Sucralose – Literature Review

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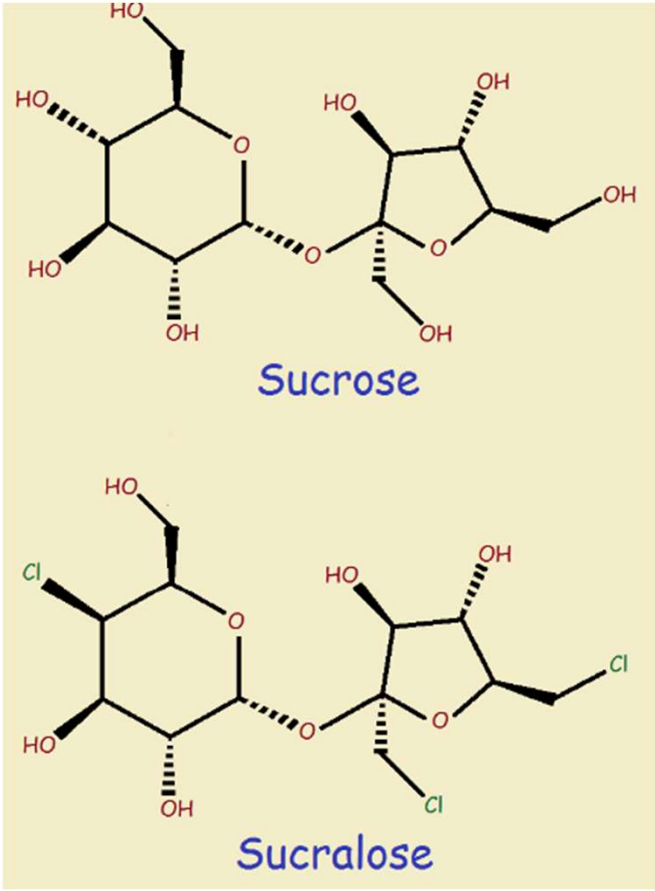
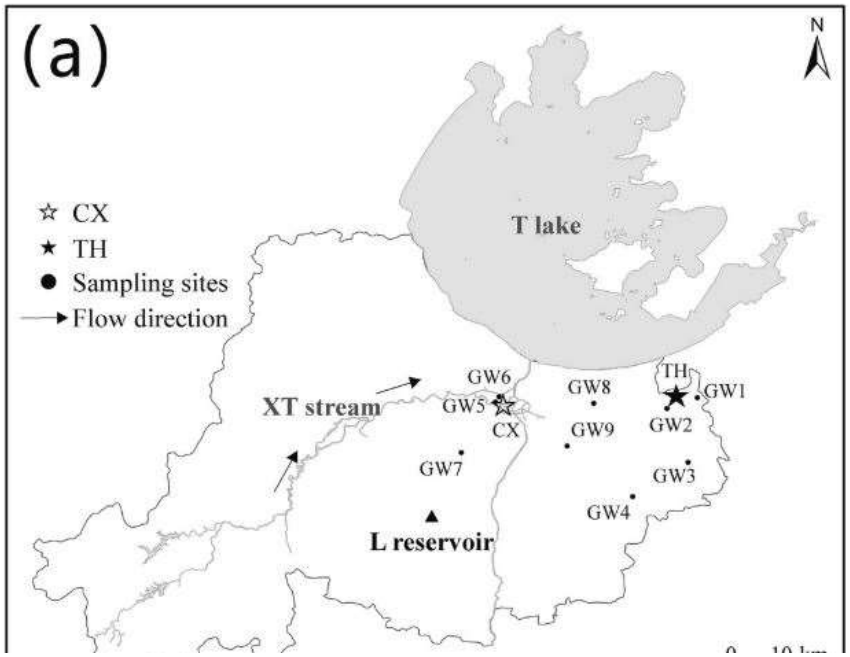
What is Sucralose?

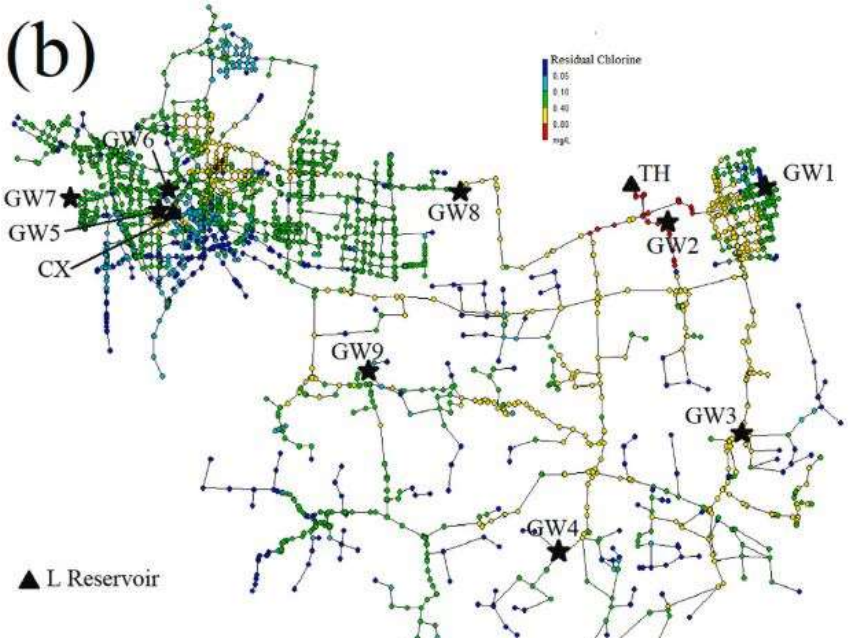
- Sucralose is an artificial sweetener 600x sweeter than natural sucrose
- Found in foods, beverages, pharmaceuticals, and personal care products
- The USA leads consumption ~1,500 T per year
- Global consumption has increased 5.1% per year from 2008-2015 and is expected to continue

Chemical Properties of Sucralose

- Sucralose is the chlorinated version of sucrose
  - Chemical formula: $C_{12}H_{19}Cl_3O_8$
- Sucralose experiences little environmental degradation
  - 92-97% survives mammal digestion
  - hydrolysis degradation only occurs in highly acidic conditions
  - Studies of microbial degradation have been mixed
    - Estimated sucralose life of ~4 months depending on soil properties
  - Sucralose is not removed in conventional water treatment

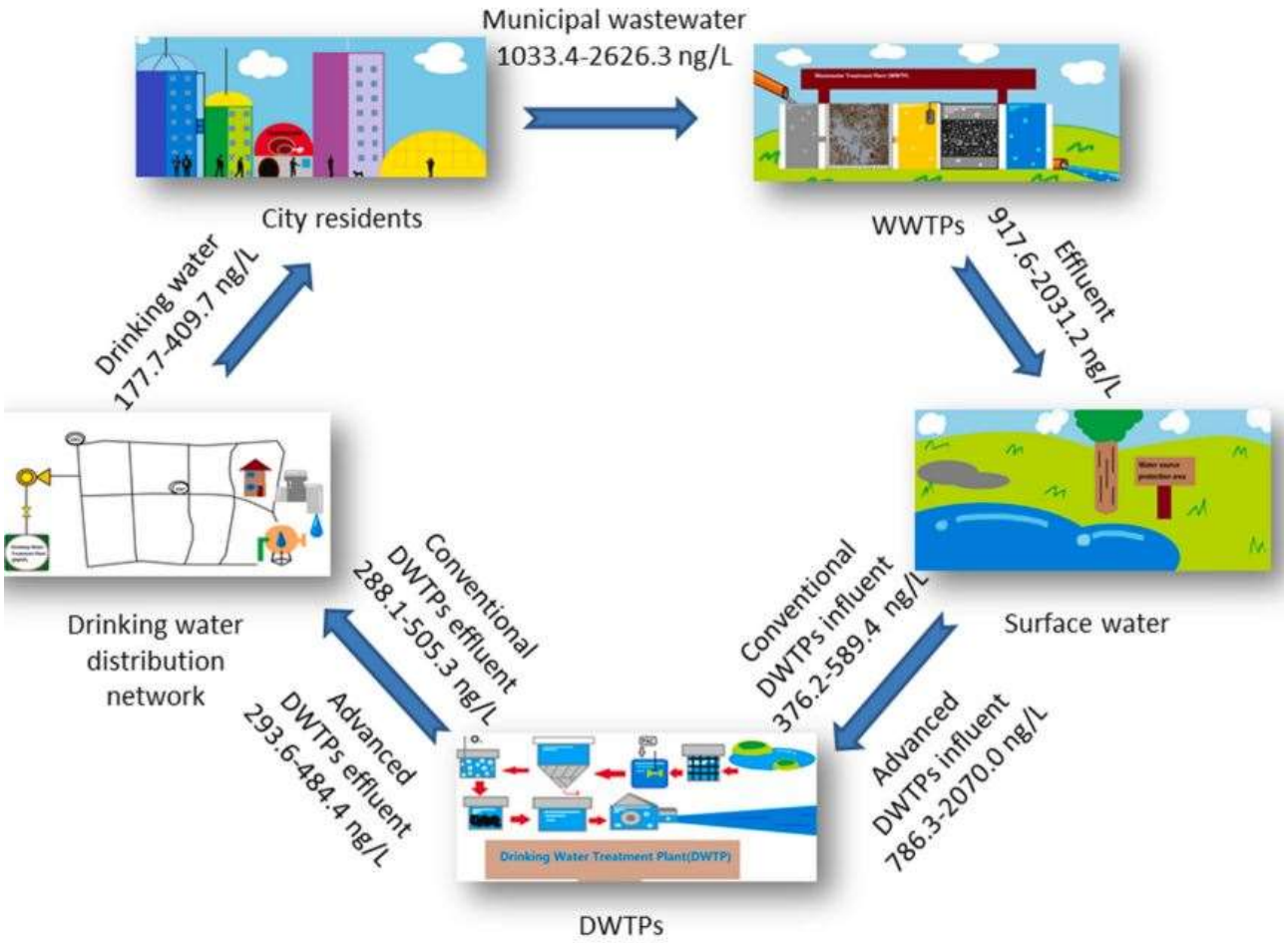






Prevalence of Sucralose-Case Study: Zhejiang Province

- Found sucralose in all water sources; municipal wastewater > surface water > drinking water
- DWTP removed 19.7% of sucralose (advanced processes removed 56.5-85.7%)
  - But removal processes could create DBPs


Municipal wastewater
1033.4-2626.3 ng/L
City residents
WWTPs
Effluent
917.6-2031.2 ng/L
Surface water
Conventional
DWTPs influent
376.2-589.4 ng/L
Advanced
DWTPs influent
786.3-2070.0 ng/L
DWTPs
Conventional
DWTPs effluent
288.1-505.3 ng/L
Advanced
DWTPs effluent
293.6-484.4 ng/L
Drinking water
distribution
network
Drinking water
177.7-409.7 ng/L
Drinking Water Treatment Plant(DWTP)

Why is Sucralose Important?

- Widespread detection of sucralose in water sources has become a concern for some
  - Sucralose has been approved by the FDA (1998) and many other food safety agencies around the world
  - Studies have shown that sucralose is poorly absorbed in mammals and does not accumulate in the body over time
  - Studies have shown sucralose is a relatively safe product, but with rising detection in aquatic environment concerns have been raised
    - Breakdown of sucralose in WWTPs can lead to an increase in formation of disinfection by-products (DBPs) which have been associated with increased cancer risk

Safety of Sucralose

- Sucralose has been found in the environment in concentration ranging from the ng/l – mg/l
- 5 mg/kg body weight per day has been set as acceptable daily intake

Table 10 Compounds' half-lives and predicted no effect concentrations (PNEC) for aquatic invertebrates followed by imidaclc pesticide registration benchmarks for aquatic life

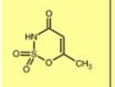
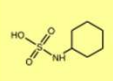
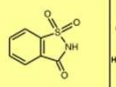
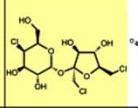
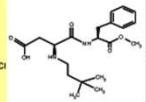
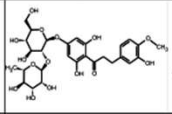
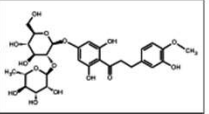
Compound	Half-life water	PNEC	Reference	
Sucralose	> Year	930,000 ng/L	Tollefsen et al. 2012	
Acetaminophen	Days to weeks	9200 ng/L	Kim et al. 2007, Table 3	
Carbamazepine	Days to weeks	31,600 ng/L	Kim et al. 2007, Table 3	
Primidone	Days to weeks	ND	ND	
Imidacloprid	Weeks to months	10 ng/L	USEPA 2017b	
US EPA pesticide registration program benchmarks[a]				
Compound	Fish (acute)	Fish (chronic)	Invert (acute)	Invert (ch
Imidacloprid	> 114,500,000 ng/L	9,000,000 ng/L	385 ng/L	10 ng/L

ND = not determined

[a] U.S. EPA Office of Pesticide Program aquatic life benchmarks (https://www.epa.gov/pesticide-science-and-assessing-pest risks/aquatic-life-benchmarks-pesticide-registration)

Why is Sucralose Important Cont?

- Sucralose is a useful environmental tracer of wastewater
  - Popularized first in Europe, sucralose has been increasingly used in the U.S since 2009
  - Sucralose is just one of many artificial sweeteners has proven usefulness in aquatic studies

CAS no.	ACE 33665-90-6	CYC 100-88-9	SAC 81-07-2	SUC 56038-13-2	Aspartame 22839-47-0	Neotame 165450-17-9	NHDC 20702-77-6
Structure							
Molecular formula	$C_4H_5NO_4S$	$C_6H_{13}NO_3S$	$C_7H_5NO_3S$	$C_{12}H_{19}Cl_3O_8$	$C_{14}H_{18}N_2O_5$	$C_{20}H_{30}N_2O_5$	$C_{28}H_{36}O_{15}$
Molecular weight in (g/mol)	163.15	179.24	183.19	397.63	294.31	378.47	612.58
Sugar equivalence	200 [66]	30 [67]	300 [68]	600 [69]	160–220 [68]	7,000–13,000 [70]	up to 1,800 [71]
Water solubility in (g/L)	270 (20 °C) [66]	1.000 [69], 133 [67]	4 [69]	283 (20 °C) [72]	~10 (25 °C) [73]	12.6 [74]	0.4-0.5 [71]
pK_a [a]	2.0 [75]	1.9 [76]	2.2 [76]	11.8[c] [77]	3.19 and 7.87 [78]	3.01 and 8.02 [79]	9.7[c] [77]
log K_{OW} [b]	-1.33 [69]	-1.61 [69]	0.91 [69]	-1.00 [69] -0.51±0.05 [72]	0.07 [69]	2.39 (nonionic species) [77]	0.75 (nonionic species) [77]
Human excretion	100 % unchanged [66], mainly unchanged [19]	mainly unchanged [19], inter-individual variations in conversion to cyclohexylamine [80]	mainly unchanged [19]	>92 % unchanged [81]	complete metabolic breakdown into aspartic acid, phenylalanine, and methanol [82]	<2 % [70] (deesterification major metabolic pathway)	complete metabolism by hydrolysis and conjugation is anticipated [83]
ADI mg/kg body weight	9 (potassium salt) [84]	7 [80]	5 (sodium salt), 3.8 (free acid) [85]	15 [86]	40 [82]	2 [87]	5 [83]

Sucralose as an Environmental Tracer

- Pros
  - High environmental concentrations
  - Highly water solvable and chemically stable
  - Most WWTP processes remove little sucralose
  - No known environmental effects
- Cons
  - Does not discriminate source (i.e septic, treated wastewater, or untreated wastewater)
  - Long survivability in low mixing conditions can build concentrations
  - Signal strength depends on human consumption, can vary regionally

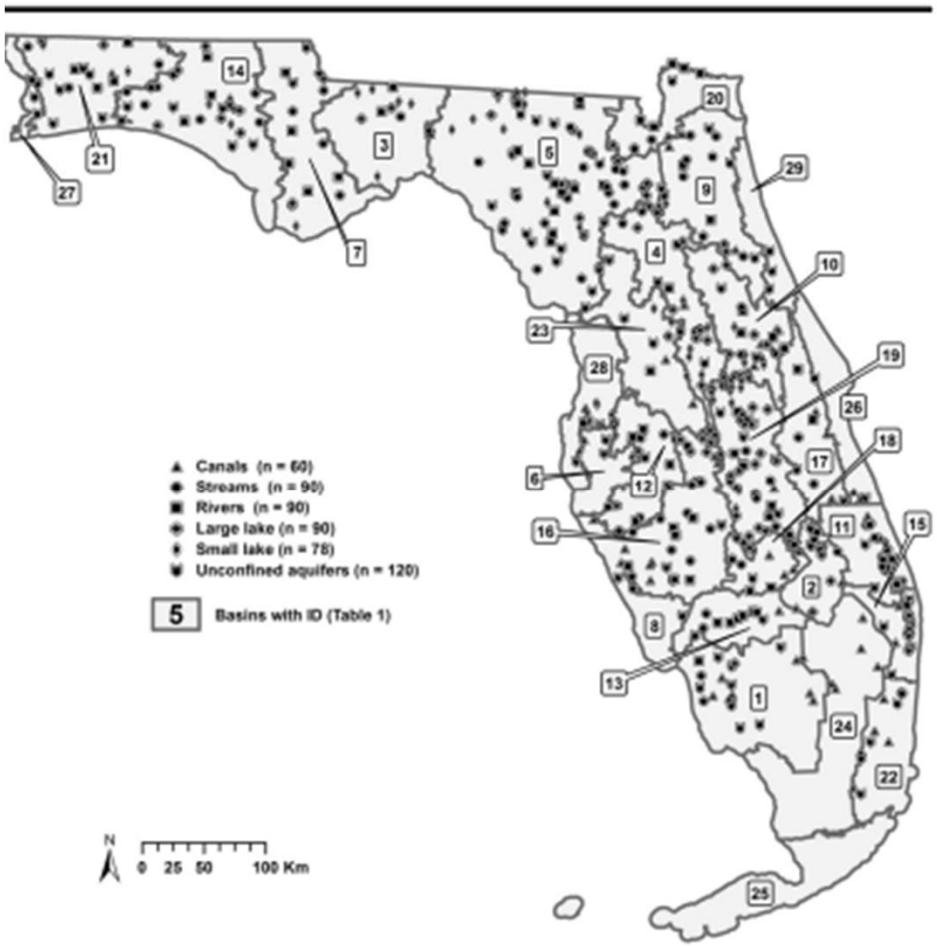
Environmental Tracer Studies

- Occurrence and suitability of sucralose as an indicator compound of wastewater loading to surface waters in urbanized regions -2011
- Evaluation of the artificial sweetener sucralose as a sanitary wastewater tracer in Narragansett Bay, Rhode Island -2019
- Comparison of environmental tracers including organic micropollutants as groundwater exfiltration indicators into a small river of a karstic catchment - 2020
- Comparative analysis of nitrogen concentrations and sources within a coastal urban bayou watershed: A multi-tracer approach -2021

Sucralose in Florida

Sampling of water bodies was completed in 2015 as follows

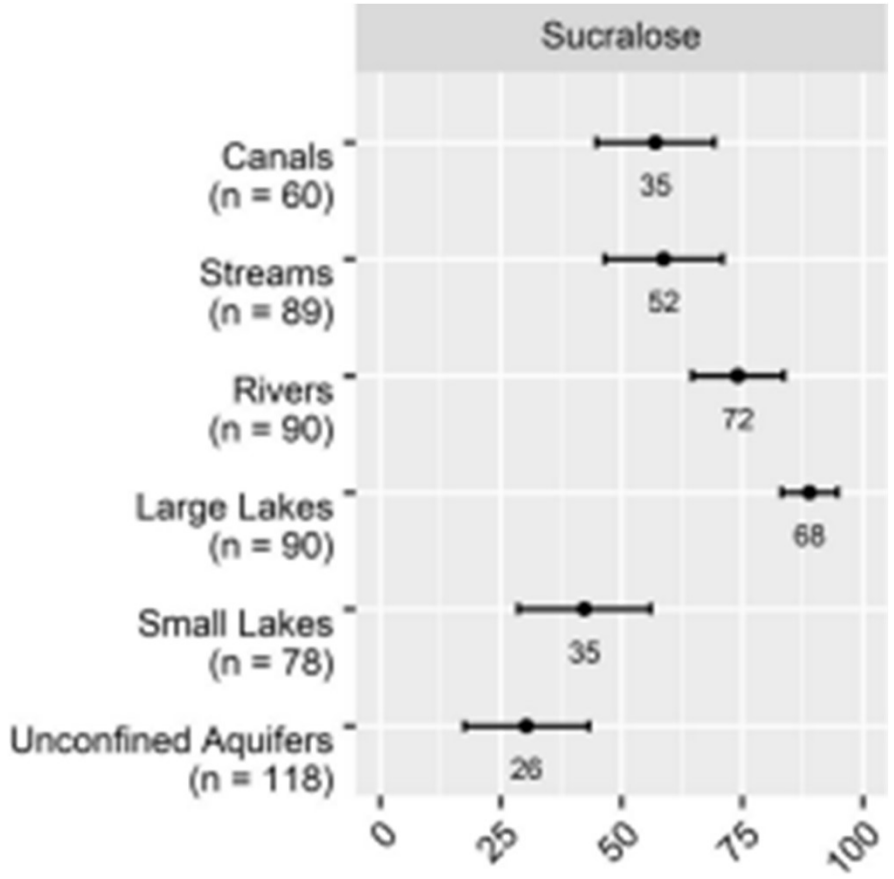
- Feb-Mar: canals
- May-Jun: rivers
- Jul-Sep: streams
- April-May: large lakes
- Sep-Oct: small lakes
- Nov-Dec: unconfined aquifers



Estimated percentage of waters with detectable concentrations

- The Status Monitoring Network sampling in 2015 monitored 528 sites, Sucralose was detected in all water resources and found in 292/528

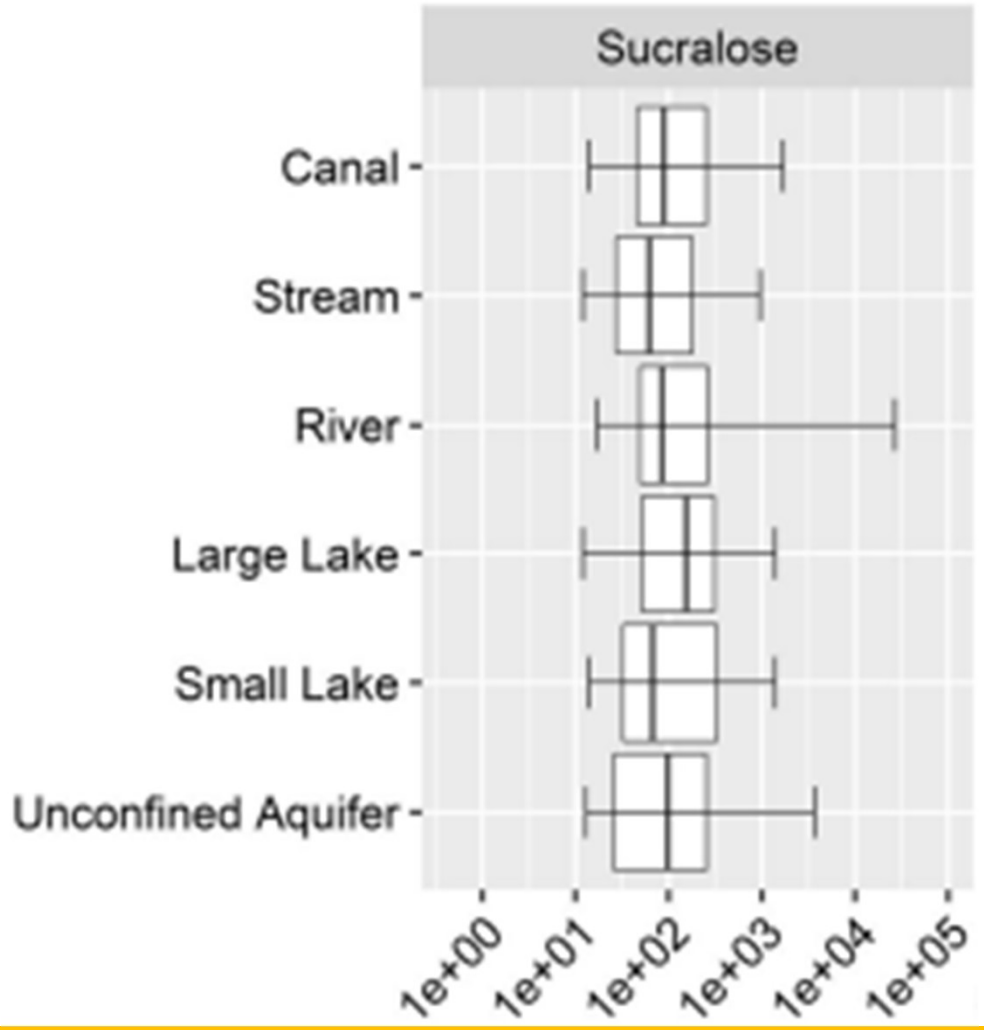
*units for area are as follows canals, streams, and rivers = km; lakes =ha, unconfined aquifers = # of wells



Concentration of Sucralose in waters

- Sucralose concentrations in Florida were found to between 100 to 40,000 ng/l

*units of figure in ng/l



Sucralose in Tallahassee

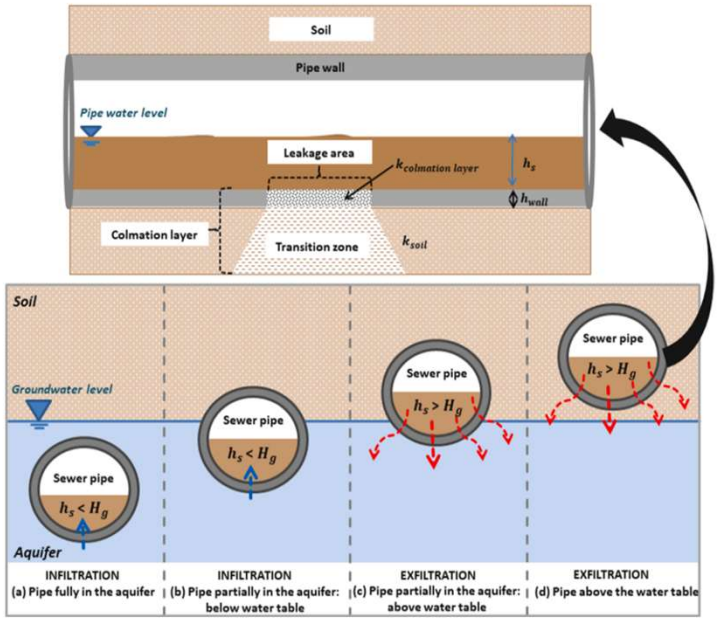
Sucralose has been detected in several ponds around Tallahassee

Possible leakage of sewage from older pipes

Exfiltration of sewage from pipelines can impair surface and groundwater

Exfiltration

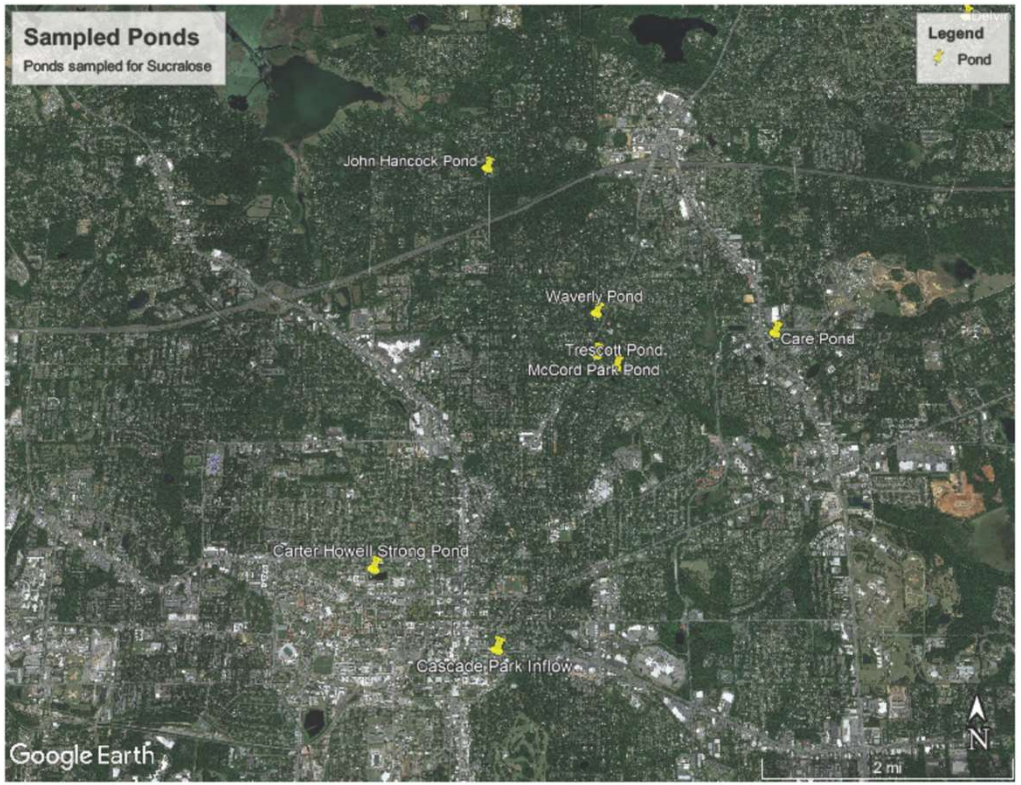
- Exfiltration is the process of water (sewage) loss out into the environment
  - Pipeline failures
  - Bedrock dissolution
  - Soil undermining
- Conditions for Exfiltration
  - Sewer system failure
  - Location of failure above local GW table
  - Hydraulic potential of sewer pipe is higher than hydraulic potential in the surrounding soil



Tallahassee Sampling

Site Name	Sucralose (ng/l)
Care Pond	371
Carter Howell Strong Pond	85.7
Cascade Park Pond Inflow	62.2
Delvin Pond	ND
John Hancock Pond	143
McCord Pond	153
Waverly Pond	ND

Sampling preformed in Aug 2021



General Take-Away

- Sucralose is a man made contaminate that is increasingly detected in waters affected by urban processes
- Sucralose is a useful, highly used environmental tracer
- Sucralose can be used to answer many questions, but may require other tracers for more specific information
- More studies of sucralose are needed to
  - Investigate environmental effects
  - Further understand relationships with environments and different environmental tracers