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USING FLUORESCEIN AS A FLUOROPHORE TO TEST UV AND LIGHT PENETRATION OF FLOCCULATED PARTICLES

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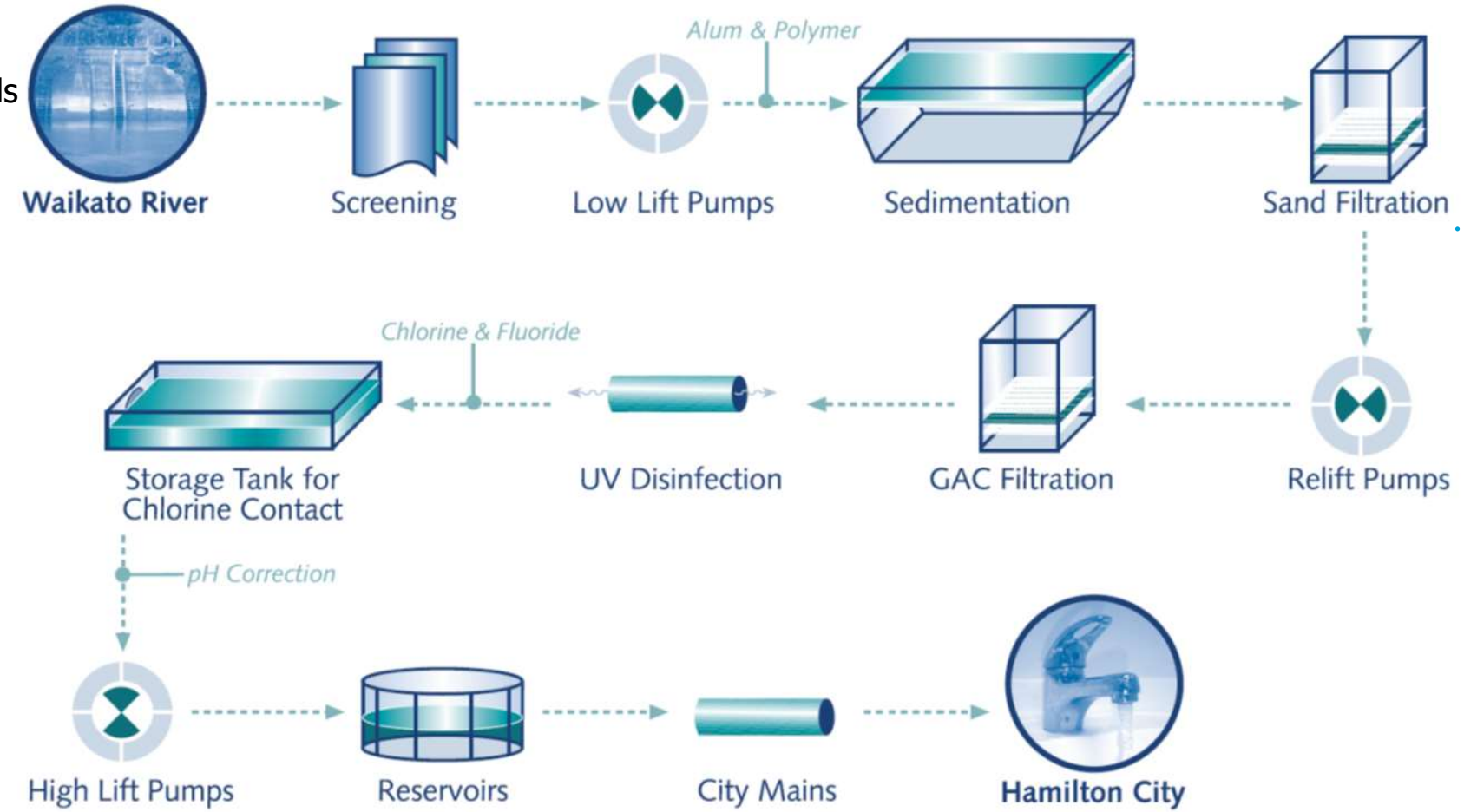
The New Zealand Water & Wastes Association Wai ora Aotearoa

water NEW ZEALAND CONFERENCE & EXPO
17–19 OCTOBER 2023
Tākina, Te Whanganui-a-Tara Wellington

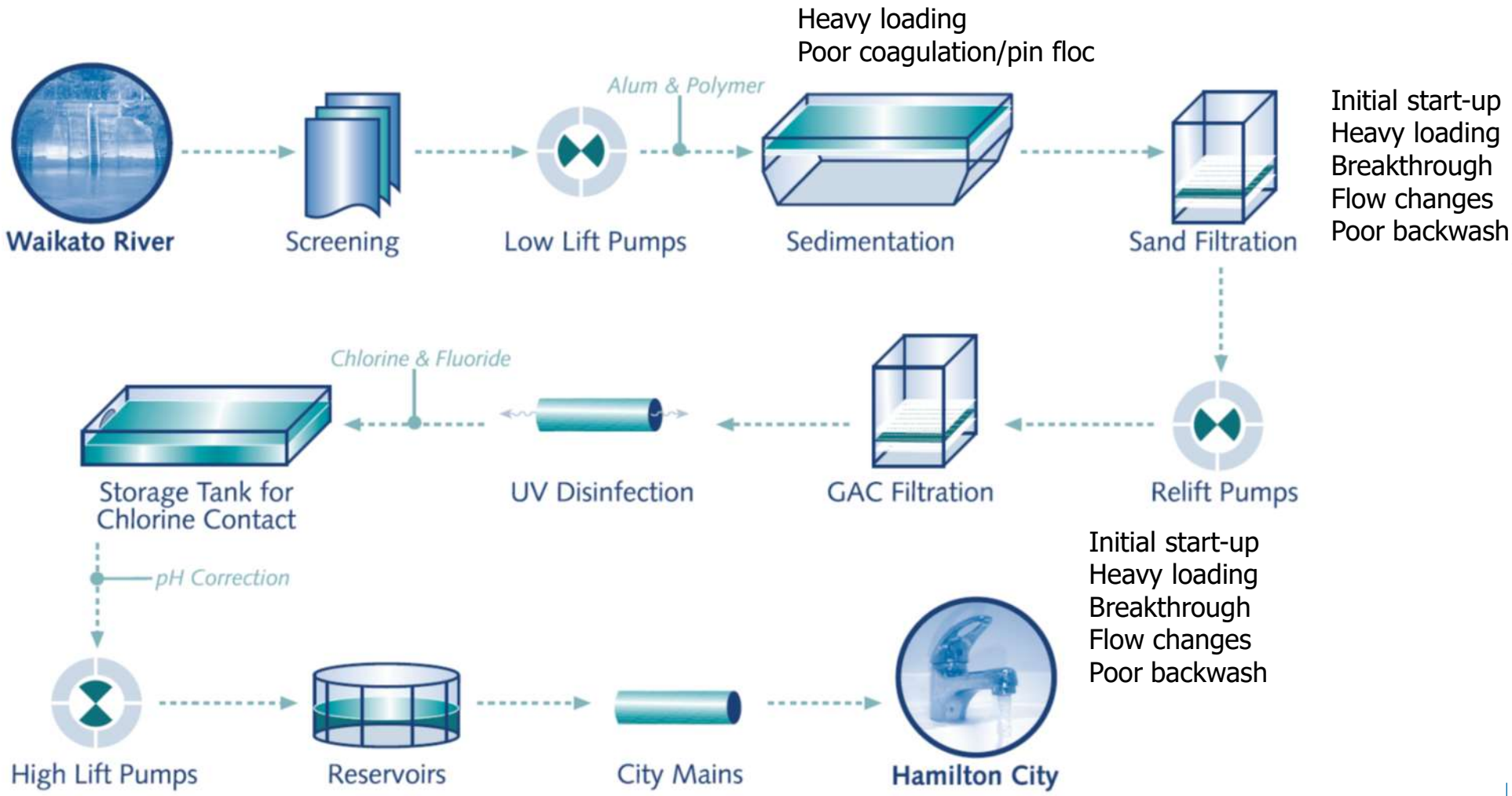
Water treatment – raw water

Contaminants:
- Sediment
- Organic compounds
- Pathogens:
  - Cryptosporidium
  - Giardia
  - Legionella
  - Coliforms
  - Viruses

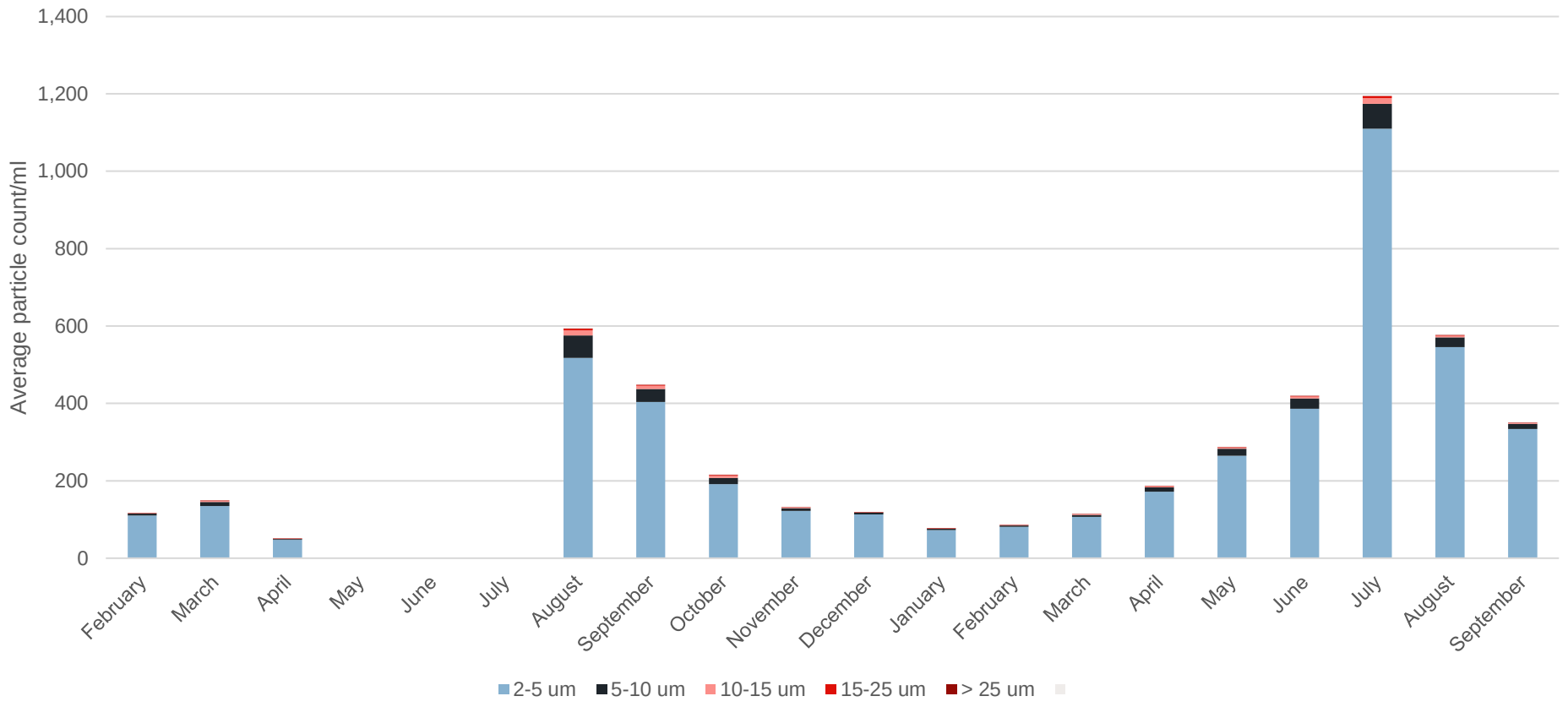


Pathogen log removal

Challenging situations



Particle count going through UV treatment



Challenges for UV treatment

Particles containing/shielding pathogens

- Cryptosporidium 4-6 µm – chlorine resistant - 12 mJ/cm2
- Giardia 10-14 µm - 11 mJ/cm2
- Entamoeba histolytica 10-20 µm
- Coliforms 1-2 µm
- Viruses 143 mJ/cm2

Particulate material can be strongly UV absorbing

- e.g. humic substances, organic substances

Particulate material can be UV reflecting

- e.g. silicate material

Examples of shielding in UV treatment

UV disinfection effectiveness is reduced with organic particle sizes 2 µm and smaller

[Templeton et al. (2005)]

UV light incapable of inactivating coliform bacteria protected by particles as small as 11 µm

[Cantwell and Hofmann (2008)]

Aggregated *Escherichia coli* (*E. coli*) and particle sizes larger than 25 µm reduces the inactivation of *E. coli*

[Kollu and Örmeci (2012)]

My research

How to measure UV penetration in floc?

Can any information about the floc and what is in it be obtained?

One approach to measuring light penetration is using fluorescence

Want I need

Need a fluorescent probe

e.g. quantum dots or fluorescent dyes that can easily incorporated into floc

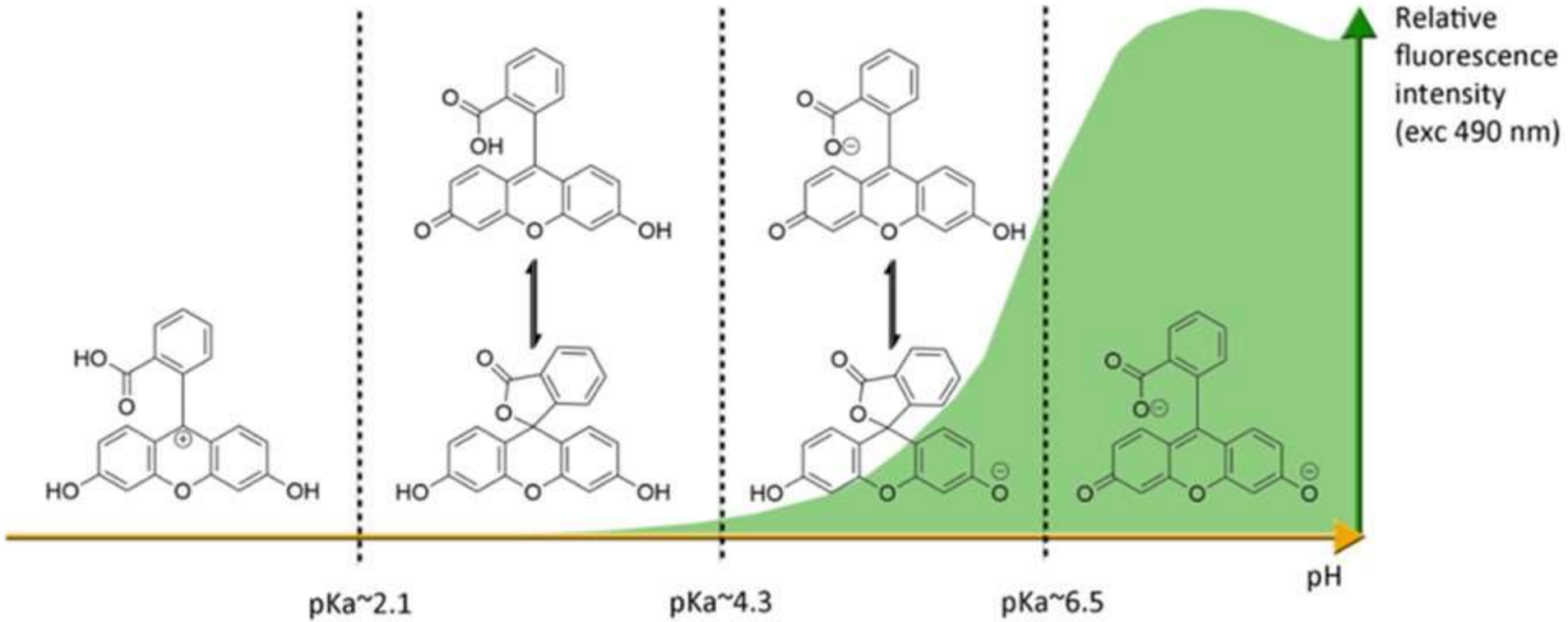
Ideally something that emits light at a higher wavelength that the wavelength used to induce fluorescence

Ideally something whose fluorescence lifetime changes depending on what it is attached to

Need a set-up that can easily measure fluorescence

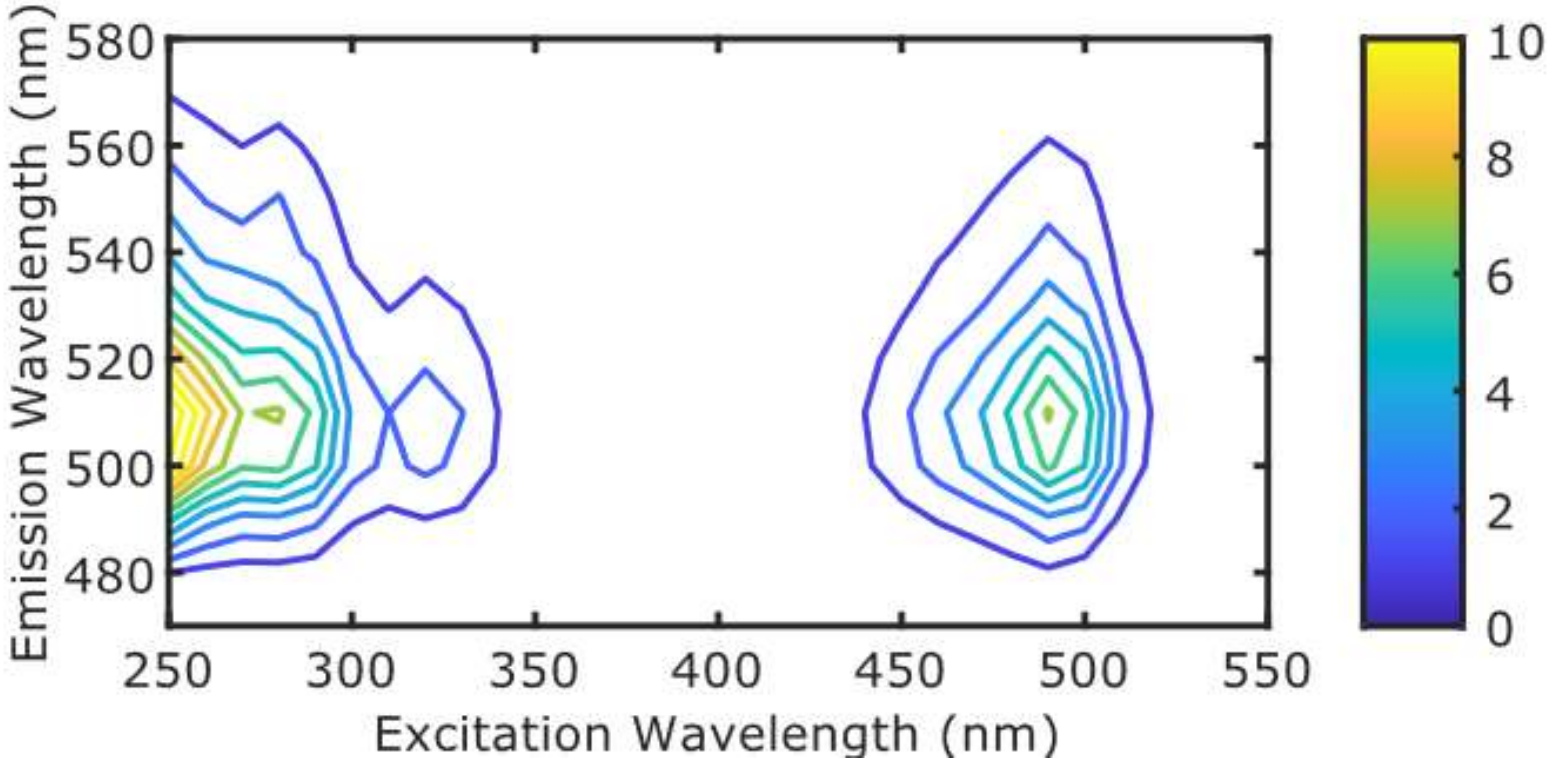
Need a set-up that can measure fluorescence lifetime to give information about the floc

Fluorescein as a fluorescence probe

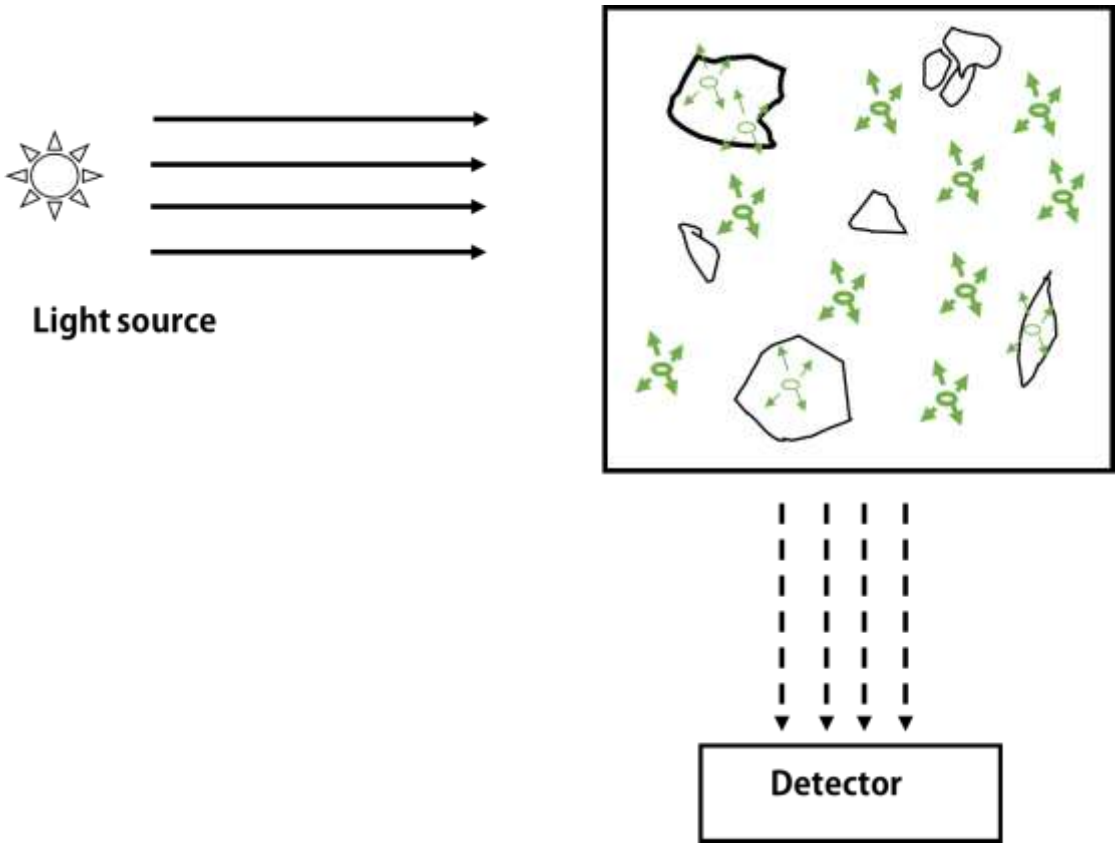


[Le Guern et al, 2020]

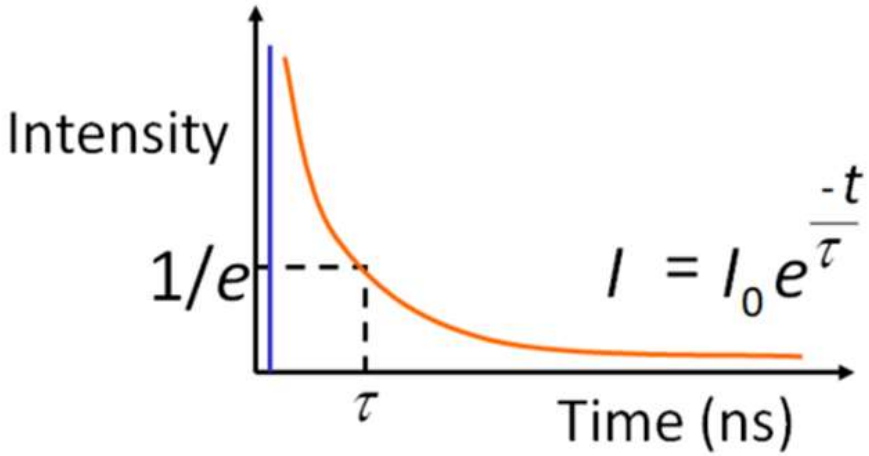
Fluorescein emission



Using fluorescence to measure light penetration



- Fluorescence **Intensity** base
- Fluorescence **Lifetime** based



Examples of using fluorophores

Fluorescent probes to detect different pathogens in environmental and medical studies.

[Key et al., 2009; Singh et al.,2016]

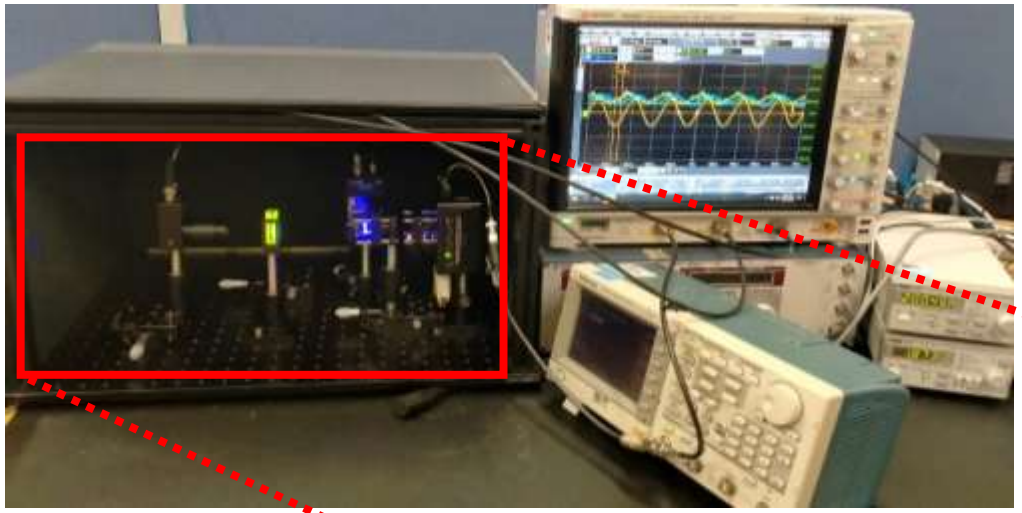
Fluorescent microparticles were substituted as Cryptosporidium parvum to test the efficiency of a metallic membrane in drinking water treatment.

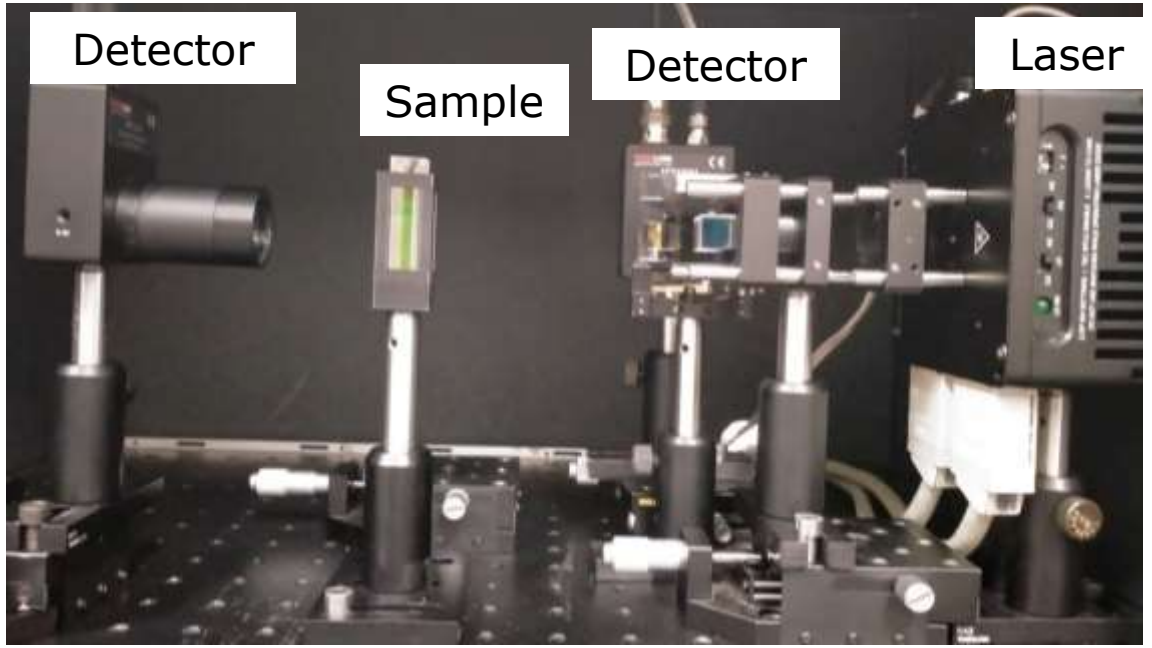
[Li et al., 2019]

Modified microspheres to study pathogen transport in ground water.

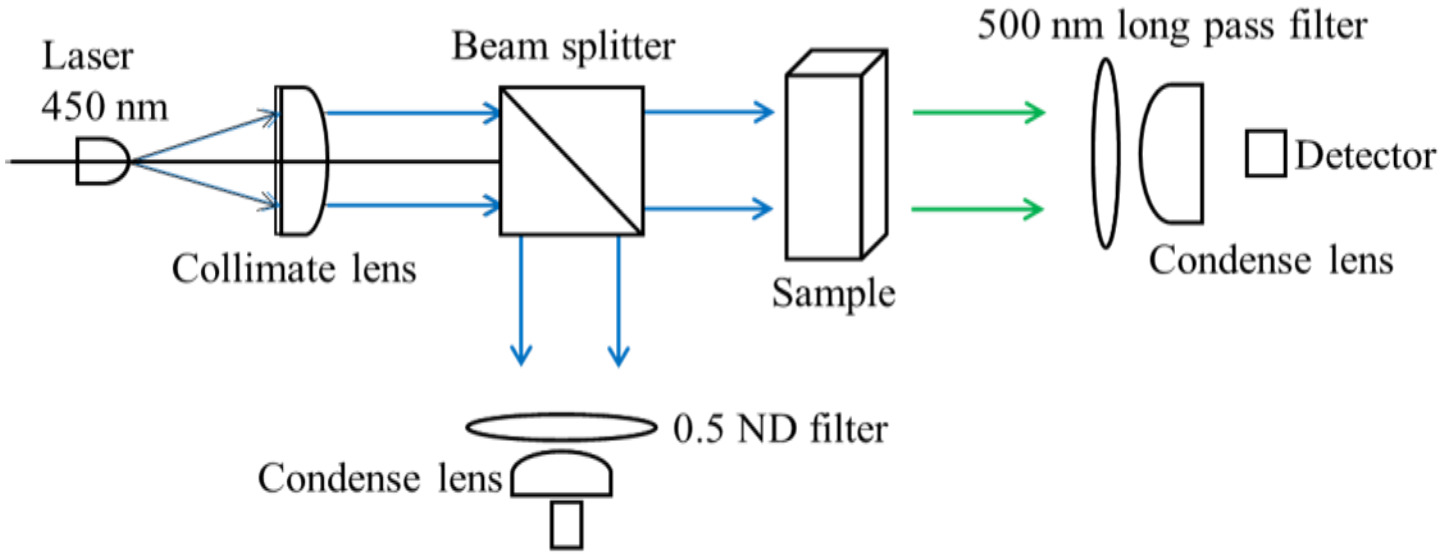
[Pang et al., 2009]

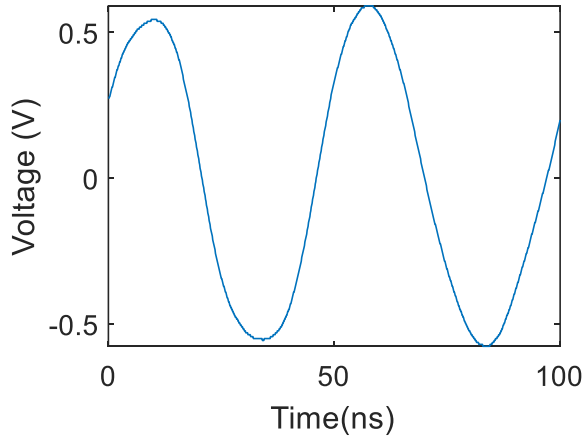
My prototype for measuring fluorescence and lifetime

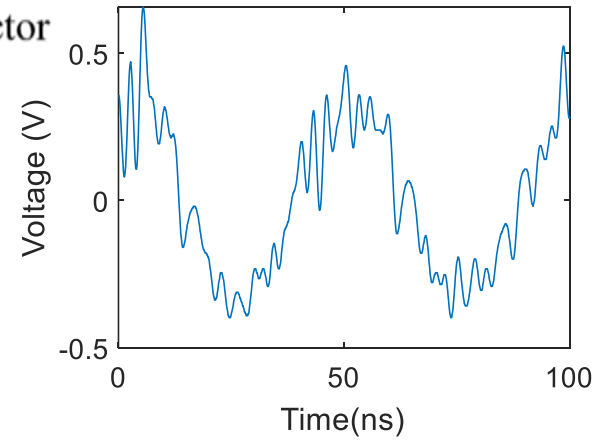




Data obtained







Testing

Need to get the fluorescein into floc, ideally without changing floc properties

Made humic acid and kaolin floc using alum as a flocculant

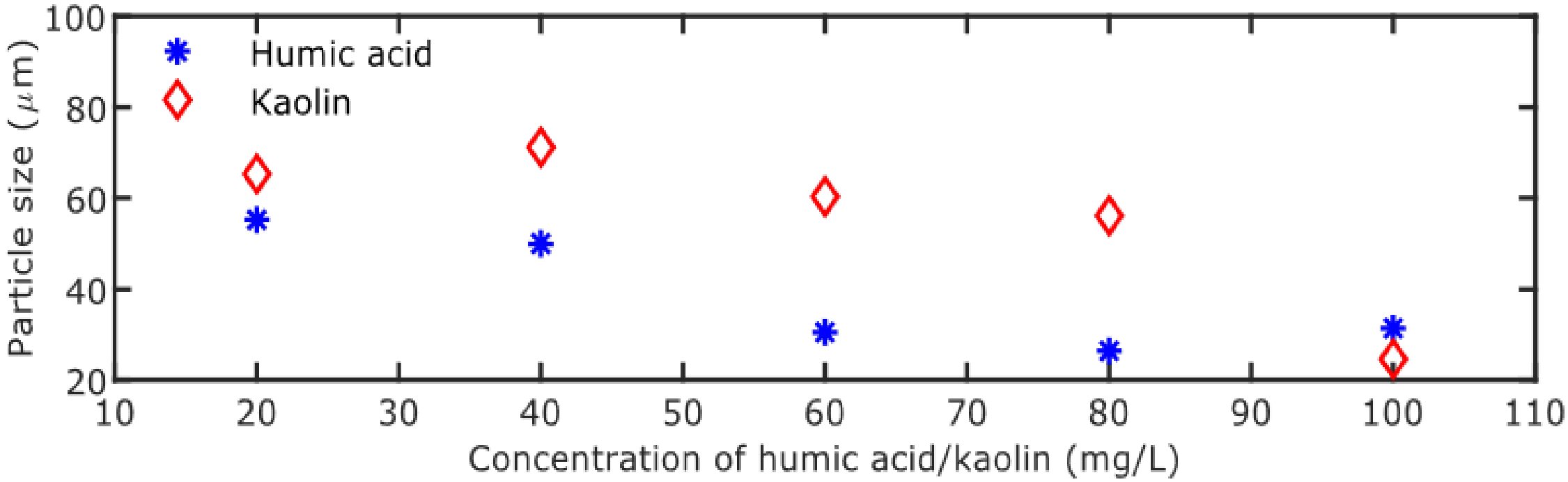
Samples flocculated in a boltac jar tester

Examined the effect of humic acid, kaolin, alum and fluorescence concentrations at native pH and pH 7 on:

Turbidities, particle sizes, floc morphology and fluorescence

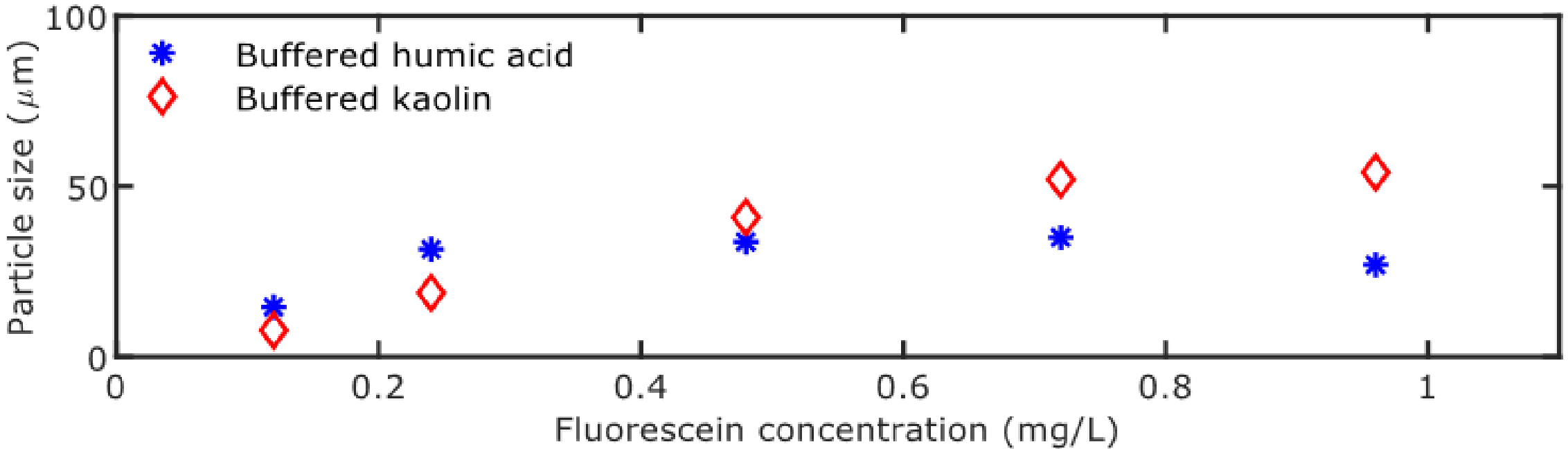
Particle size of the floc

Unbuffered flocculated solutions at different concentrations of humic acid and kaolin and 0.48 mg/L fluorescein and alum dose adjusted according to solution concentration and zeta potential measurements.



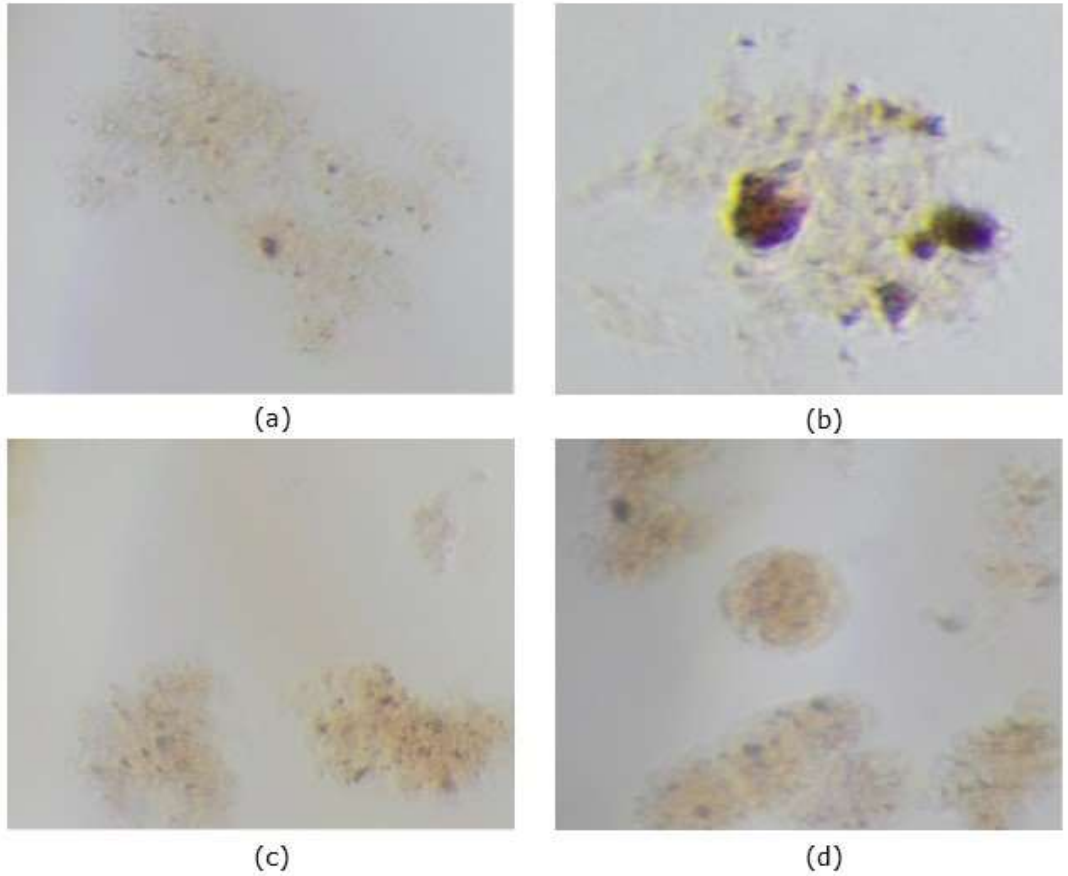
Particle size of the floc

Buffered flocculated solutions 60 mg/L humic acid and kaolin solutions at different fluorescein concentrations and 20 mL 1g/L alum to 400 mL humic solution and 14 mL for kaolin solution..

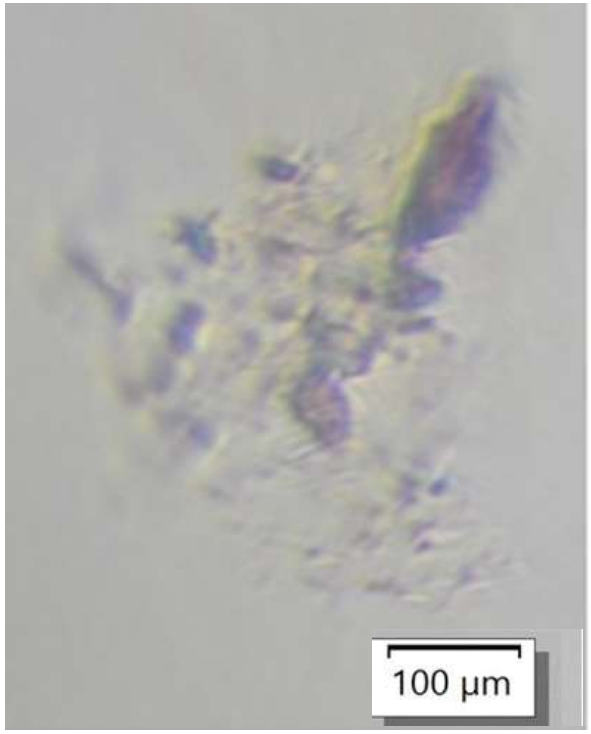


Floc morphology

Microscope images (20x magnification)

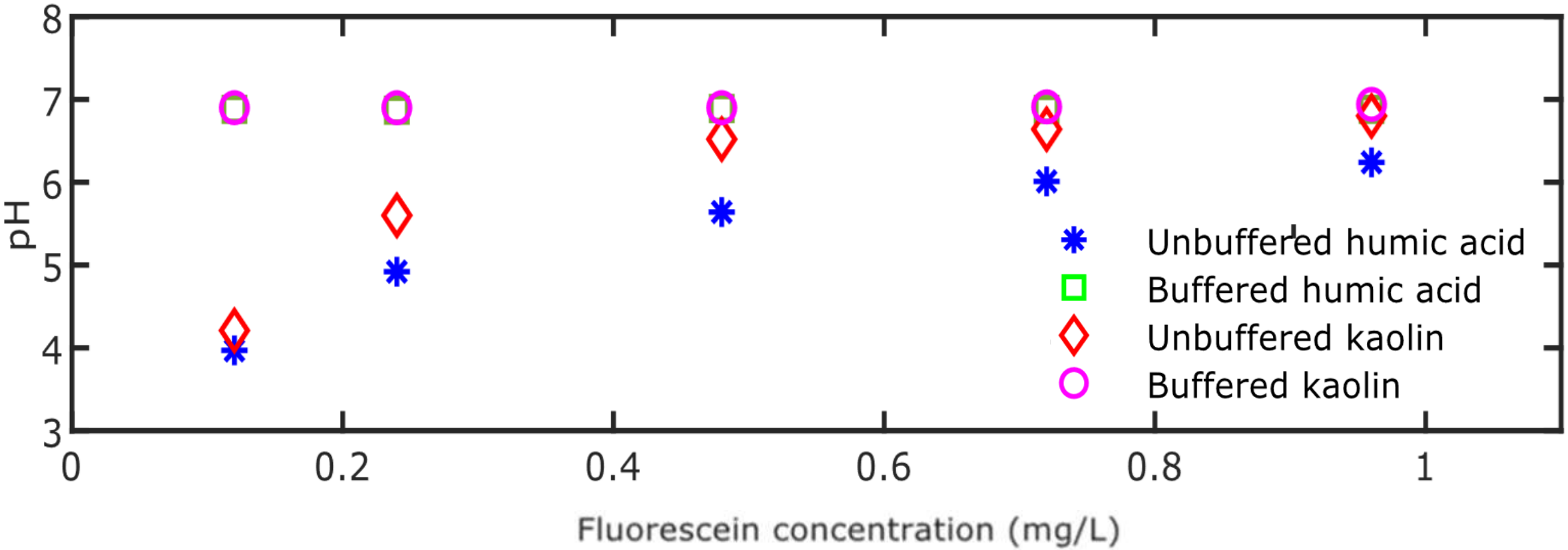


Humic acid floc particles (a) 20 mg/L, (b) 40 mg/L, (c) 60 mg/L and (d) 80 mg/L, unbuffered with 0.48mg/L fluorescein.

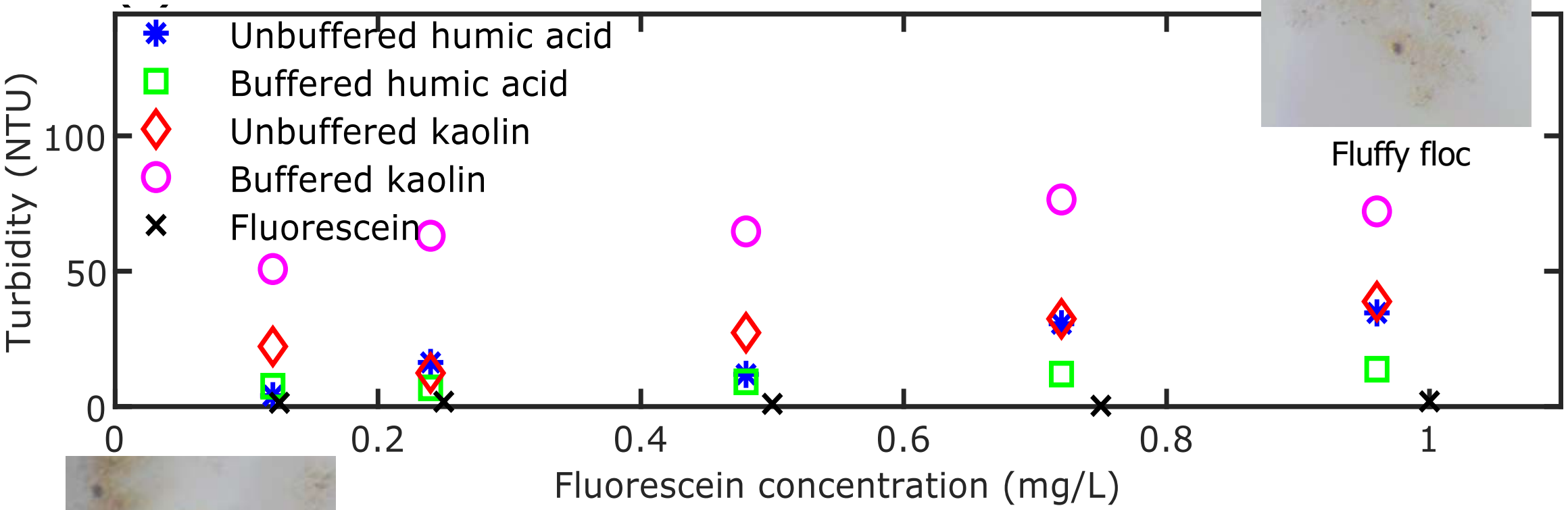


Kaolin floc particles 20 mg/L unbuffered with 0.48mg/L fluorescein.

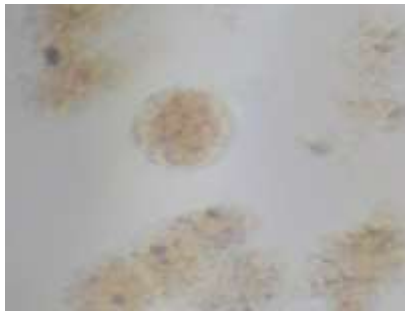
pH measurements different fluorescein concentrations



Turbidity of 60 mg/L humic acid and kaolin solutions at different fluorescein concentrations

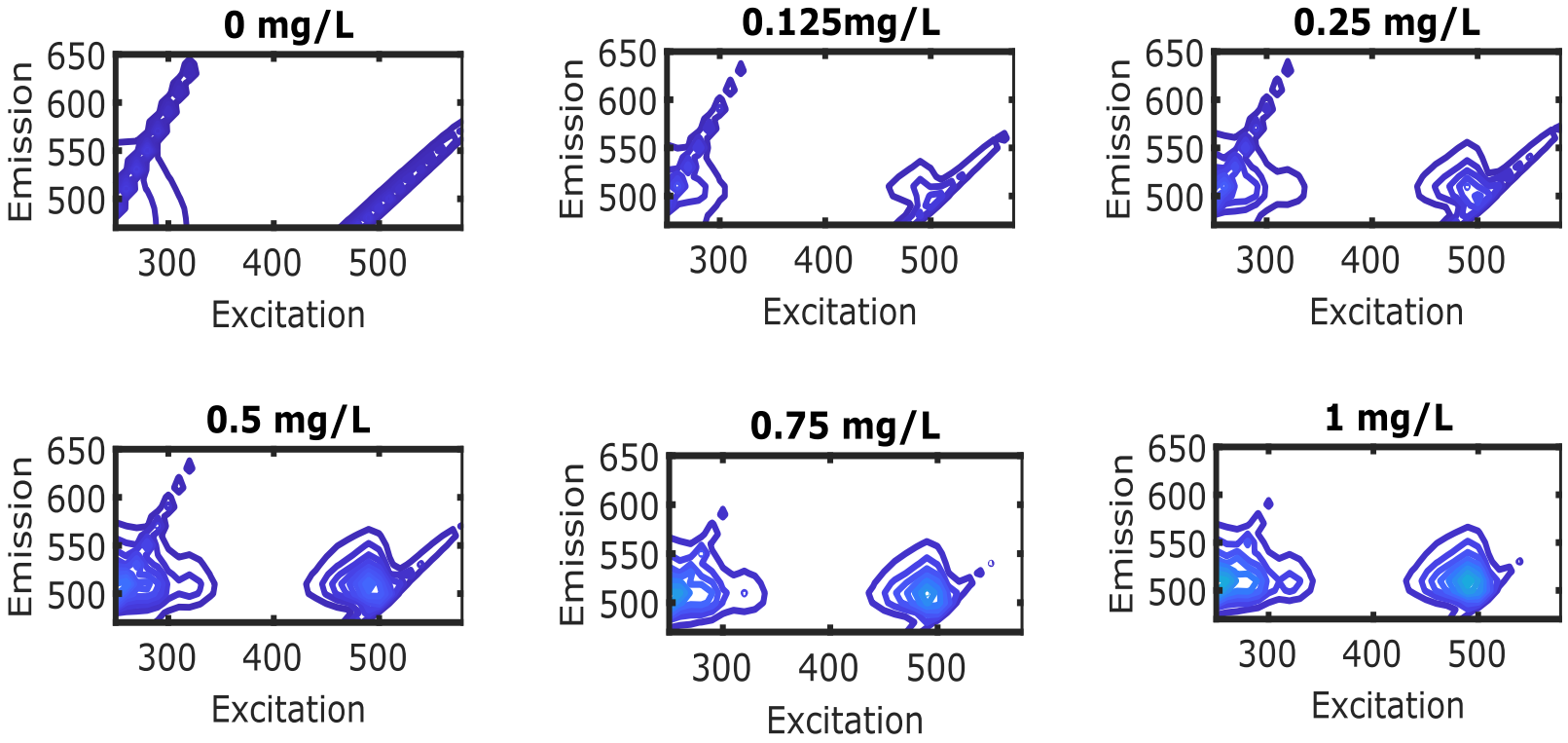


Fluffy floc

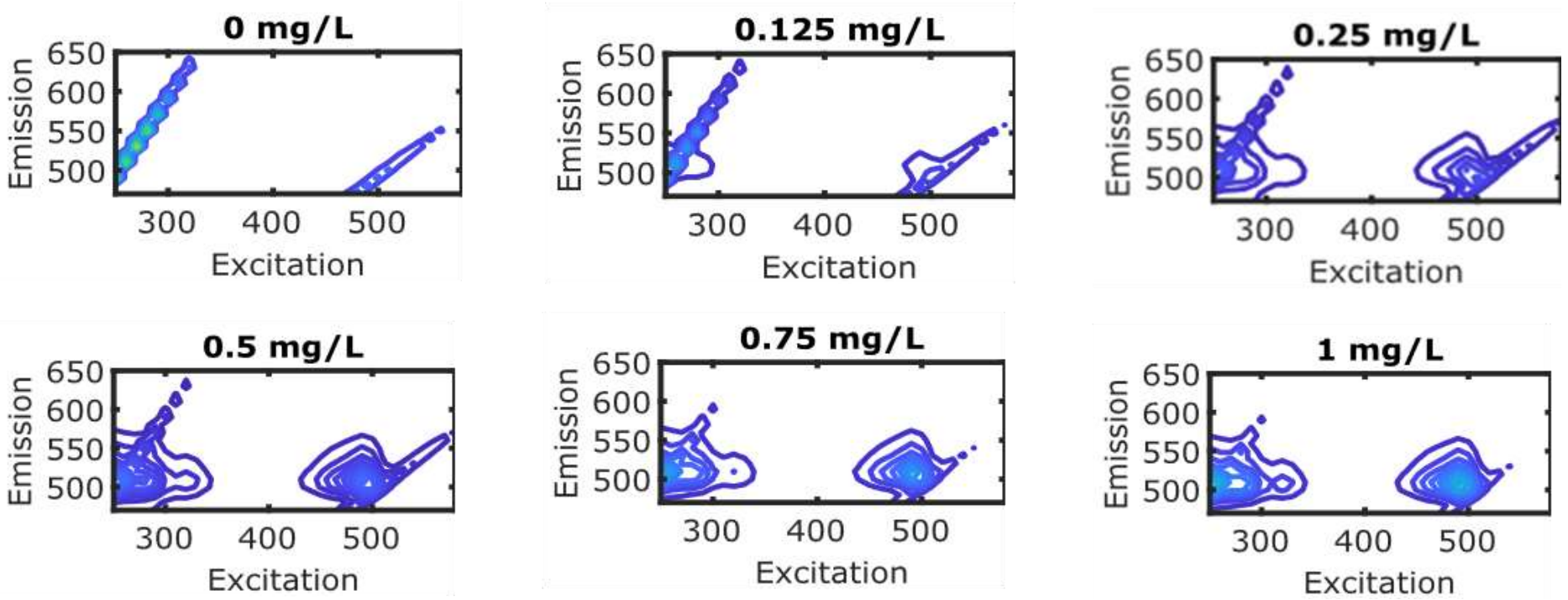


Dense floc

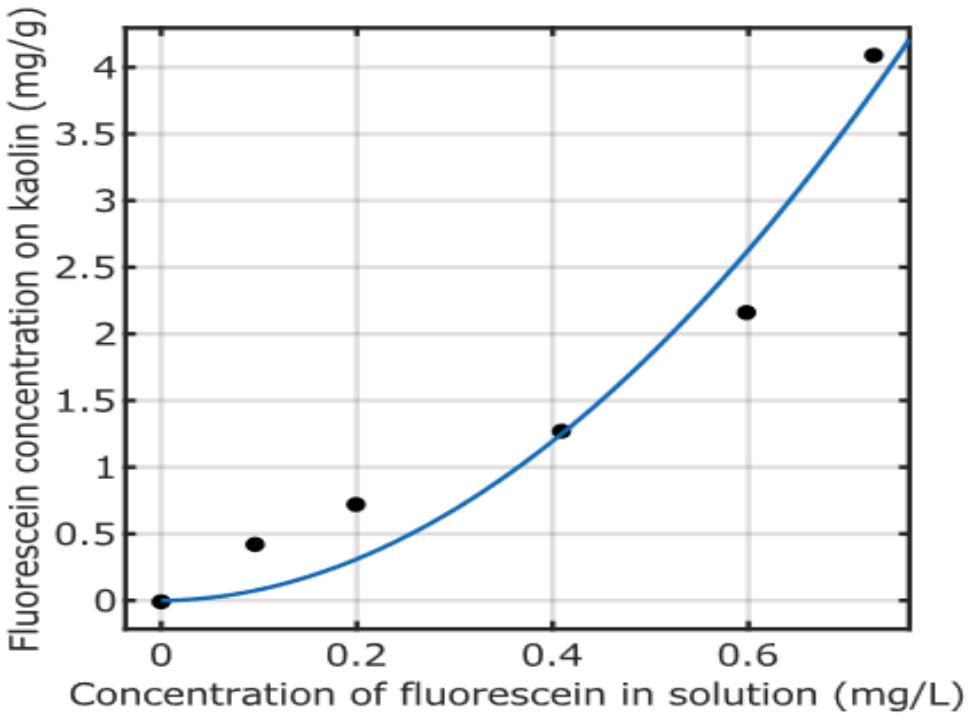
Fluorescence emission data for flocculated solutions containing different concentrations of fluorescein in 60 mg/L of humic acid

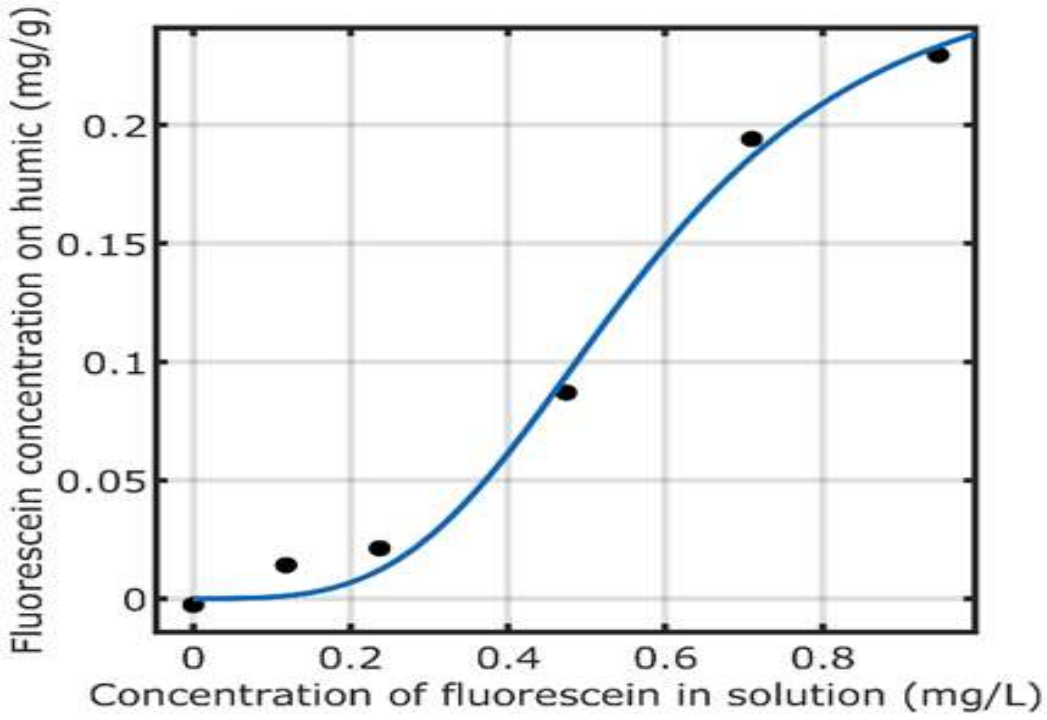


Fluorescence emission data for flocculated solutions containing different concentrations of fluorescein in 60 mg/L of kaolin



Fluorescein adsorption





Freudlich isotherm, $Q = KC^{1/n}$

SIPs isotherm, $Q = \frac{K'C^{\beta}}{1 + \alpha C^{\beta}}$

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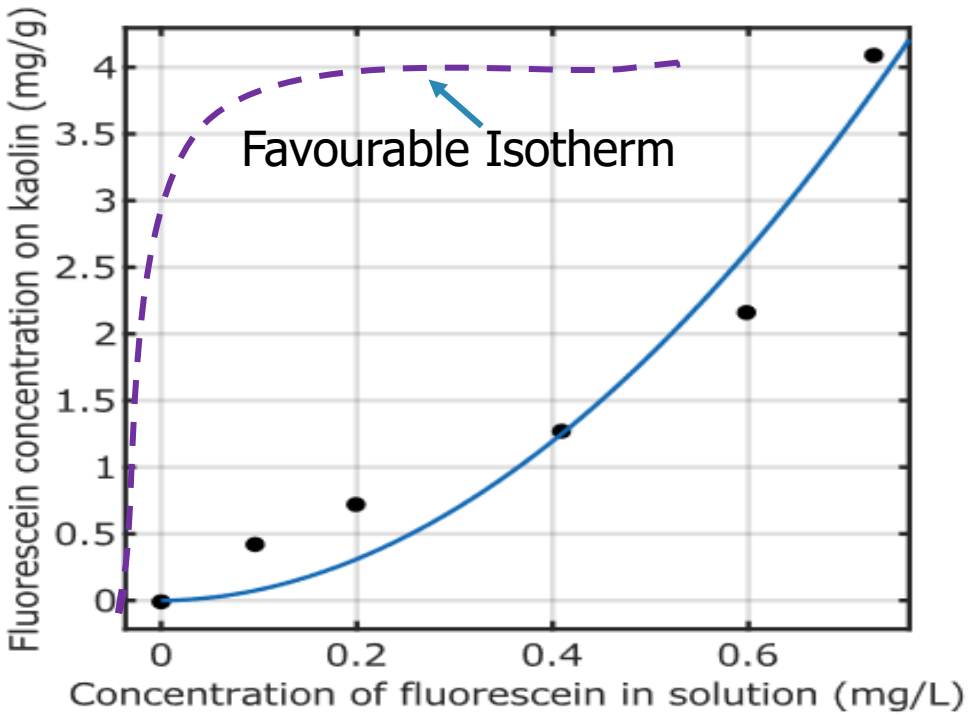
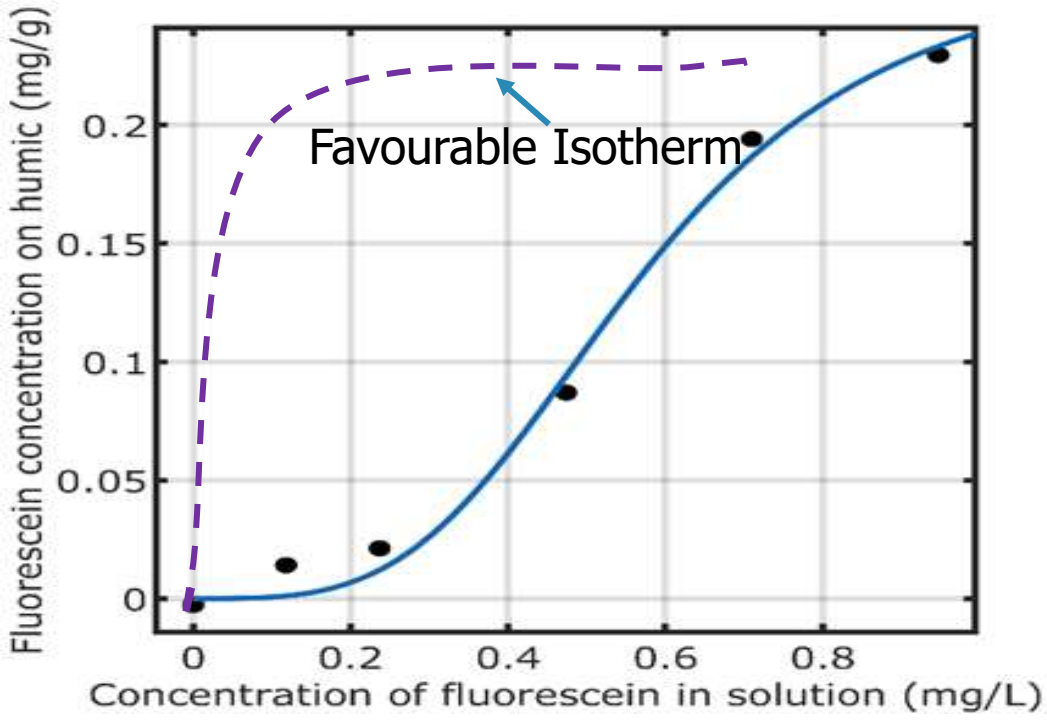
Fluorescein adsorption





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CONCLUSION

We have an experimental set up to measure the fluorescence lifetime and intensity from floc

But fluorescein changed floc morphology from a dense spherical floc to a flat non-spherical shape and also did not like to stick to the floc

Need an alternative fluorophores or modify the fluorophore to measure floc penetration

e.g. by chemically grafting it to a particle

THANK YOU

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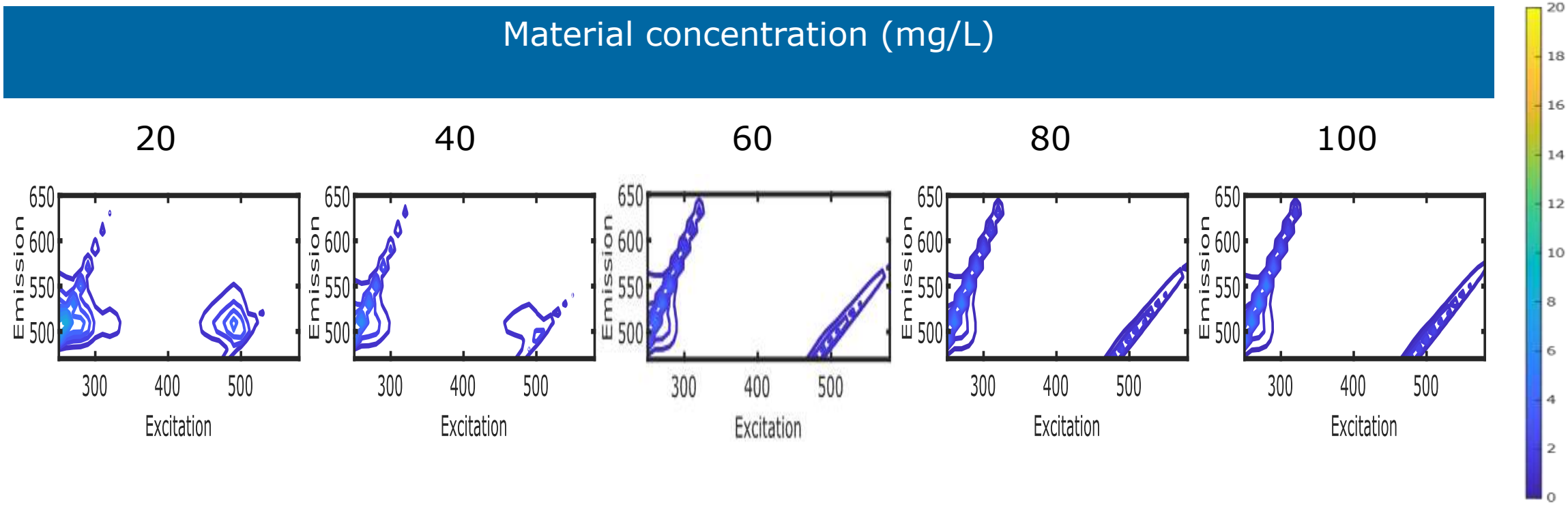
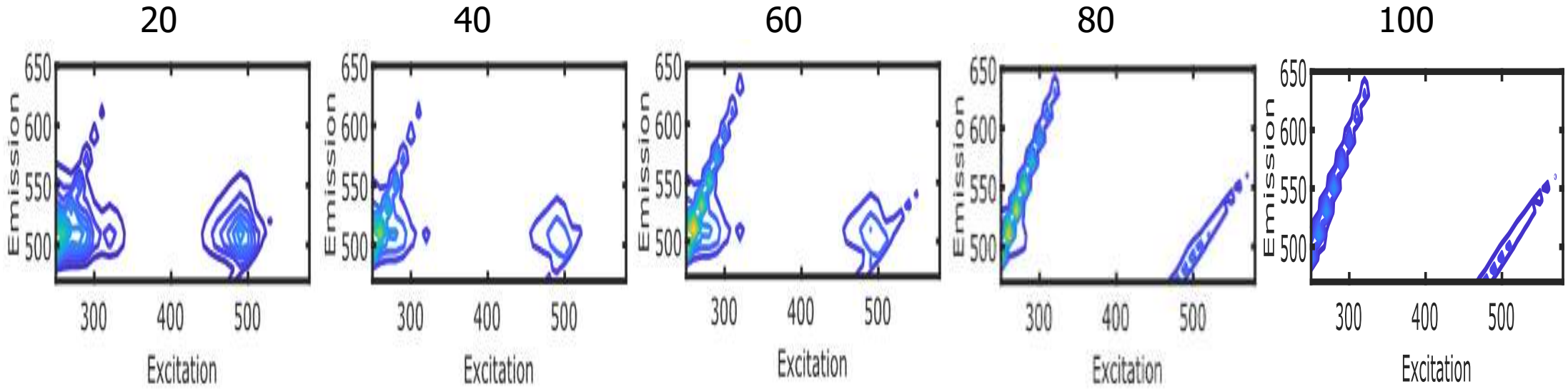
EEM measure for different concentration of humic acid

Material concentration (mg/L)



EEM measure for different concentration of Kaolin

Material concentration (mg/L)



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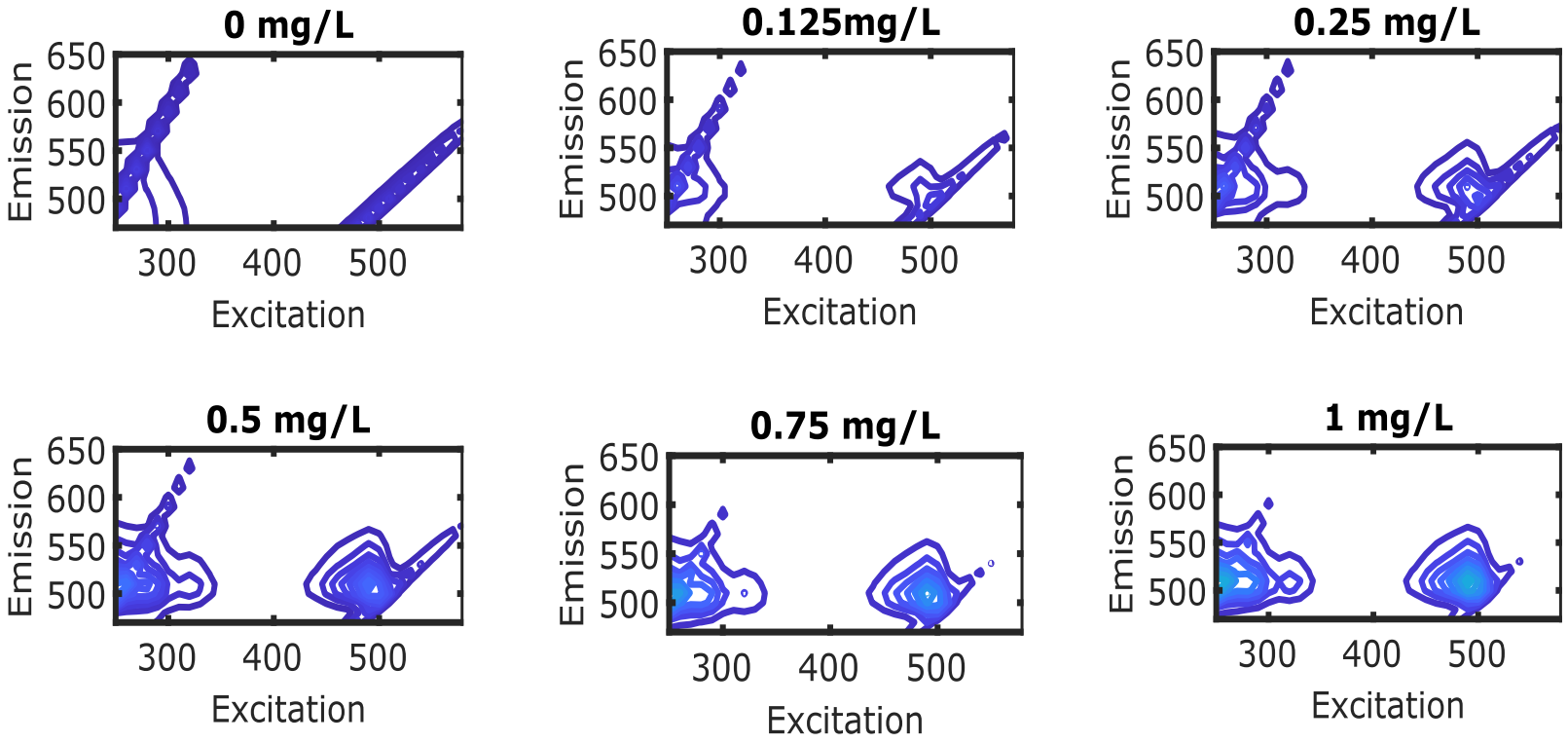
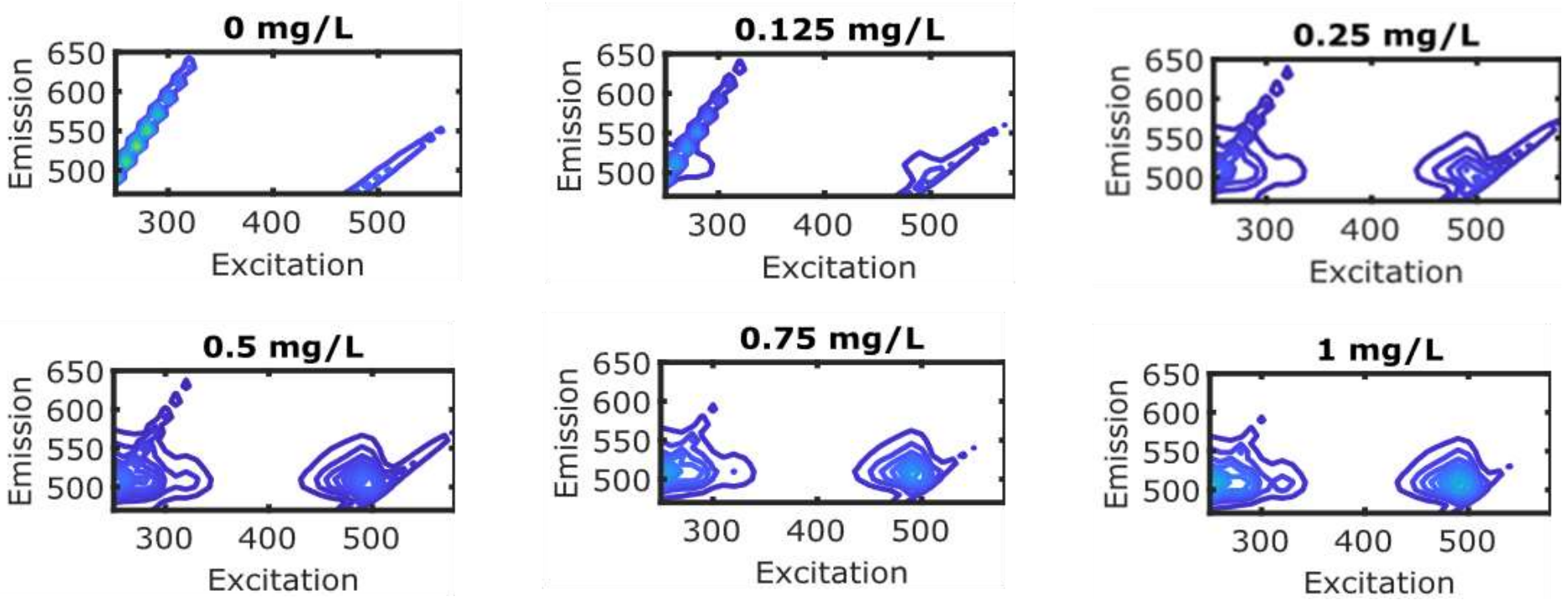


Fluorescence emission data for flocculated solutions containing different concentrations of fluorescein in 60 mg/L of kaolin



EEM MEASURE FOR DIFFERENT CONCENTRATIONS