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Evaluation of New Technology for Real-Time Detection of Illicit Connections in Storm Drains

Brown AND Caldwell

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Agenda

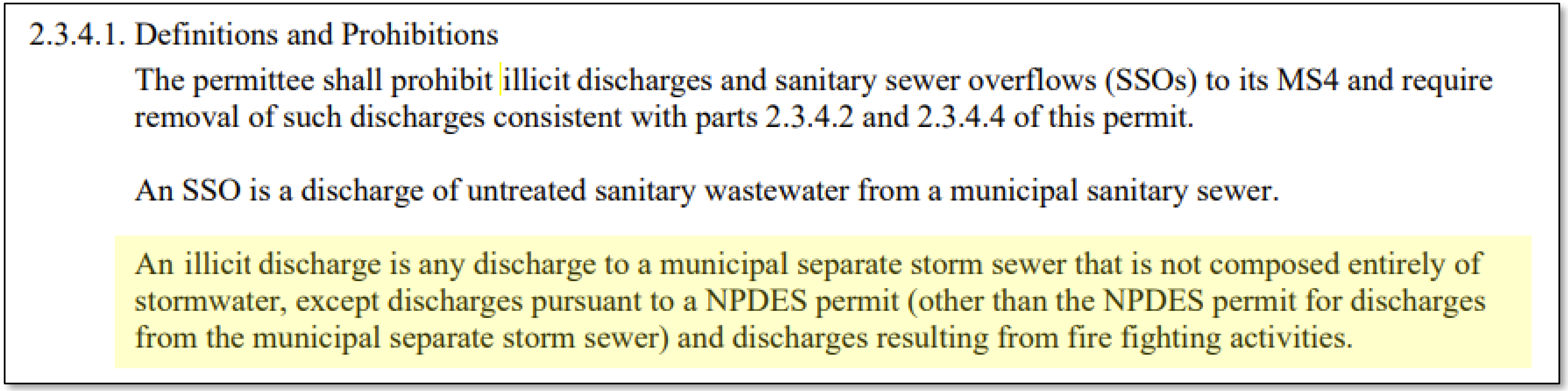
- Illicit source tracking procedures
- Excitation emission matrix (EEM) analysis
- EEM analysis of waters from various sources
- Potential of EEM analysis for illicit source tracking

Illicit Source Tracking Procedures

Illicit Discharge Detection and Elimination (IDDE) is a program for finding and removing ‘illicit’ discharge to storm drains

Photo Credit: Gerick Bergsma 2008 | Marine Photobank

What are illicit discharges?



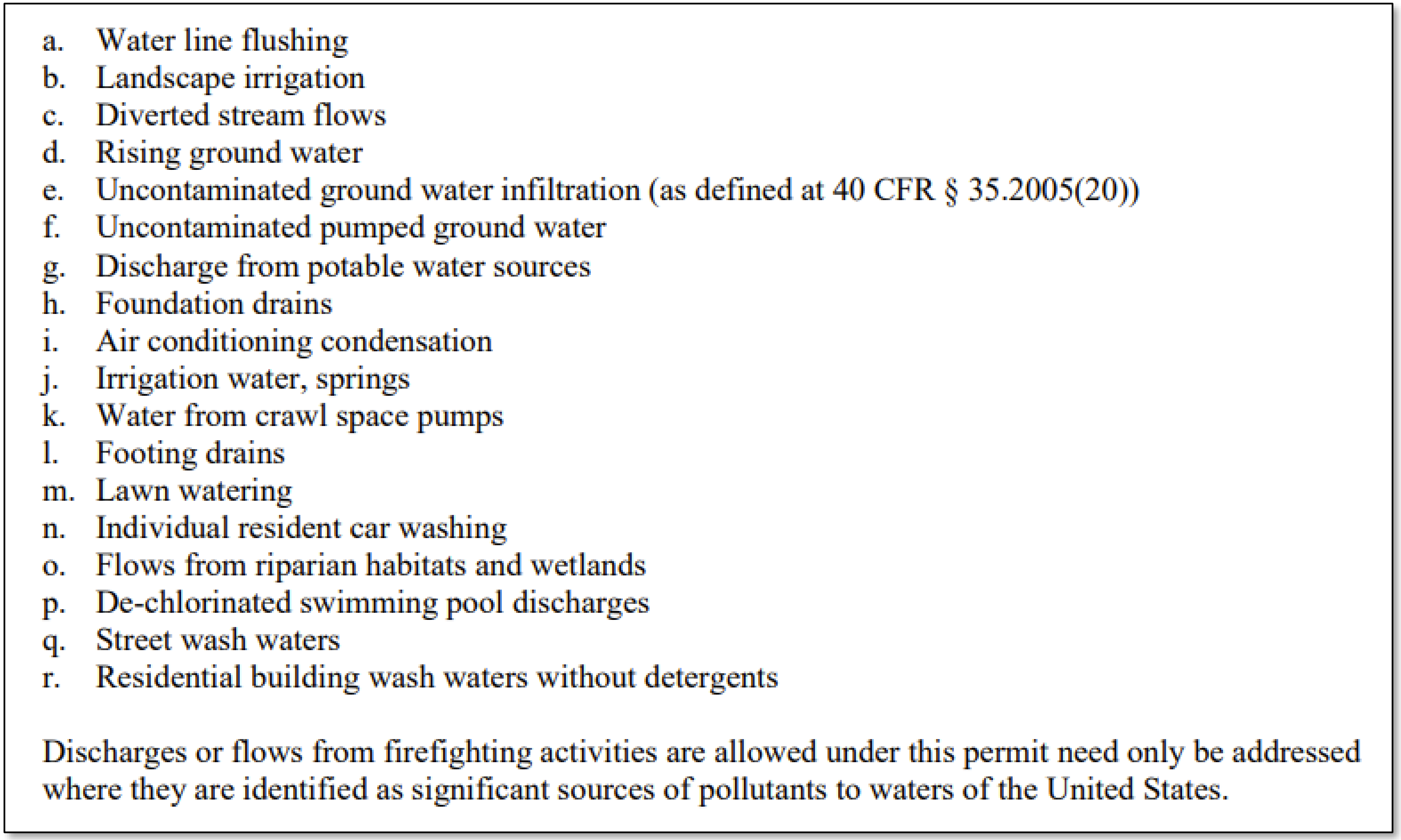
2.3.4.1. Definitions and Prohibitions

The permittee shall prohibit illicit discharges and sanitary sewer overflows (SSOs) to its MS4 and require removal of such discharges consistent with parts 2.3.4.2 and 2.3.4.4 of this permit.

An SSO is a discharge of untreated sanitary wastewater from a municipal sanitary sewer.

An illicit discharge is any discharge to a municipal separate storm sewer that is not composed entirely of stormwater, except discharges pursuant to a NPDES permit (other than the NPDES permit for discharges from the municipal separate storm sewer) and discharges resulting from fire fighting activities.

Generally, don’t need to worry about these discharges to storm drains…



a. Water line flushing
b. Landscape irrigation
c. Diverted stream flows
d. Rising ground water
e. Uncontaminated ground water infiltration (as defined at 40 CFR § 35.2005(20))
f. Uncontaminated pumped ground water
g. Discharge from potable water sources
h. Foundation drains
i. Air conditioning condensation
j. Irrigation water, springs
k. Water from crawl space pumps
l. Footing drains
m. Lawn watering
n. Individual resident car washing
o. Flows from riparian habitats and wetlands
p. De-chlorinated swimming pool discharges
q. Street wash waters
r. Residential building wash waters without detergents

Discharges or flows from firefighting activities are allowed under this permit need only be addressed where they are identified as significant sources of pollutants to waters of the United States.

Primary concern is sewage


Photo Credit: Matthias Rosenkranz

Sewage discharged to storm drains enters receiving water bodies without treatment

How to find illicit discharges?

- Outfall screening/sampling
- Upstream source tracking

Outfall screening/sampling

- Typically performed during dry weather
- Visual/olfactory observations
- Water quality testing
  - Bacteria
  - Ammonia
  - Surfactants
  - Chlorine

Upstream source tracking

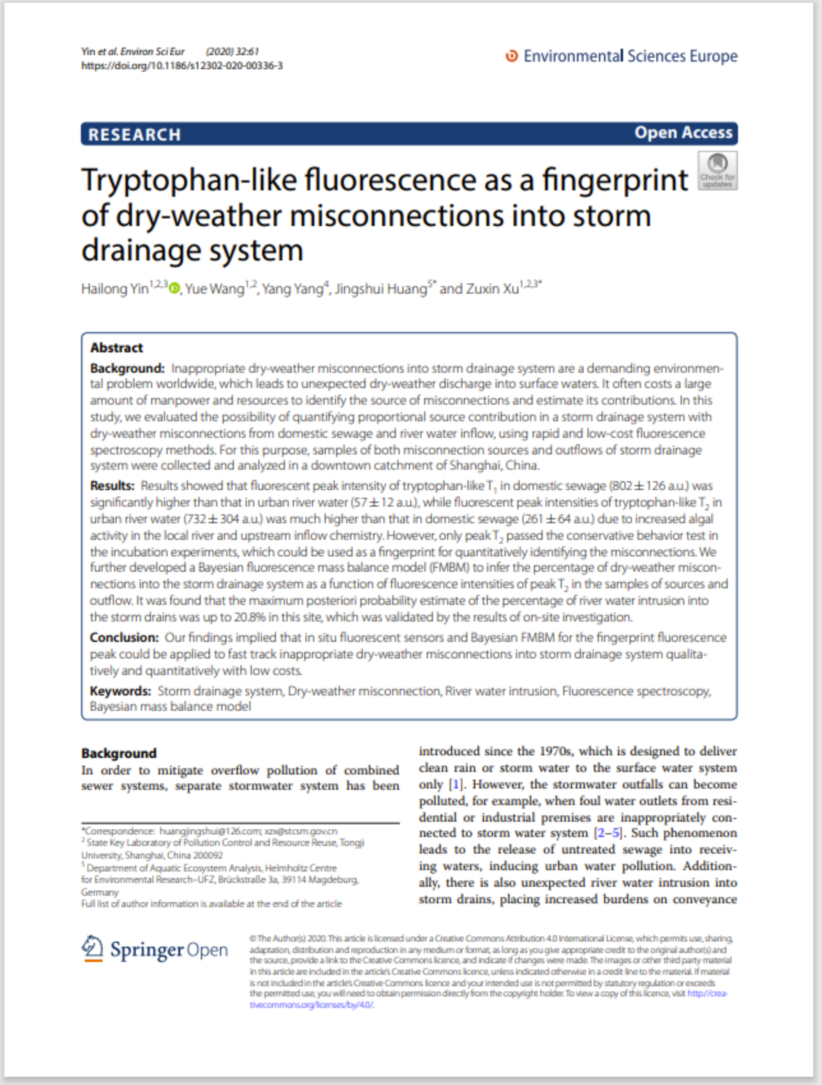
- Different approaches
  - Top-down
  - Bottom-up
- Key junction manholes
  - Performed during dry weather
  - Visual/olfactory observations
  - Water quality testing
    - Ammonia
    - Surfactants
    - Chlorine

Additional measures for real-time detection of sewage contamination are needed

- Illicit source tracking
- Water quality monitoring (e.g., beach closures)

Excitation Emission Matrix Analysis

Researchers have been studying the optical fluorescence of water samples to identify sewage contamination



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Environmental Sciences Europe

RESEARCH **Open Access**

Tryptophan-like fluorescence as a fingerprint of dry-weather misconnections into storm drainage system

Hailong Yin[1,2,3], Yue Wang[1,2], Yang Yang[4], Jingshui Huang[5*] and Zuxin Xu[1,2,3*]

Abstract

Background: Inappropriate dry-weather misconnections into storm drainage system are a demanding environmental problem worldwide, which leads to unexpected dry-weather discharge into surface waters. It often costs a large amount of manpower and resources to identify the source of misconnections and estimate its contributions. In this study, we evaluated the possibility of quantifying proportional source contribution in a storm drainage system with dry-weather misconnections from domestic sewage and river water inflow, using rapid and low-cost fluorescence spectroscopy methods. For this purpose, samples of both misconnection sources and outflows of storm drainage system were collected and analyzed in a downtown catchment of Shanghai, China.

Results: Results showed that fluorescent peak intensity of tryptophan-like T_1 in domestic sewage (802 ± 126 a.u.) was significantly higher than that in urban river water (57 ± 12 a.u.), while fluorescent peak intensities of tryptophan-like T_2 in urban river water (732 ± 304 a.u.) was much higher than that in domestic sewage (261 ± 64 a.u.) due to increased algal activity in the local river and upstream inflow chemistry. However, only peak T_2 passed the conservative behavior test in the incubation experiments, which could be used as a fingerprint for quantitatively identifying the misconnections. We further developed a Bayesian fluorescence mass balance model (FMBM) to infer the percentage of dry-weather misconnections into the storm drainage system as a function of fluorescence intensities of peak T_2 in the samples of sources and outflow. It was found that the maximum posteriori probability estimate of the percentage of river water intrusion into the storm drains was up to 20.8% in this site, which was validated by the results of on-site investigation.

Conclusion: Our findings implied that in situ fluorescent sensors and Bayesian FMBM for the fingerprint fluorescence peak could be applied to fast track inappropriate dry-weather misconnections into storm drainage system qualitatively and quantitatively with low costs.

Keywords: Storm drainage system, Dry-weather misconnection, River water intrusion, Fluorescence spectroscopy, Bayesian mass balance model

Background

In order to mitigate overflow pollution of combined sewer systems, separate stormwater system has been introduced since the 1970s, which is designed to deliver clean rain or storm water to the surface water system only [1]. However, the stormwater outfalls can become polluted, for example, when foul water outlets from residential or industrial premises are inappropriately connected to storm water system [2–5]. Such phenomenon leads to the release of untreated sewage into receiving waters, inducing urban water pollution. Additionally, there is also unexpected river water intrusion into storm drains, placing increased burdens on conveyance

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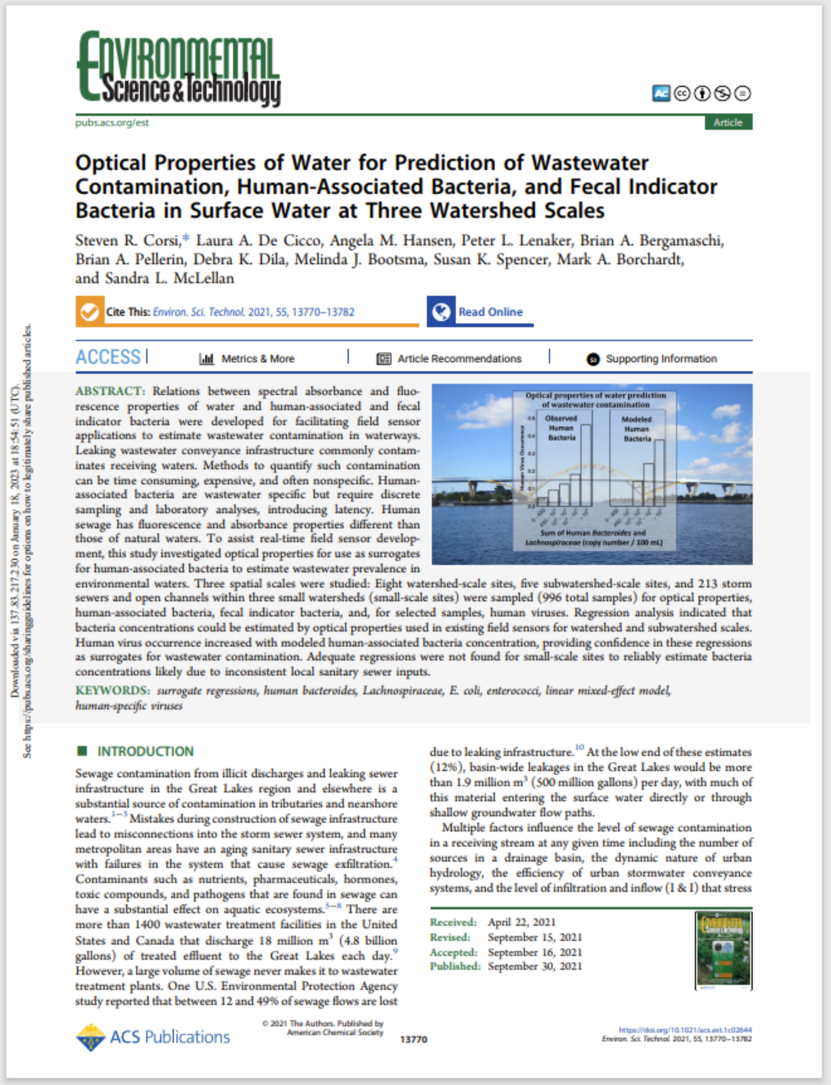

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Article

Optical Properties of Water for Prediction of Wastewater Contamination, Human-Associated Bacteria, and Fecal Indicator Bacteria in Surface Water at Three Watershed Scales

Steven R. Corsi,* Laura A. De Cicco, Angela M. Hansen, Peter L. Lenaker, Brian A. Bergamaschi, Brian A. Pellerin, Debra K. Dila, Melinda J. Bootsma, Susan K. Spencer, Mark A. Borchardt, and Sandra L. McLellan

Cite This: *Environ. Sci. Technol.* 2021, 55, 13770–13782

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ABSTRACT: Relations between spectral absorbance and fluorescence properties of water and human-associated and fecal indicator bacteria were developed for facilitating field sensor applications to estimate wastewater contamination in waterways. Leaking wastewater conveyance infrastructure commonly contaminates receiving waters. Methods to quantify such contamination can be time consuming, expensive, and often nonspecific. Human-associated bacteria are wastewater specific but require discrete sampling and laboratory analyses, introducing latency. Human sewage has fluorescence and absorbance properties different than those of natural waters. To assist real-time field sensor development, this study investigated optical properties for use as surrogates for human-associated bacteria to estimate wastewater prevalence in environmental waters. Three spatial scales were studied: Eight watershed-scale sites, five subwatershed-scale sites, and 213 storm sewers and open channels within three small watersheds (small-scale sites) were sampled (996 total samples) for optical properties, human-associated bacteria, fecal indicator bacteria, and, for selected samples, human viruses. Regression analysis indicated that bacteria concentrations could be estimated by optical properties used in existing field sensors for watershed and subwatershed scales. Human virus occurrence increased with modeled human-associated bacteria concentration, providing confidence in these regressions as surrogates for wastewater contamination. Adequate regressions were not found for small-scale sites to reliably estimate bacteria concentrations likely due to inconsistent local sanitary sewer inputs.

KEYWORDS: *surrogate regressions, human bacteroides, Lachnospiraceae, E. coli, enterococci, linear mixed-effect model, human-specific viruses*

INTRODUCTION

Sewage contamination from illicit discharges and leaking sewer infrastructure in the Great Lakes region and elsewhere is a substantial source of contamination in tributaries and nearshore waters.[1−3] Mistakes during construction of sewage infrastructure lead to misconnections into the storm sewer system, and many metropolitan areas have an aging sanitary sewer infrastructure with failures in the system that cause sewage exfiltration.[4] Contaminants such as nutrients, pharmaceuticals, hormones, toxic compounds, and pathogens that are found in sewage can have a substantial effect on aquatic ecosystems.[5−8] There are more than 1400 wastewater treatment facilities in the United States and Canada that discharge 18 million m^3 (4.8 billion gallons) of treated effluent to the Great Lakes each day.[9] However, a large volume of sewage never makes it to wastewater treatment plants. One U.S. Environmental Protection Agency study reported that between 12 and 49% of sewage flows are lost due to leaking infrastructure.[10] At the low end of these estimates (12%), basin-wide leakages in the Great Lakes would be more than 1.9 million m^3 (500 million gallons) per day, with much of this material entering the surface water directly or through shallow groundwater flow paths.

Multiple factors influence the level of sewage contamination in a receiving stream at any given time including the number of sources in a drainage basin, the dynamic nature of urban hydrology, the efficiency of urban stormwater conveyance systems, and the level of infiltration and inflow (I & I) that stress

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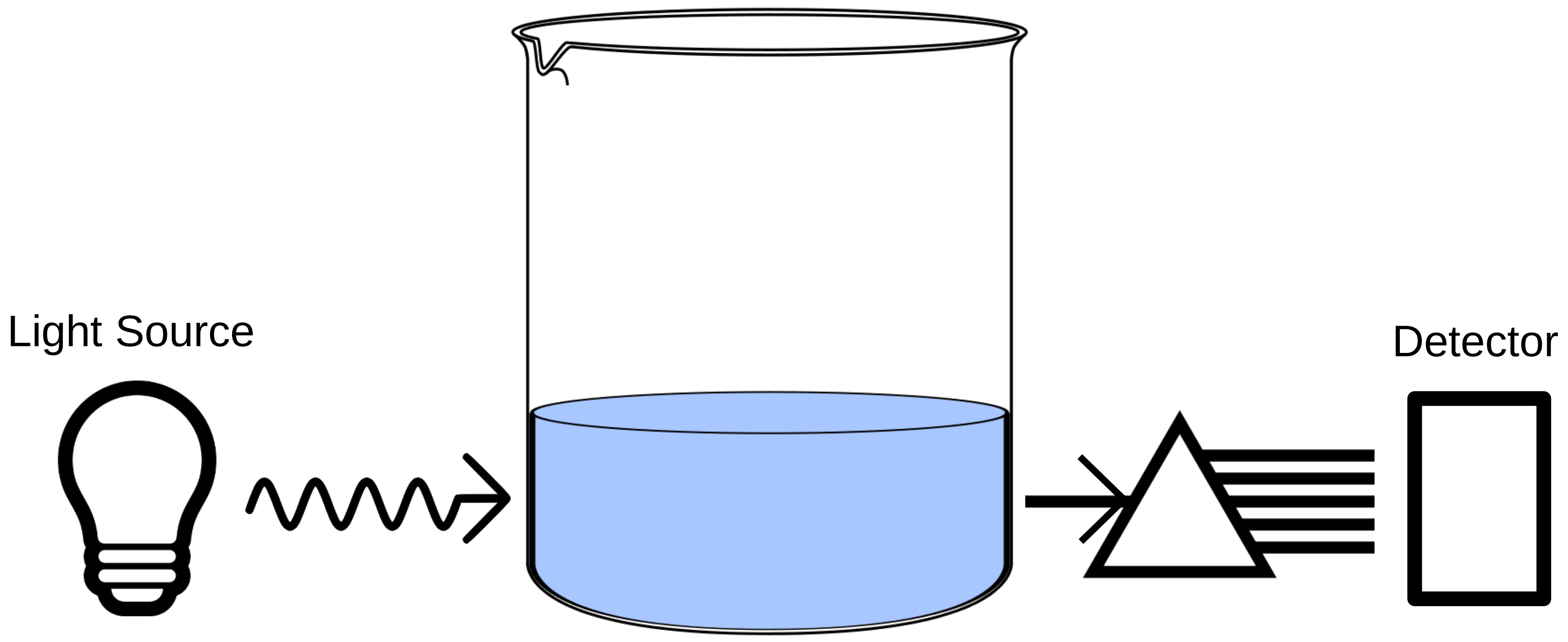
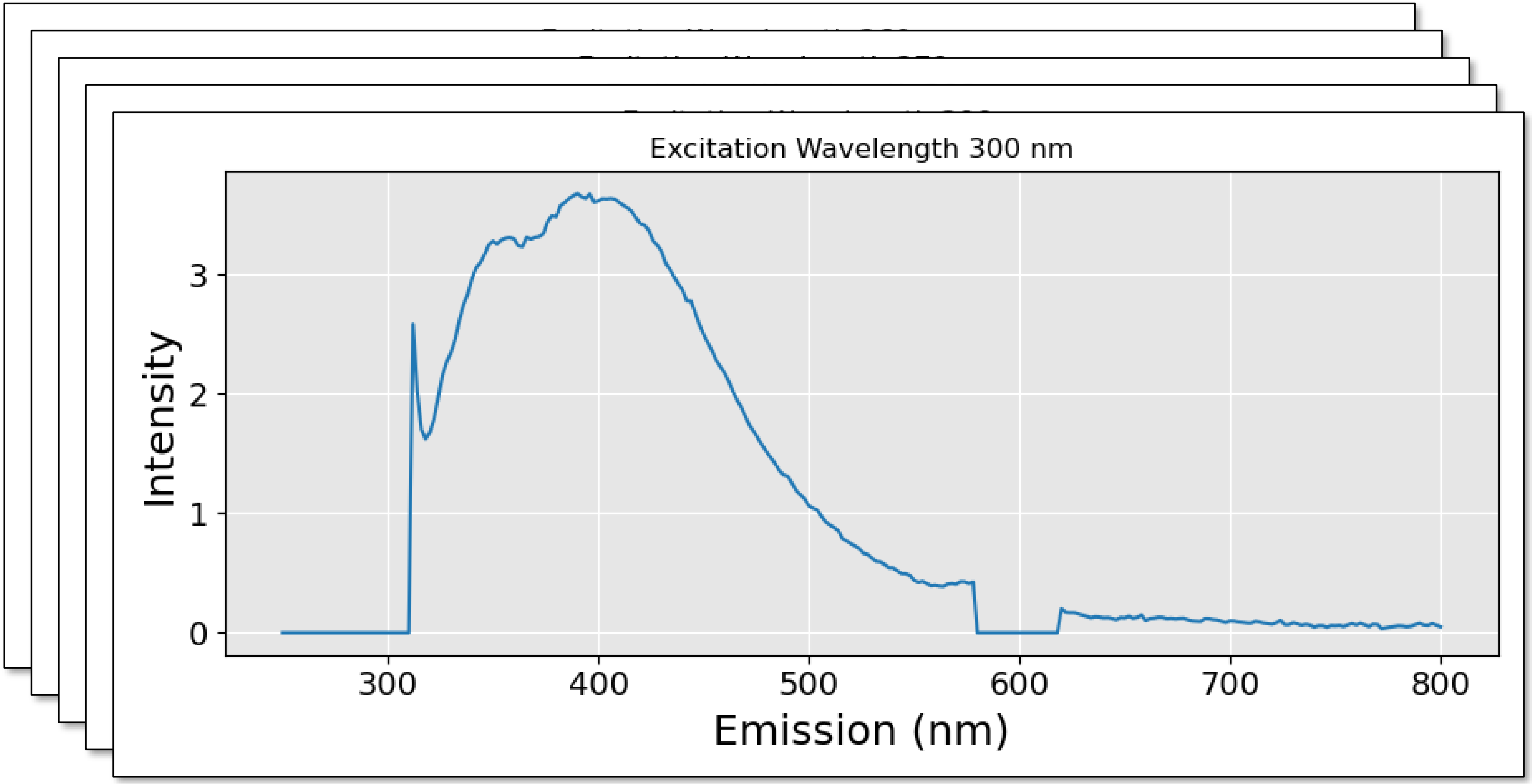
Remember black light posters?

Source: ADDWOI blacklight tapestries, amazon.com

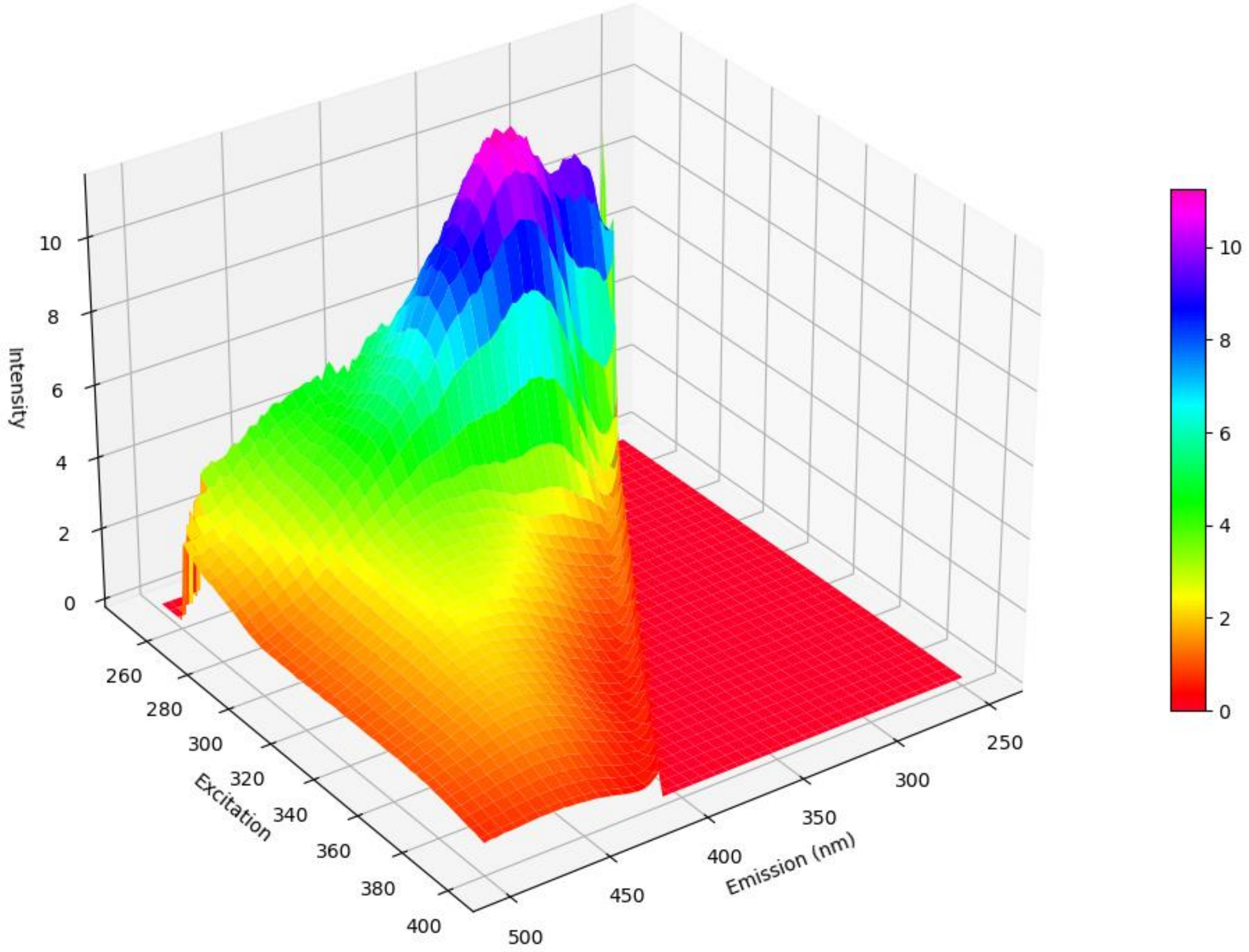
EEM captures the fluorescent fingerprint of a water quality sample



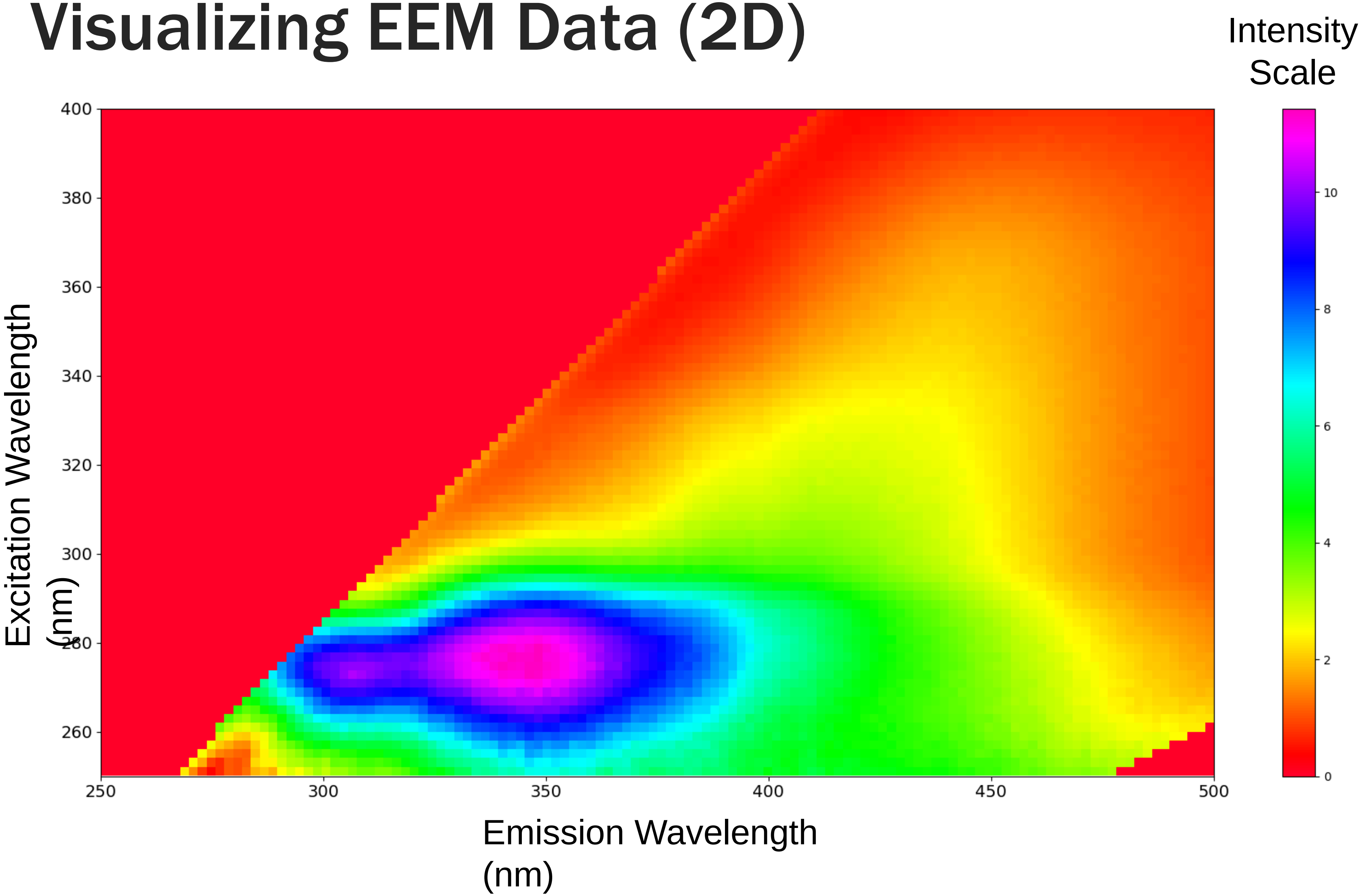
Measure emissions after exciting with specific wavelength of light



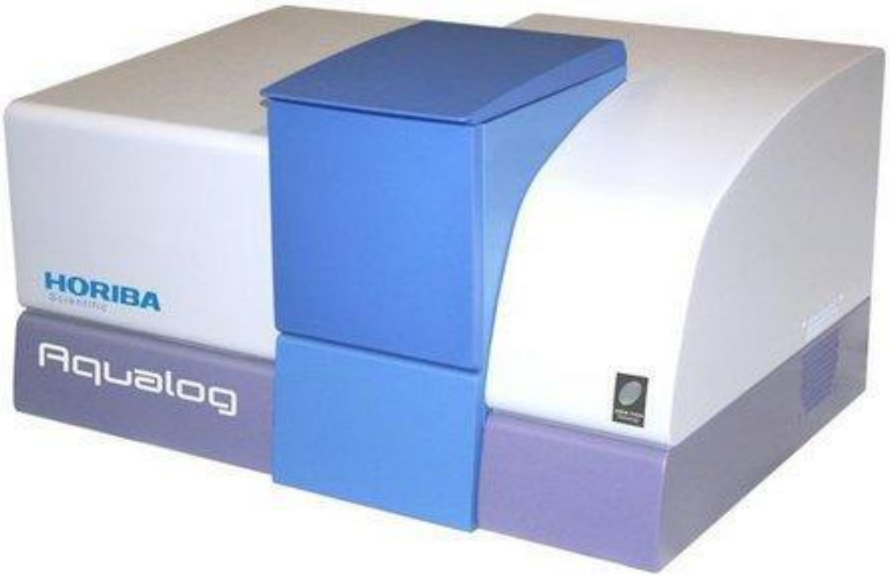
Visualizing EEM Data (3D)



Visualizing EEM Data (2D)



EEM Analyzers

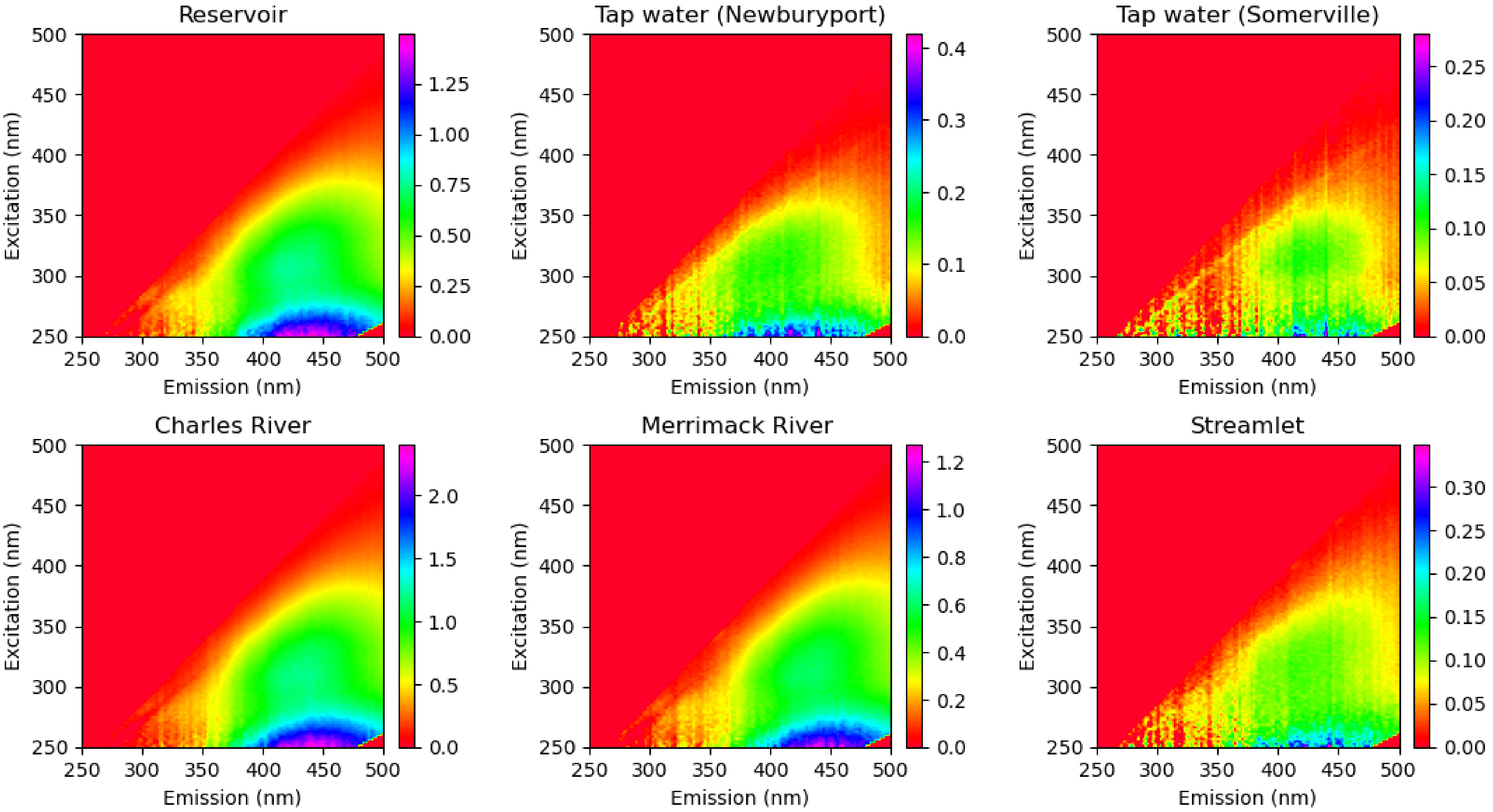


Horiba Aqualog
Desktop Analyzer

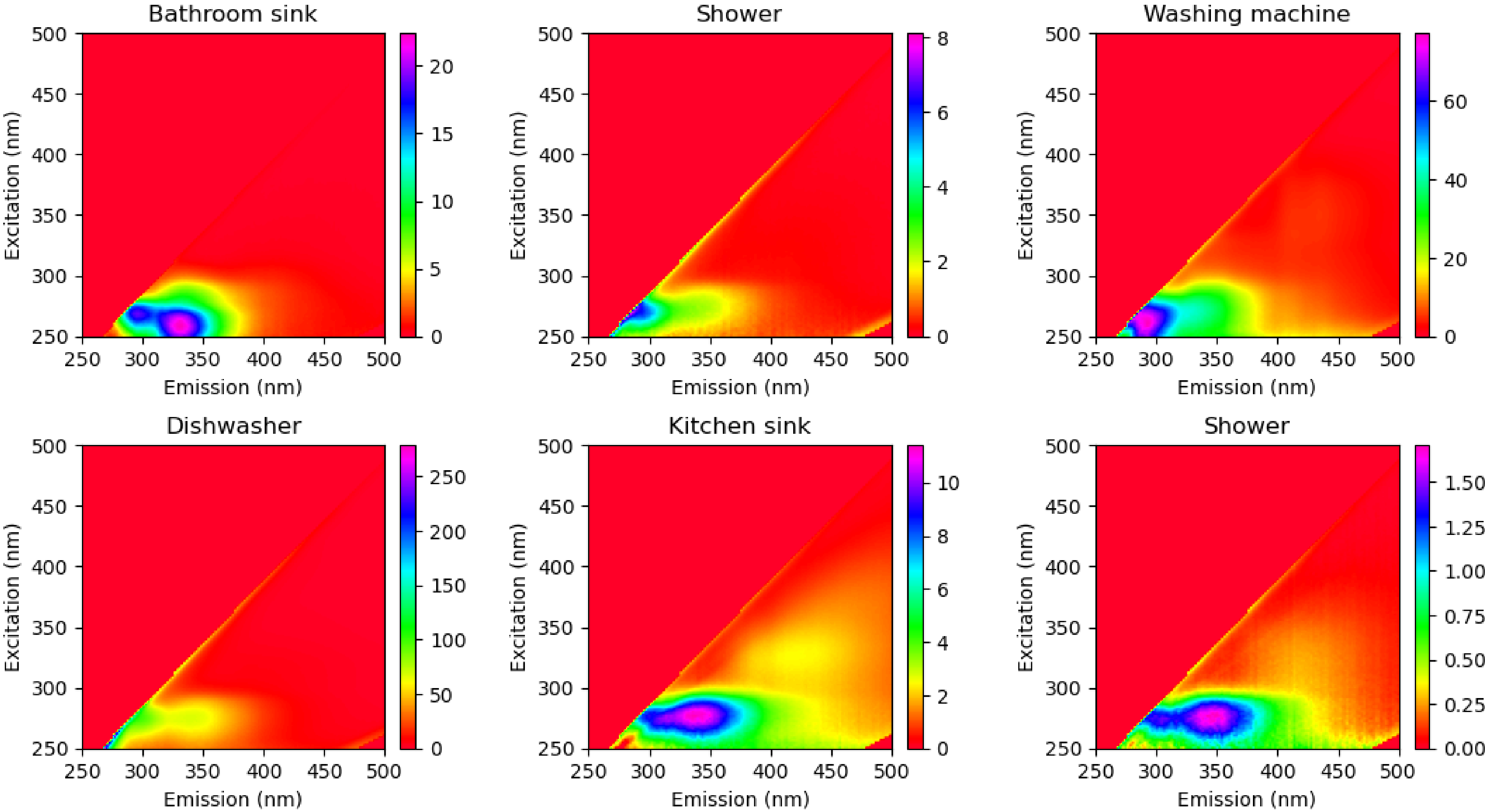
Horiba Duetta
Portable Analyzer

Image source: Horiba website (www.horiba.com)

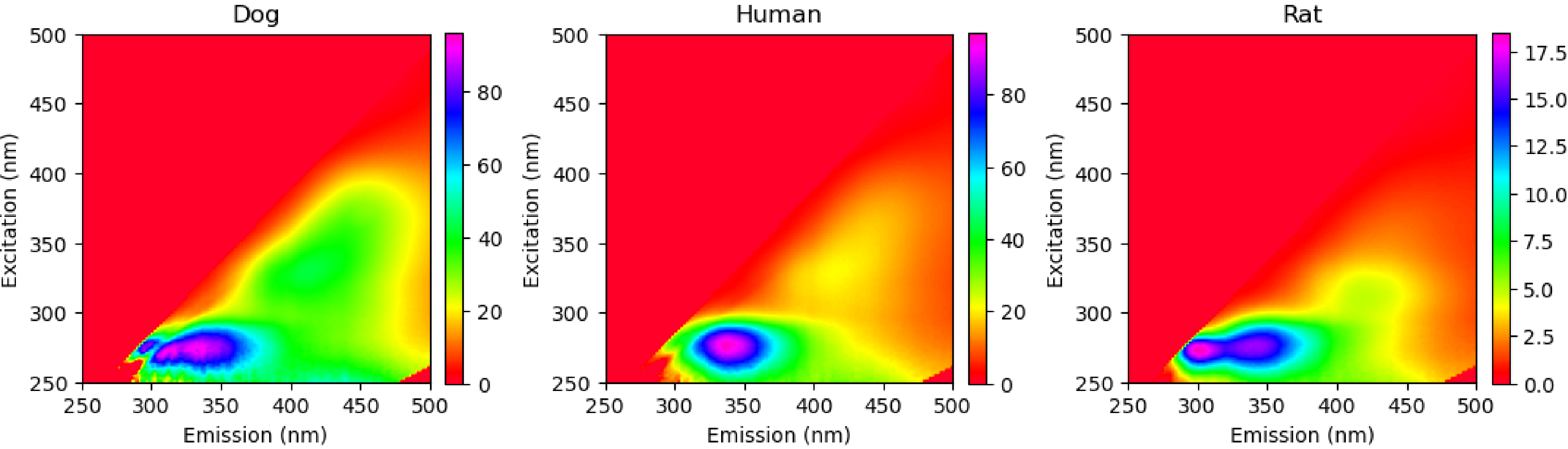
Natural Sources



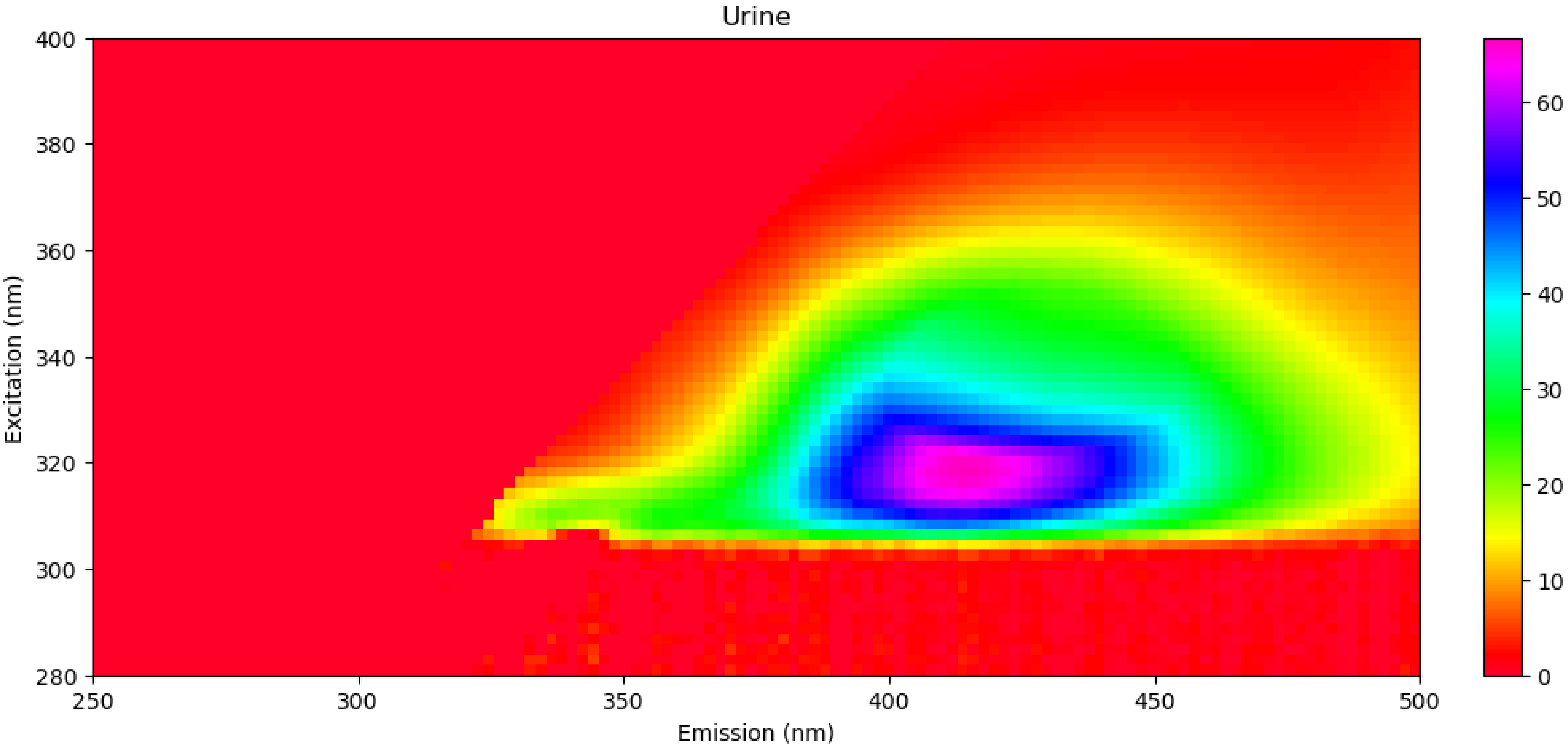
Household Sources



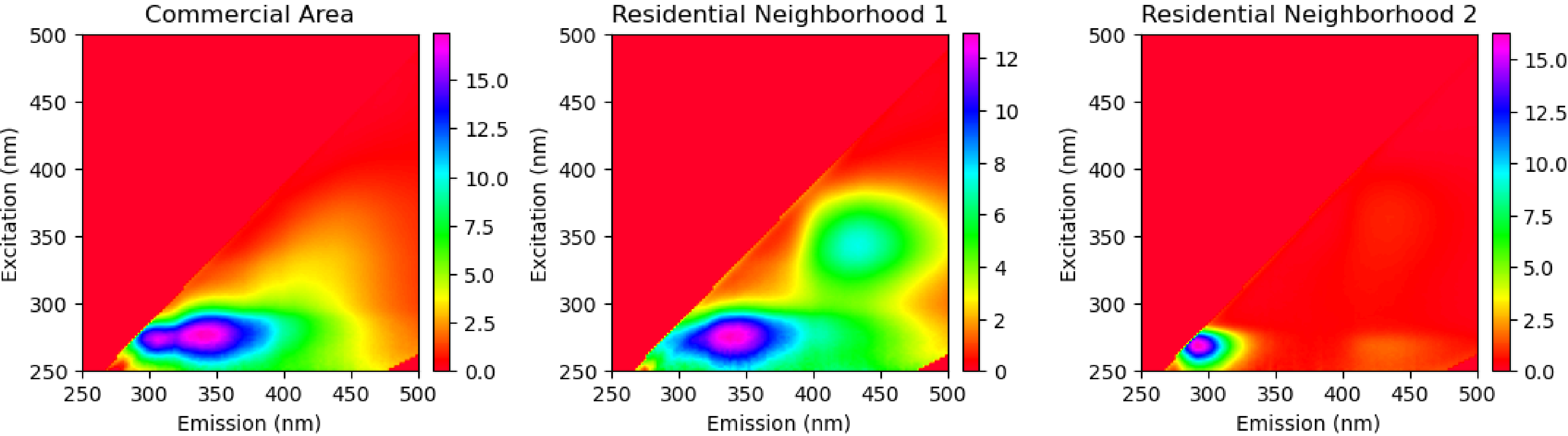
Fecal


Dog
Human
Rat
Excitation (nm)
Emission (nm)
250
300
350
400
450
500
0
20
40
60
80
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5

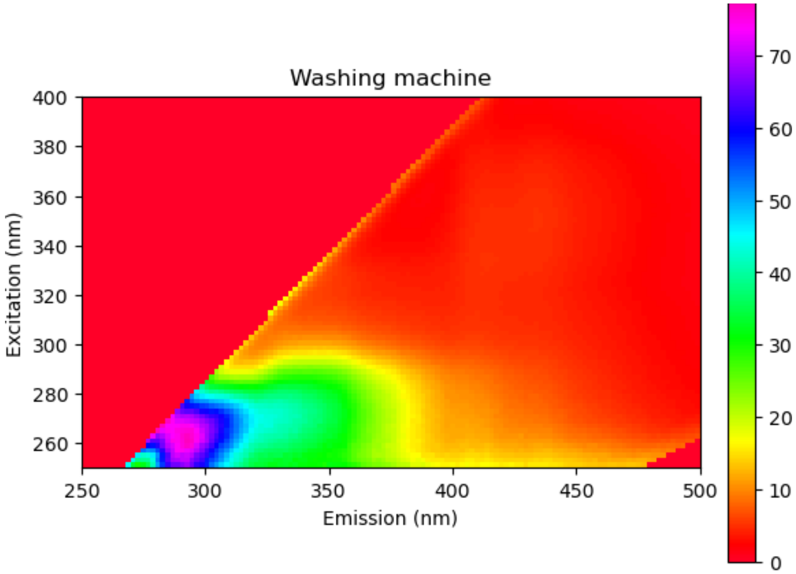
Urine

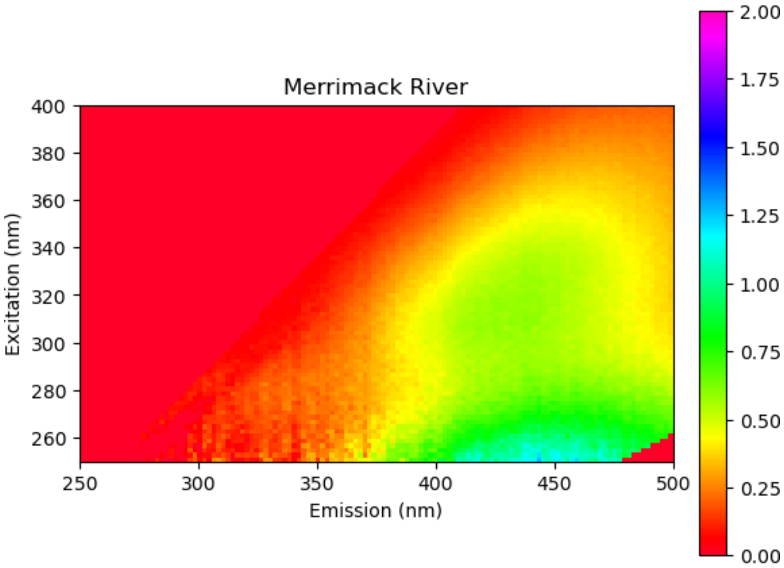

Urine
400
380
360
340
320
300
280
Excitation (nm)
250
300
350
400
450
500
Emission (nm)
60
50
40
30
20
10
0

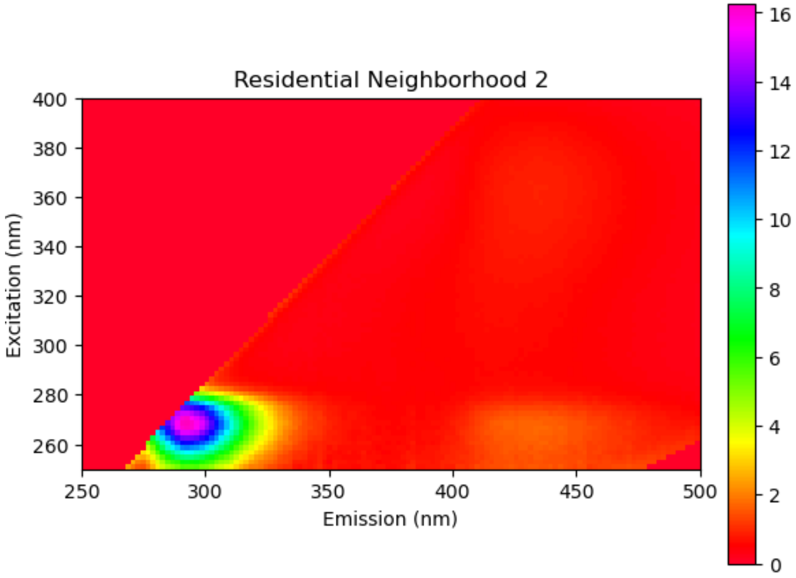
Sewers

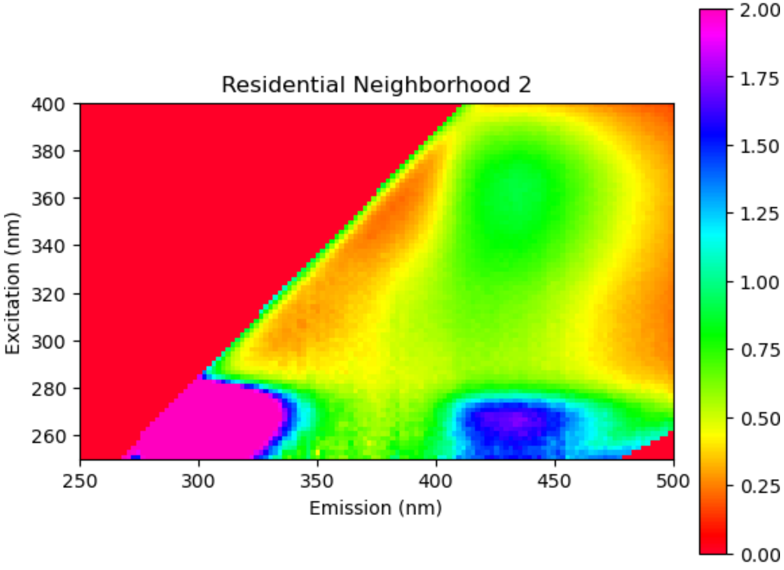

Commercial Area
Residential Neighborhood 1
Residential Neighborhood 2
Excitation (nm)
Emission (nm)
250
300
350
400
450
500
0.0
2.5
5.0
7.5
10.0
12.5
15.0
0
2
4
6
8
10
12

Sewer – Residential Neighborhood 2

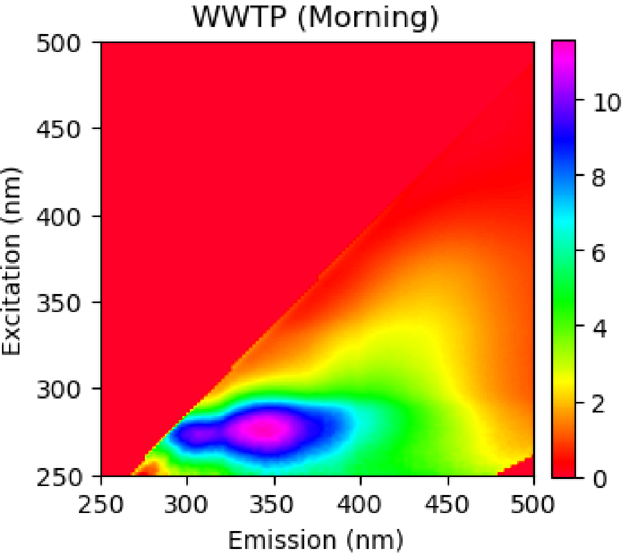

Washing machine

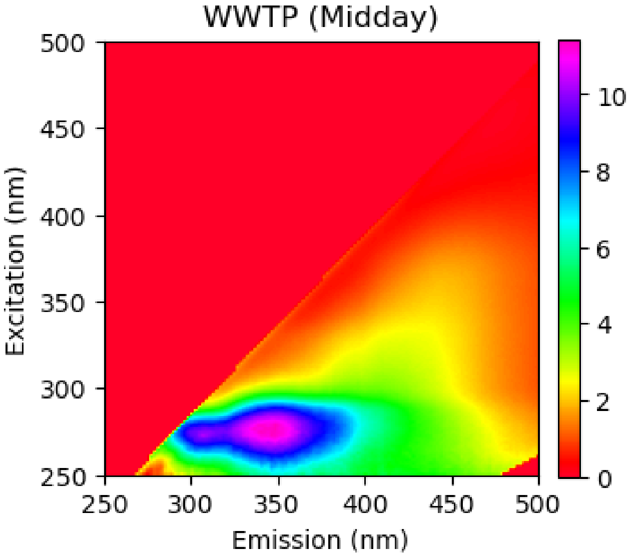

Merrimack River

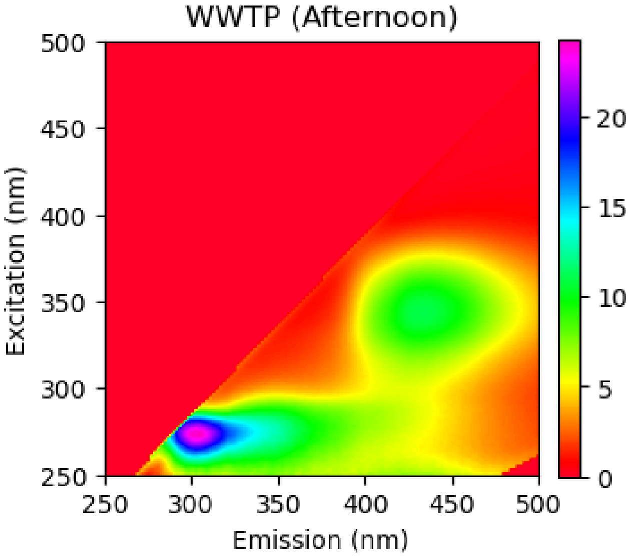

Residential Neighborhood 2


Residential Neighborhood 2

Wastewater Treatment Plant

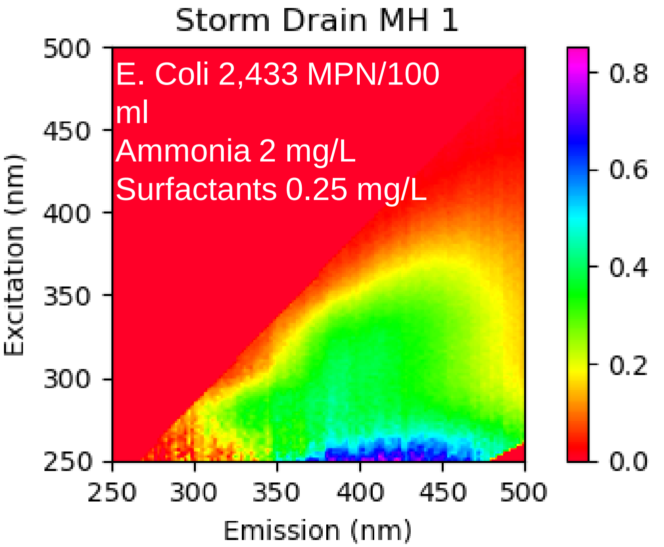


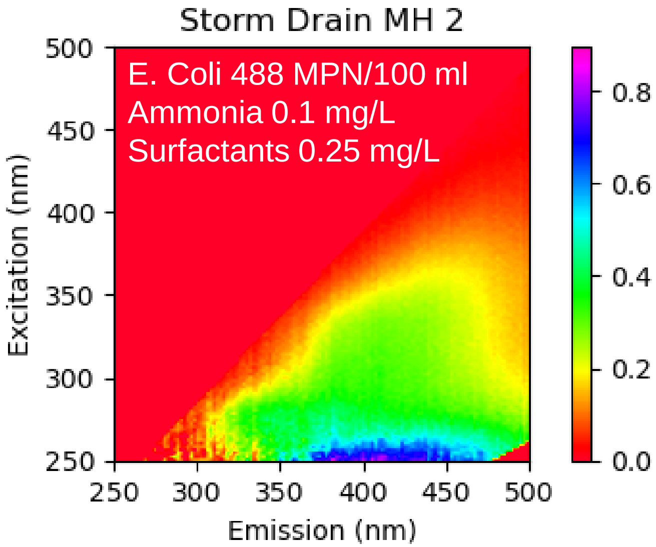


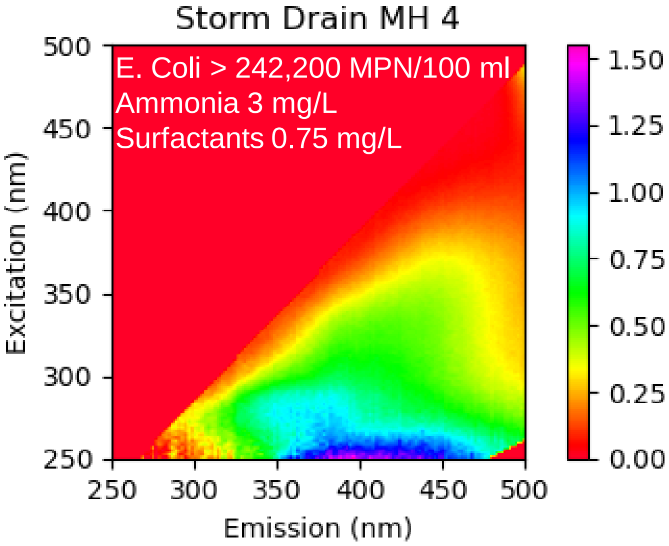


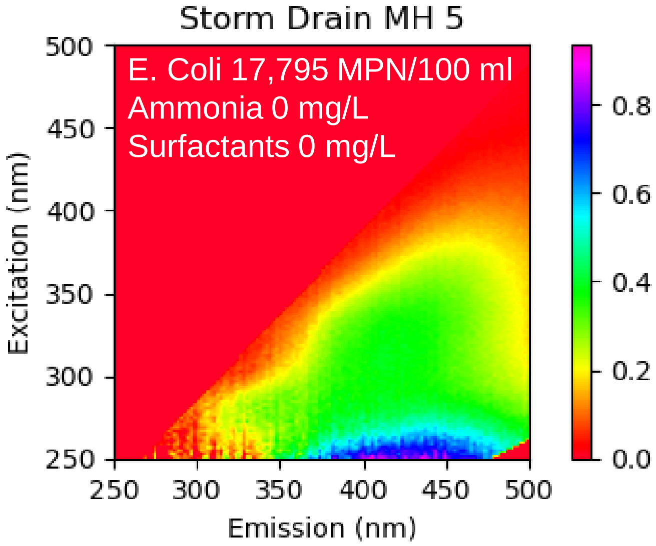
Storm Drains

Dry Weather Samples with Elevated *E. Coli* Concentrations

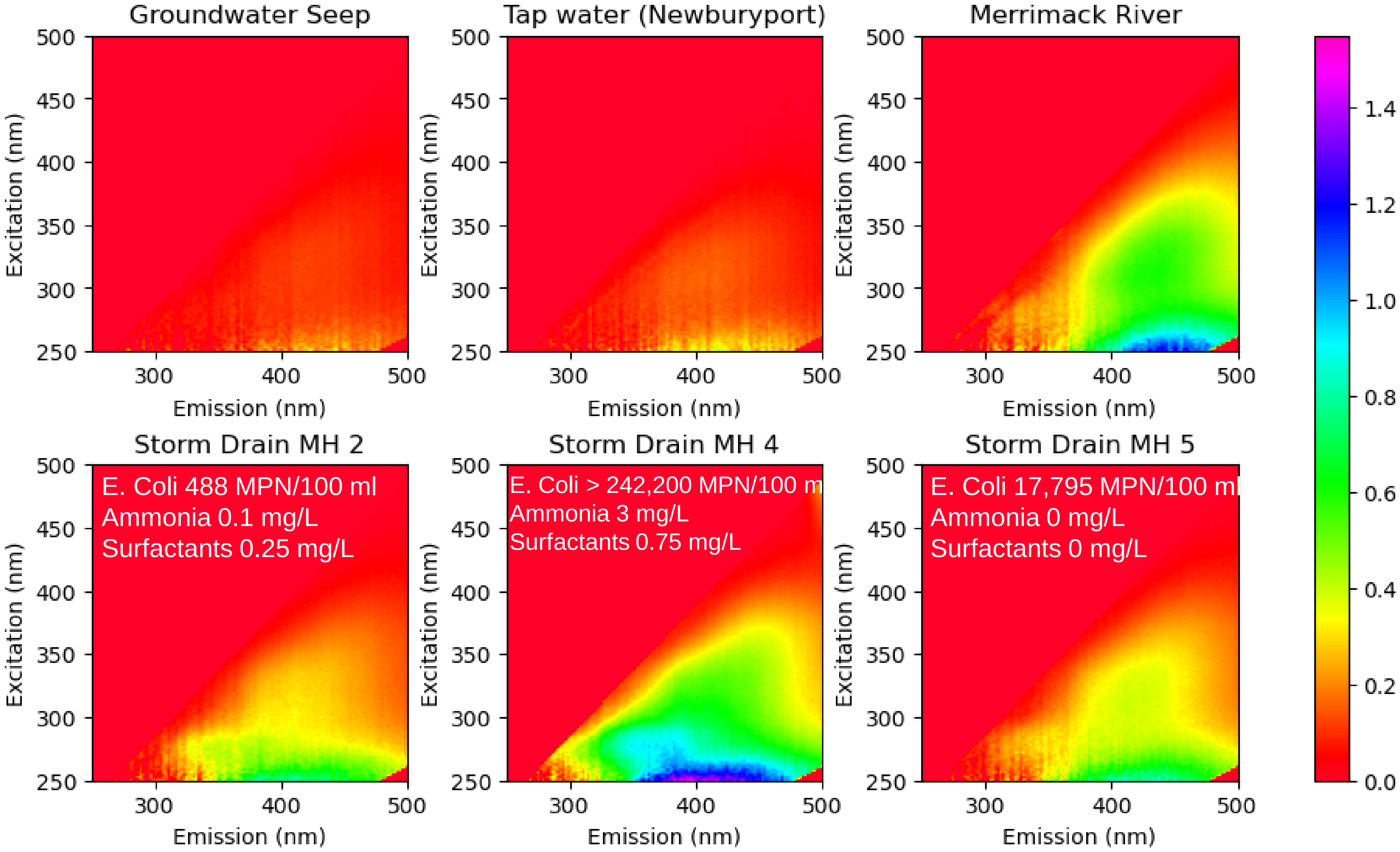








Comparison of Natural Waters vs Stormwater



Groundwater Seep

Tap water (Newburyport)

Merrimack River

Storm Drain MH 2

E. Coli 488 MPN/100 ml
Ammonia 0.1 mg/L
Surfactants 0.25 mg/L

Storm Drain MH 4

E. Coli > 242,200 MPN/100 m
Ammonia 3 mg/L
Surfactants 0.75 mg/L

Storm Drain MH 5

E. Coli 17,795 MPN/100 ml
Ammonia 0 mg/L
Surfactants 0 mg/L

Conclusions

- Technology shows promise for identifying contamination, but more work is needed
- Next step: EEM analysis + bacteria measurements
  - Dilution studies of WWTP influent
  - Analyzing ‘clean’ water in storm drains to define base profile
  - What does sewer exfiltration look like? Does it look different than direct sources?
  - Rivers (dry weather and wet weather)
- Improving analysis of EEM data to extract signs of contamination

Thank you.

Questions?

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