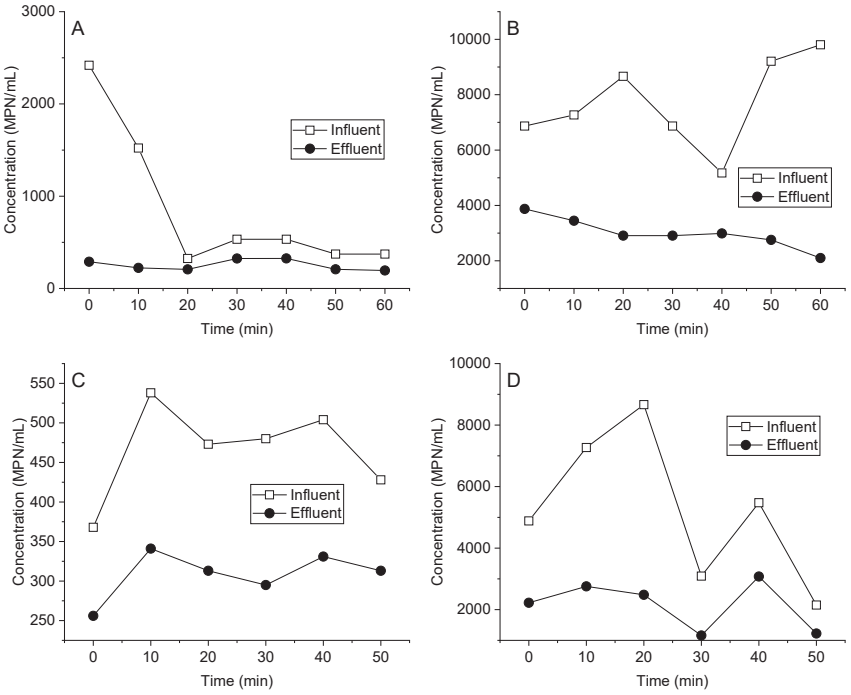
- Average E. Coli Removal: 52%

E. coli Removal - 2019



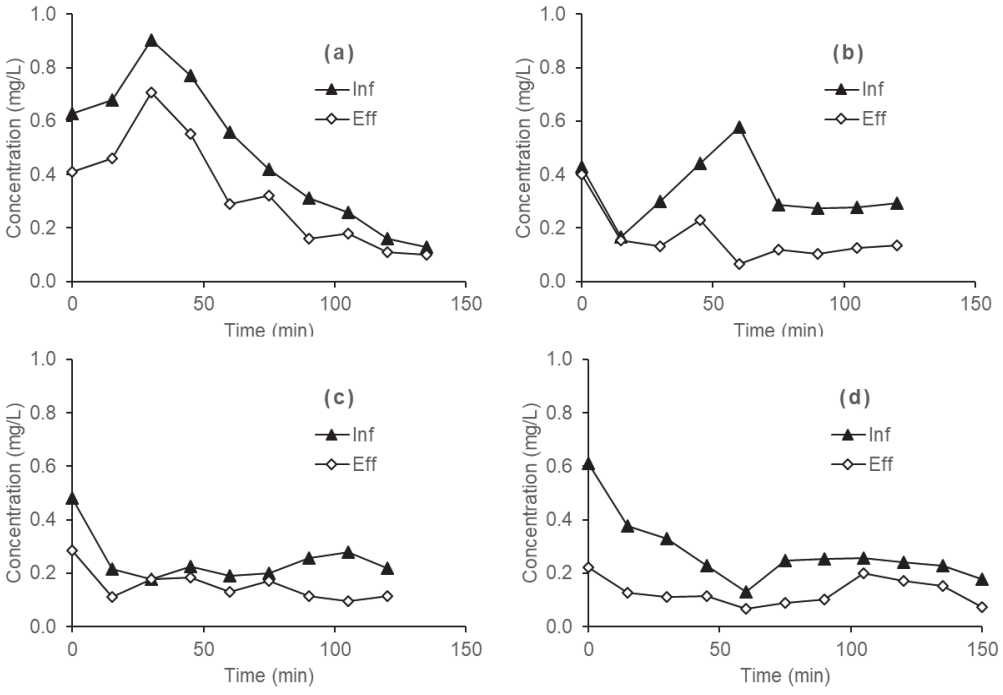
- Average E. Coli Removal: 53%

E. coli Removal - 2020



- Average E. Coli Removal: 54%

Filter Phosphate Removal-2020



- Average Phosphate Removal: 51%

Conclusions

- Steel chips showed much higher E. coli removal capacity than steel slag, limestone, and zeolite.
- Steel chip/steel slag filter removed about 50% of the E. coli and 50% of the phosphate during the 3-year field study.
- Recycled steel byproducts are efficient filter materials for E. coli and phosphate removal from stormwater runoff.

Acknowledgements

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James River Water Development District
City of Brookings (Pilot Study Location)

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On-going Research Project

A pilot scale filter will be installed at a stormwater site in Sioux Falls, SD.

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Thank you for participating!

Please take a moment to complete the evaluation included in the reminder email.

We appreciate your feedback.

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