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Micropollutant removal in sustainable biological wastewater treatment systems

Oladapo Komolafe

Presentation for Bioremediation symposium

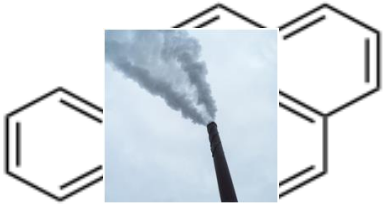
May 26, 2017

Selection of micropollutants

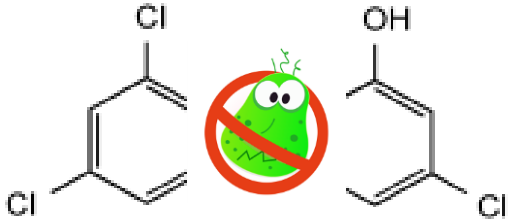
- Ubiquitous presence in wastewater.
- Priority substances listed in the EU directives
- From a wide range of applications

Estrogens (e.g. EE2)

PBDEs



PAHs (e.g. Benzo(a)pyrene)



Triclosan

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The problem

- The sources of some of the micropollutants cannot be eliminated e.g. Natural estrogens
- Continuous usage and deposition of the micropollutants into treatment plants
- Effluents from conventional wastewater treatment plants identified as major route into open water bodies

- Tertiary treatment processes like Advanced Oxidation Processes and sorption onto granular activated carbon are expensive and carbon polluting.

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The problem

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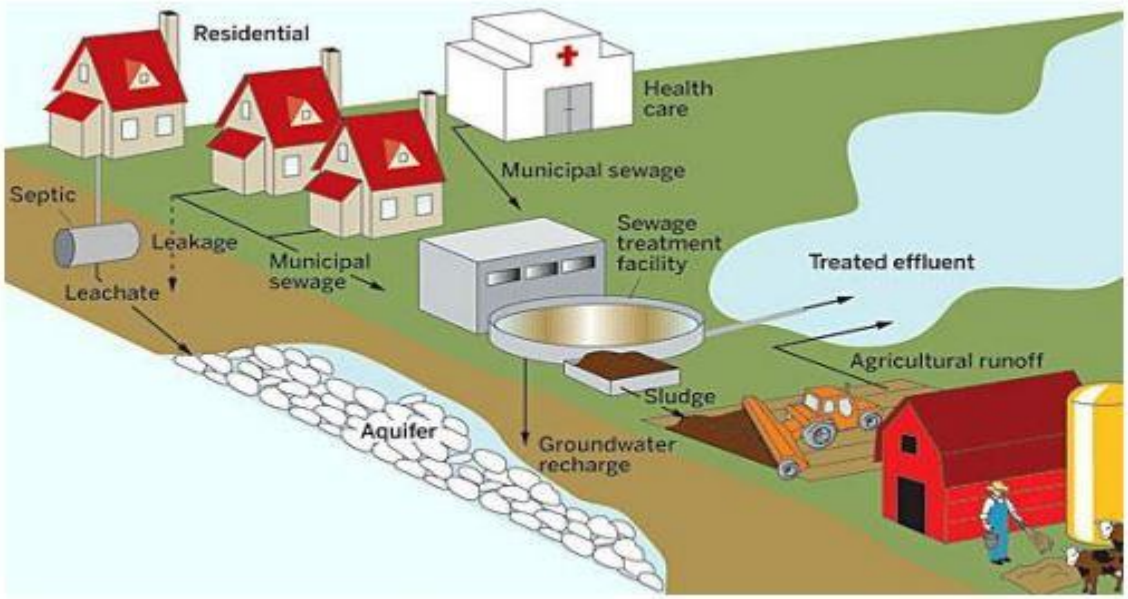

Sources, transport, and fate of micropollutants in the environment (EPA).

- Tertiary treatment processes like Advanced Oxidation Processes and sorption onto granular activated carbon are expensive and carbon polluting.

Research Motivation

- Little is known about the true biological limits of micropollutant removal by alternative low energy technologies in comparison with conventional treatment systems currently advocated.

  Alternative low energy systems like Up-flow Anaerobic Sludge Blanket Reactor (UASBs) and Waste Stabilization Ponds (WSP).

- Individual treatment systems may be biased in the removing different group of micropollutants (e.g halogenated vs non-halogenated compounds)

Objectives

- Validate analytical methods using SPE-GC-MS, SPE-GC-ECD or SPE-LCMS to measure micropollutants in wastewater.

- Investigate the removal of micropollutants from the aqueous phase by real wastewater treatment plants utilizing UASB and WSP technologies- collective system and unit processes.

- Investigate the relative effect of structure/type of compound and microbial community on degradation of the micropollutants in these treatment systems

- Obtain degradation rates for the micropollutants under different conditions

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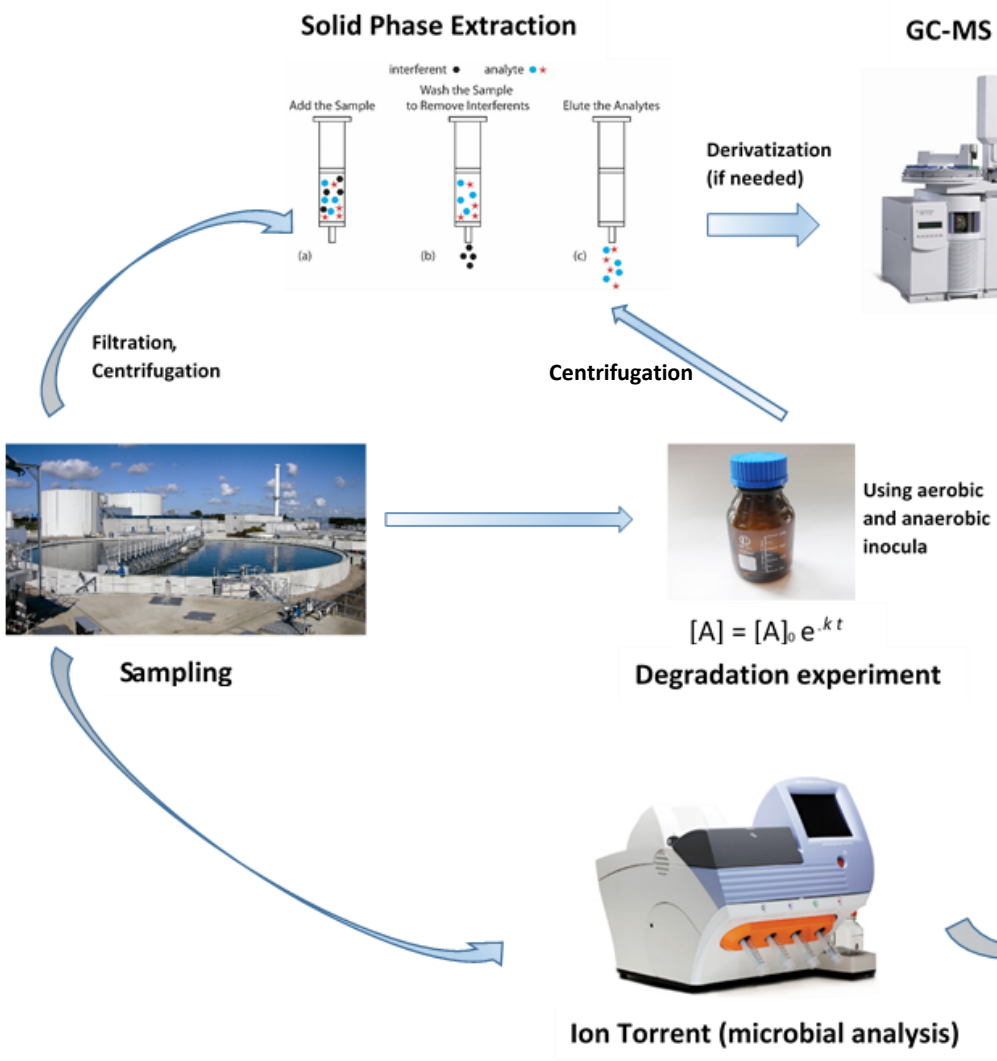
Approach



- To determine fate of the micropollutants across the WWTP
- Removal rates.
- Degradation rates
- Dominant microbial community
- Relationship between the above measurements

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Method Validation

Compound	Recovery in effluent, Mean %, (RSD), n=3	MDL (ng/L)	Method
Triclosan	102 (11.8)	5.6	SPE-GC-MS/ EI
Low molecular weight PAHs	62 – 128 (3.8 – 6.8)	0.4 – 2.7	SPE-GC-MS/ EI
Middle molecular weight PAHs	109 – 133 (0.4 – 0.8)	3.0 – 7.2	SPE-GC-MS/ EI
High molecular weight PAHs	23 – 88 (3.3 – 8.0)	2.7 – 7.4	SPE-GC-MS/ EI
PBDE 28,47, 99,100	83 – 129 (4.7 – 15.2)	0.6 – 2.7	SPE-GC-ECD
PBDE 153, 154, 183	60 – 150 (6.7 – 9.1)	0.2 – 4.2	SPE-GC-ECD
PBDE 209	113 (2.3)	10.8	SPE-GC-ECD

Recovery at 100 ng/L for all compounds except PBDEs at 10 ng/L

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PBDE 153, 154, 183	60 – 150 (6.7 – 9.1)	0.2 – 4.2	SPE-GC-ECD
PBDE 209	113 (2.3)	10.8	SPE-GC-ECD

US EPA recommends 70 – 130% recovery with RSD less than 20%

Recovery at 100 ng/L for all compounds except PBDEs at 10 ng/L

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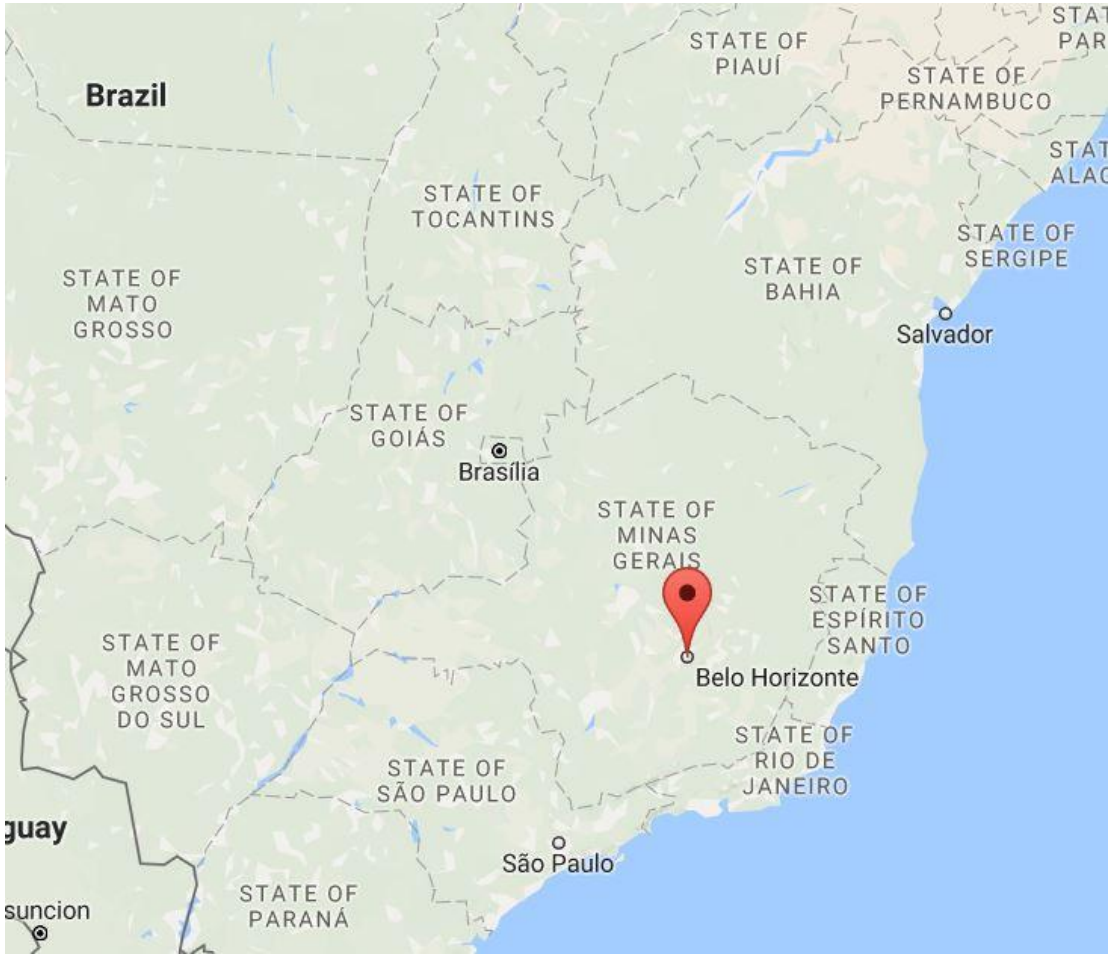
Survey in Brazil



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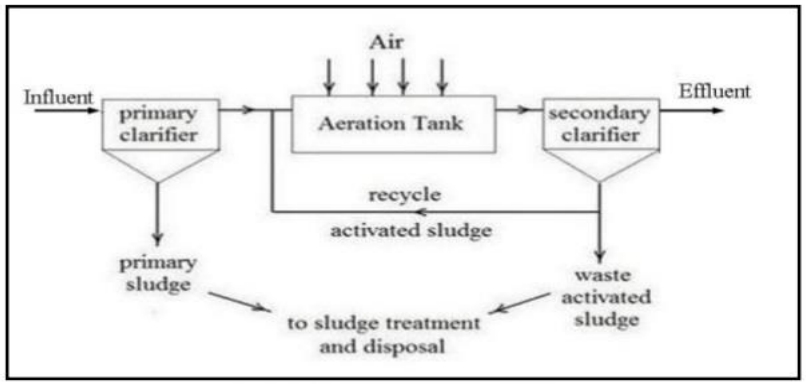
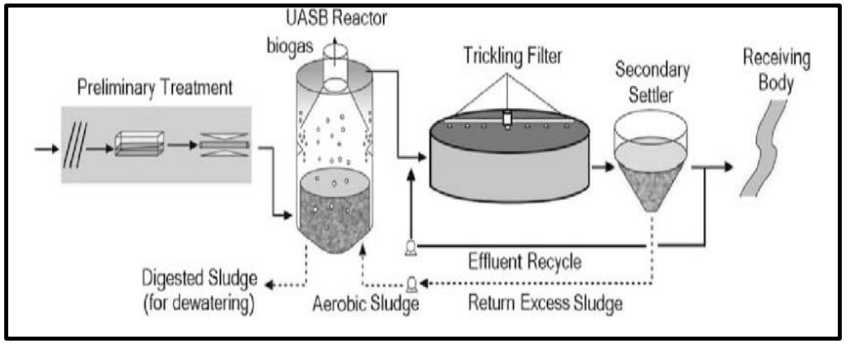
Survey in Brazil

Plants investigated

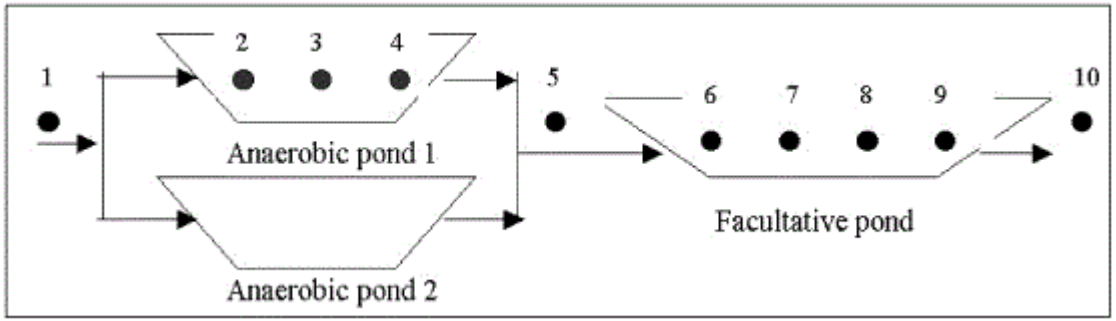
Activated sludge



UASB- Trickling filter



WSP



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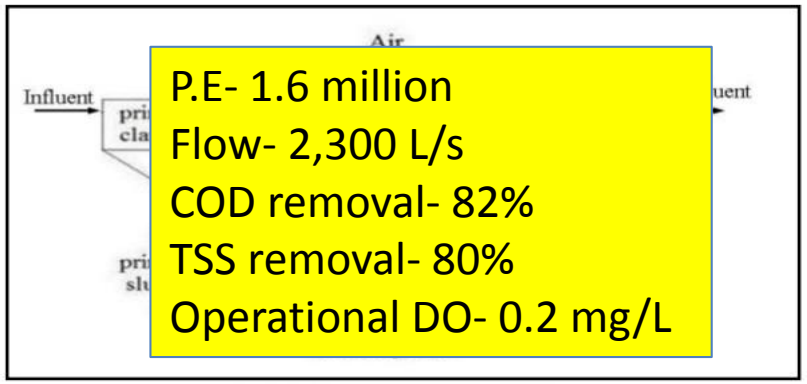
Activated sludge



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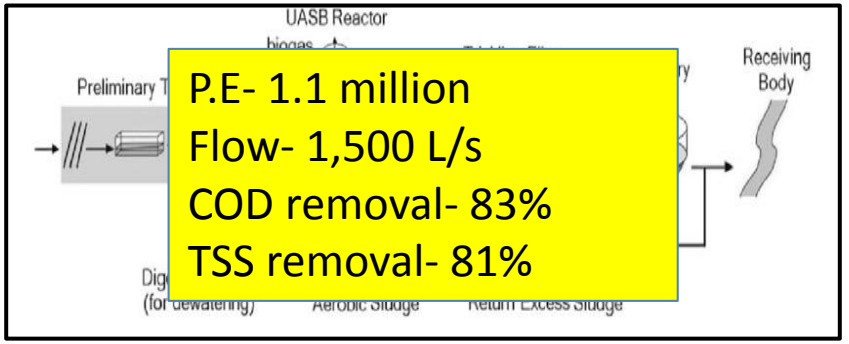
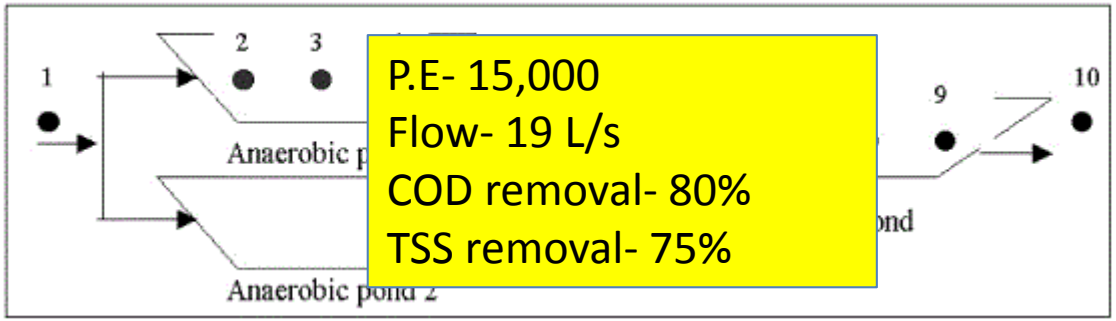


WSP



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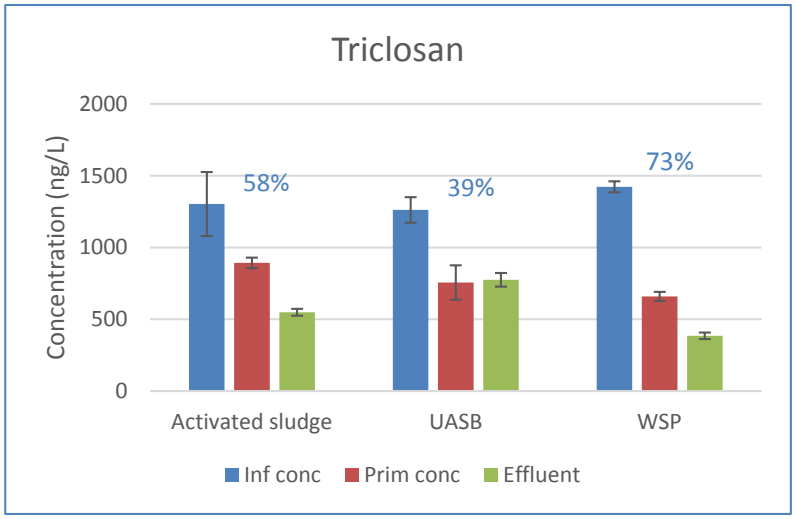
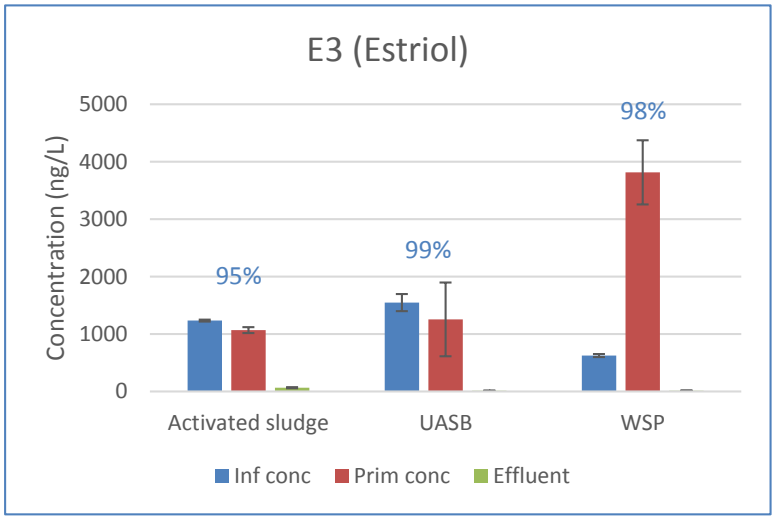
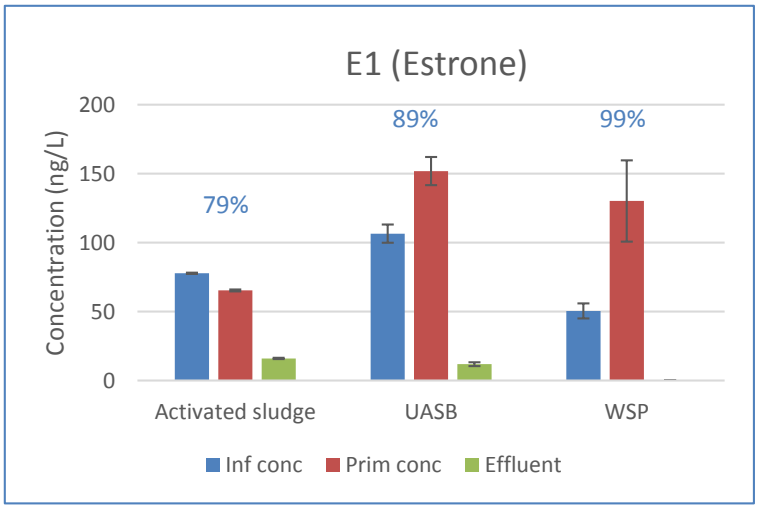
Triclosan and Estrogens in Brazil WWTP







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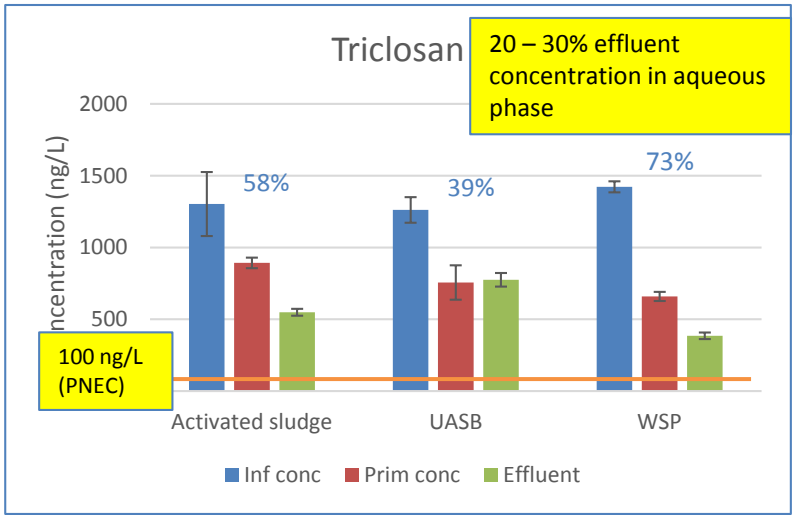

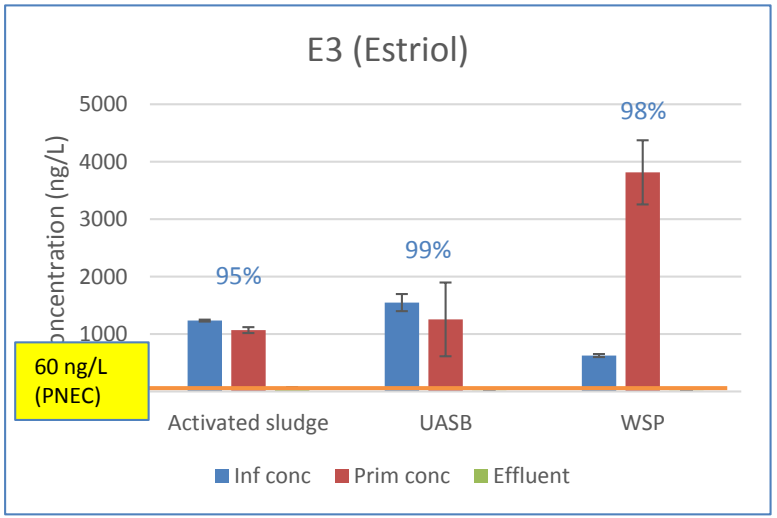

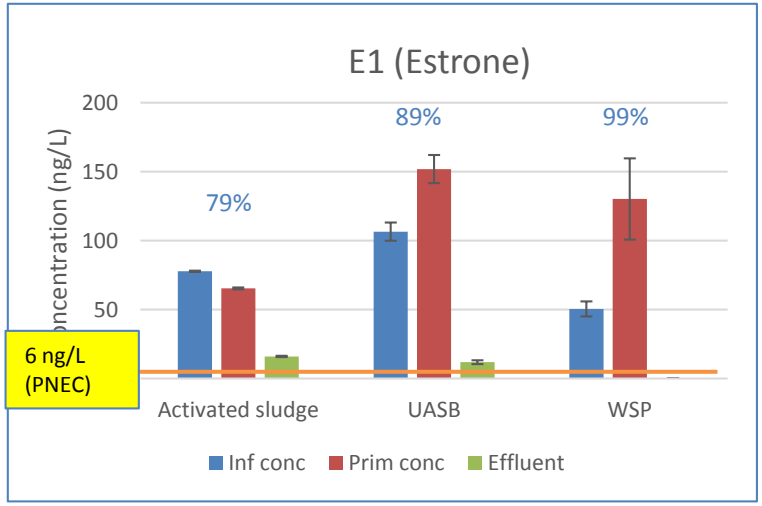

Estradiol (E2) and ethinylestradiol (EE2) was not found

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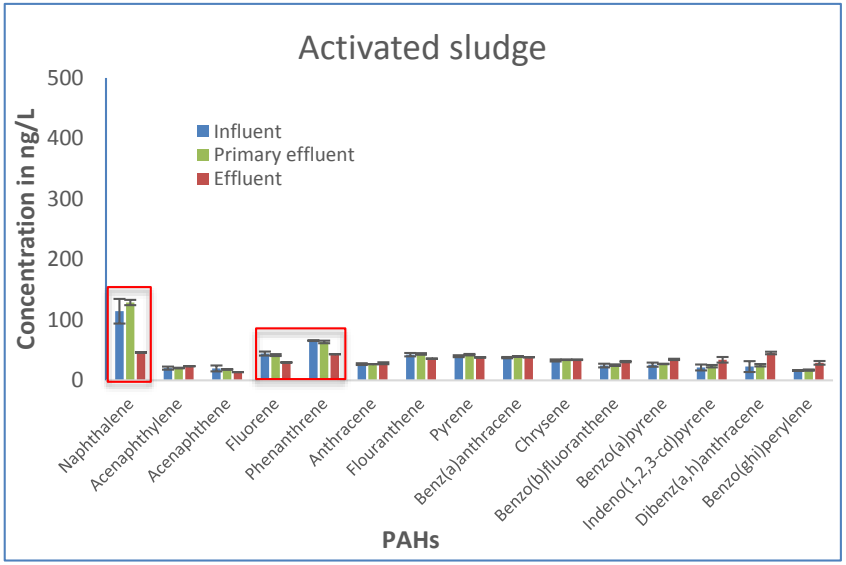
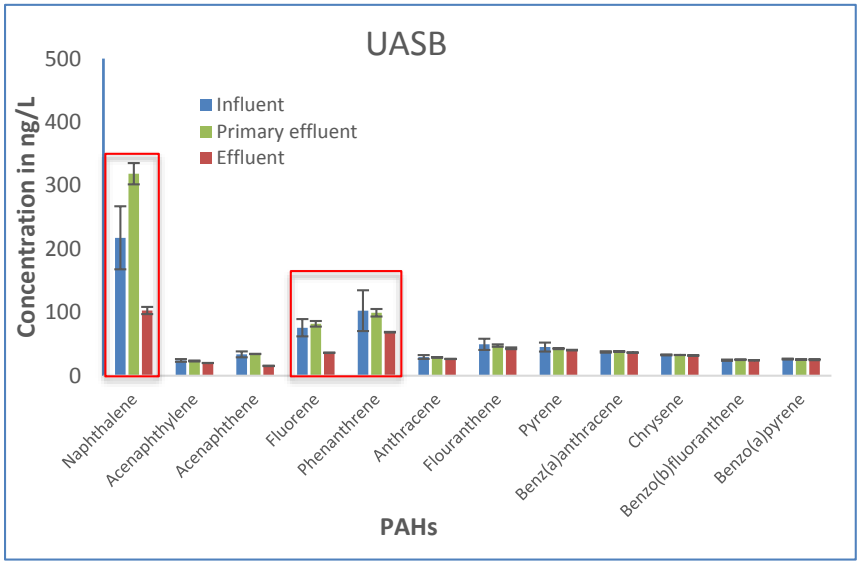
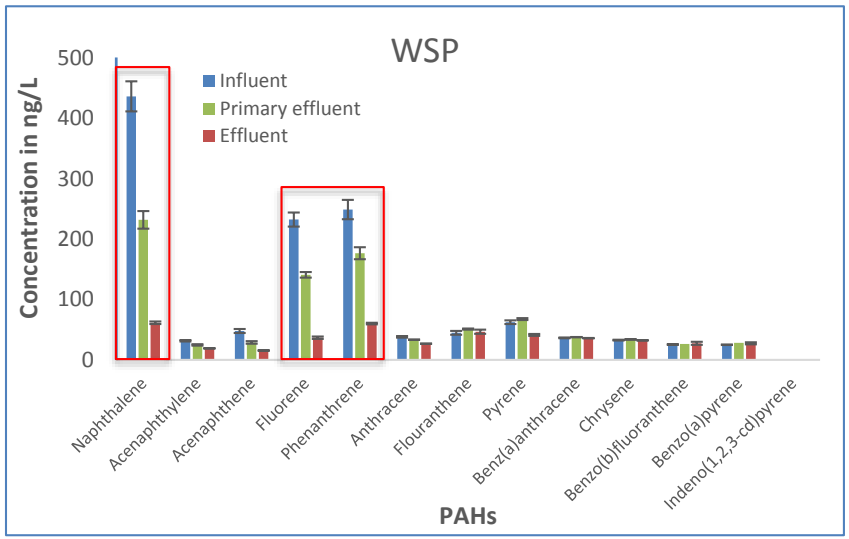
Concentration of PAHs in WWTPs in Brazil







EQS Standards

Naphthalene: 2000 ng/L

Anthracene: 100 ng/L

Fluoranthene 6.3 ng/L

Benzo(a)pyrene: 0.2 ng/L

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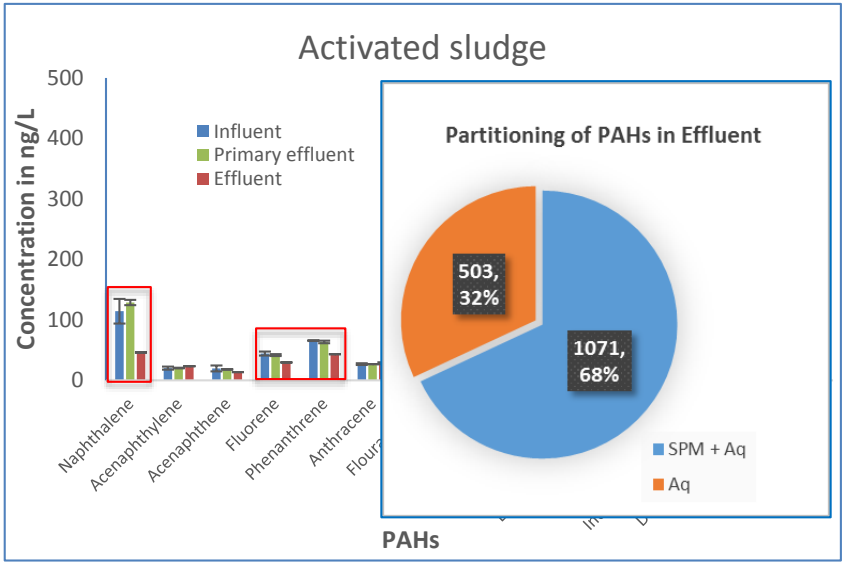

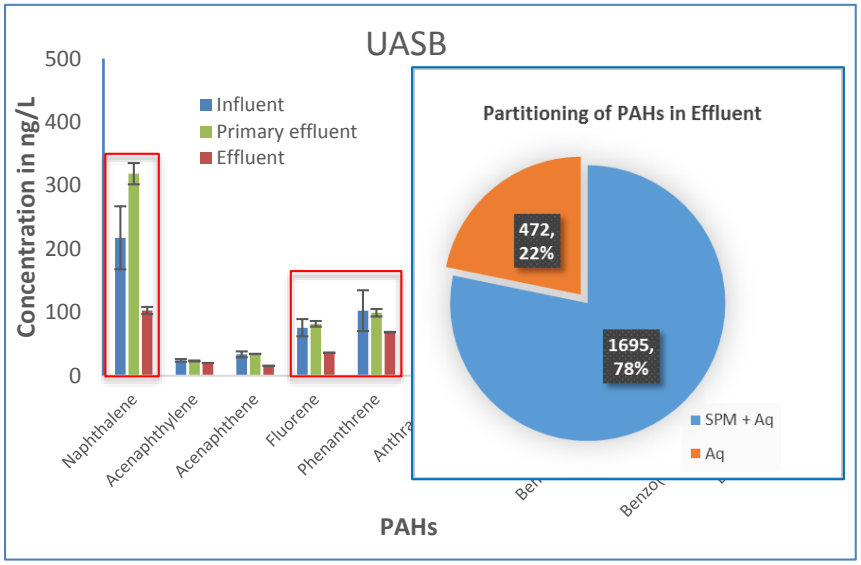

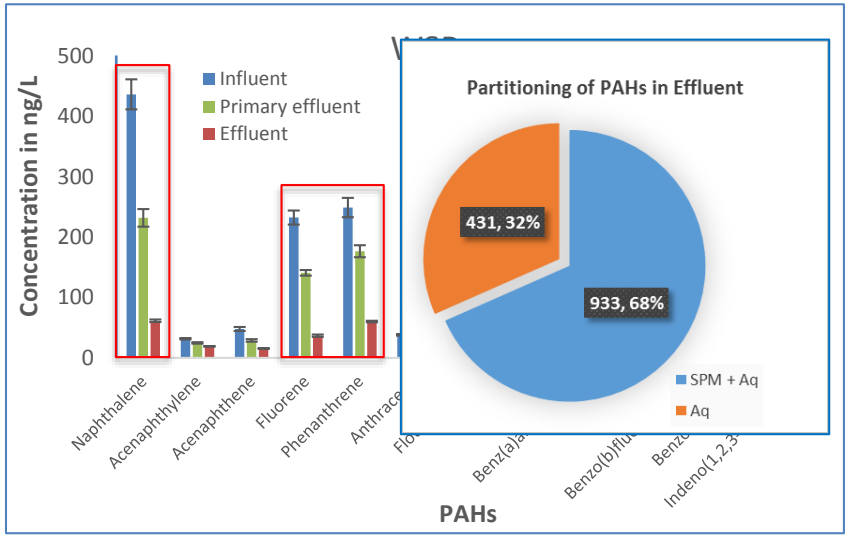

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Degradation experiment

- The inocula used was collected from the same WWTPs investigated in survey
- Abiotic and adsorption control were maintained in addition to the reactors.
- Experiments were carried out at room temperature (27-32^{o}C)

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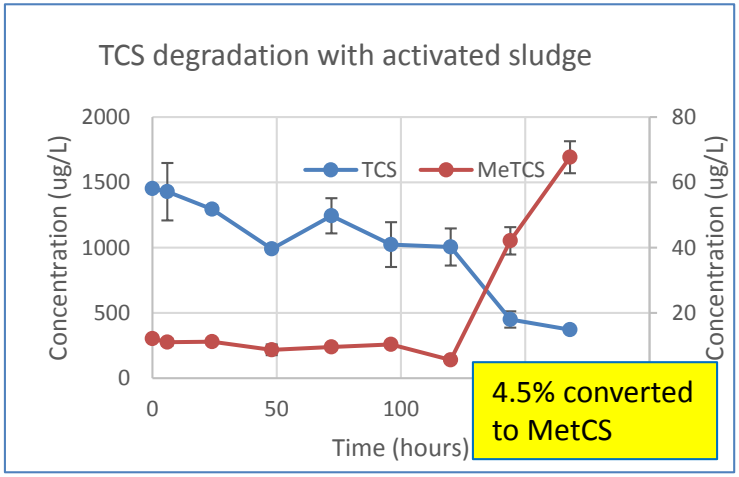
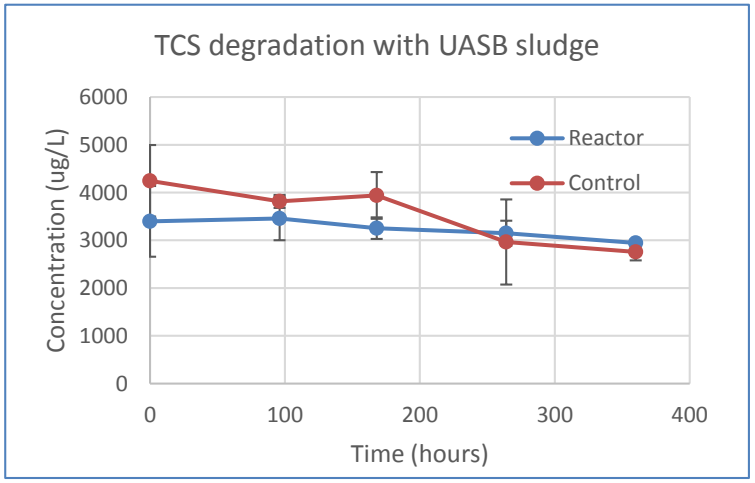
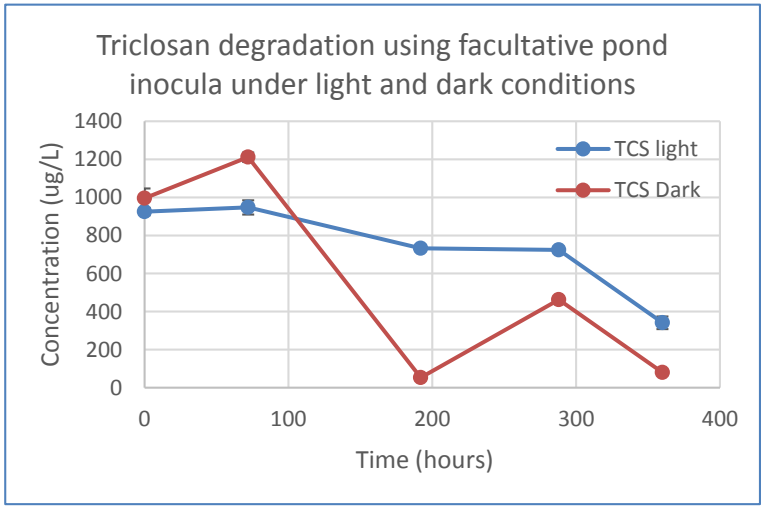
Triclosan degradation





Disappearance of Triclosan		
Conditions	**K (h^{-1})**	**$t_{1/2}$ (h)**
Aerobic inocula	0.0072	96
Anaerobic inocula	0	0
Facultative inocula (light)	0.0024	289
Facultative inocula (dark)	0.0063	110



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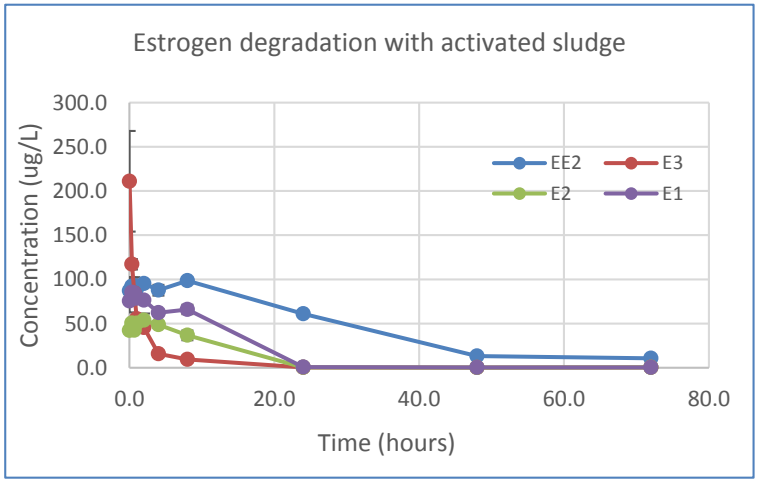
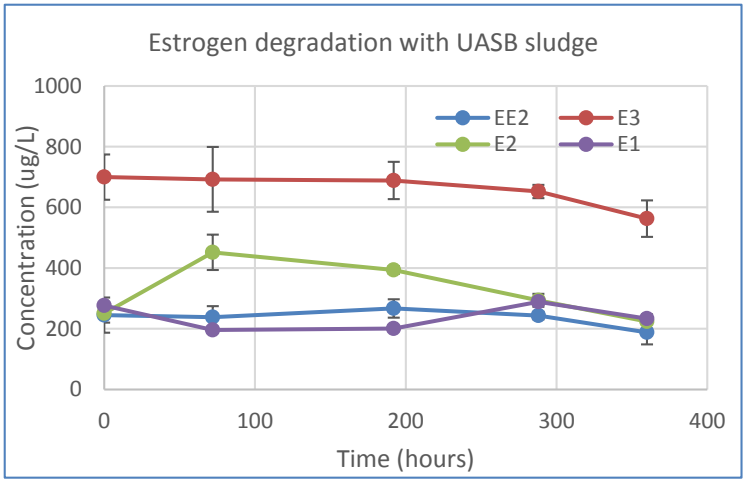
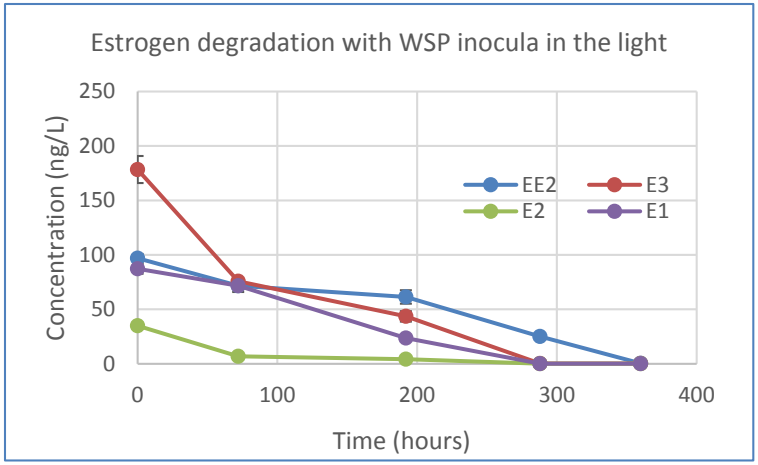
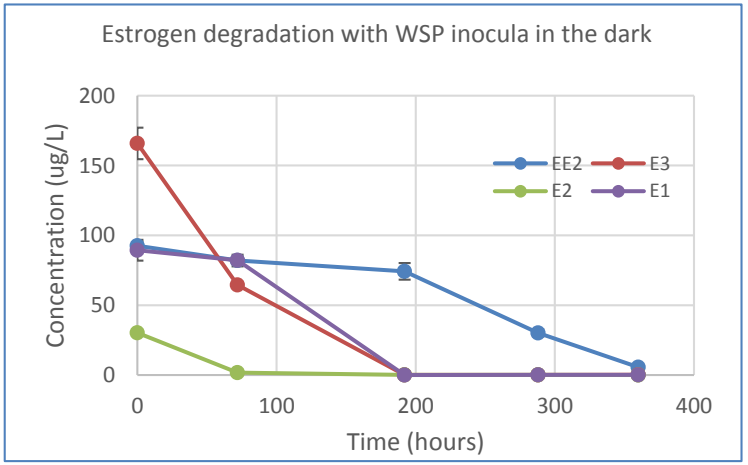
Estrogen degradation









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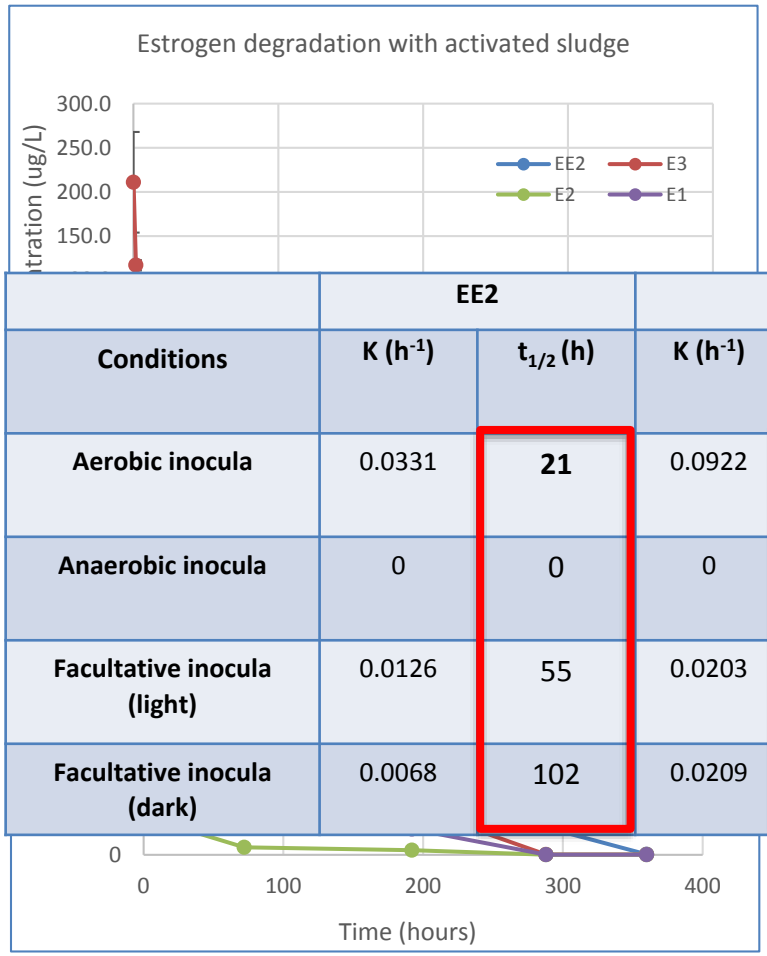

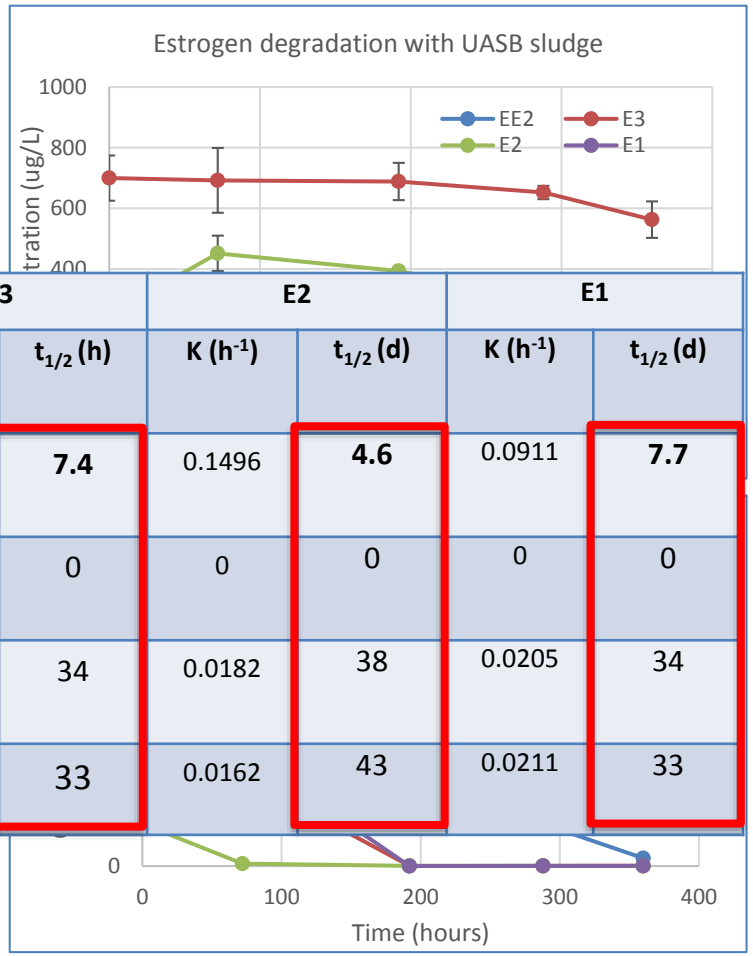

	EE2		E3		E2		E1	
Conditions	**K (h^{-1})**	**$t_{1/2}$ (h)**	**K (h^{-1})**	**$t_{1/2}$ (h)**	**K (h^{-1})**	**$t_{1/2}$ (d)**	**K (h^{-1})**	**$t_{1/2}$ (d)**
Aerobic inocula	0.0331	**21**	0.0922	**7.4**	0.1496	**4.6**	0.0911	**7.7**
Anaerobic inocula	0	0	0	0	0	0	0	0
Facultative inocula (light)	0.0126	55	0.0203	34	0.0182	38	0.0205	34
Facultative inocula (dark)	0.0068	102	0.0209	33	0.0162	43	0.0211	33

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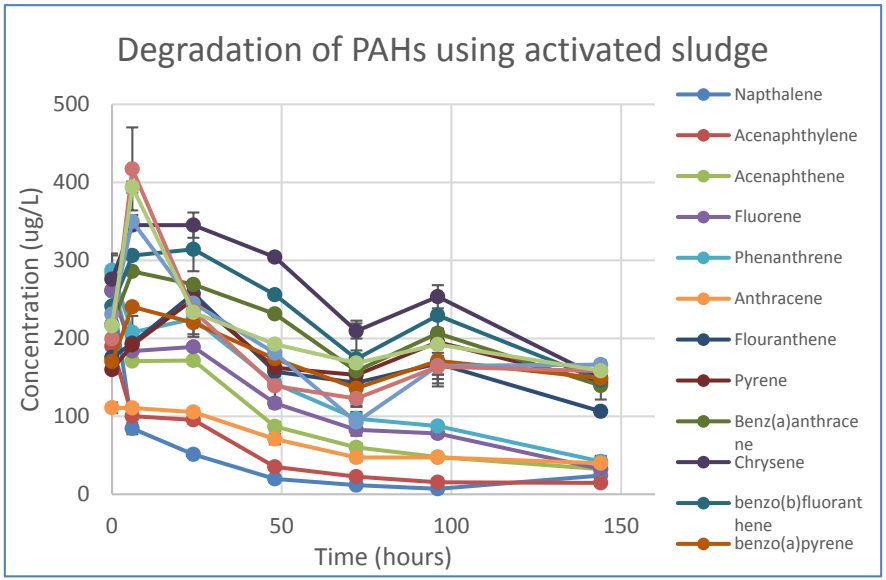
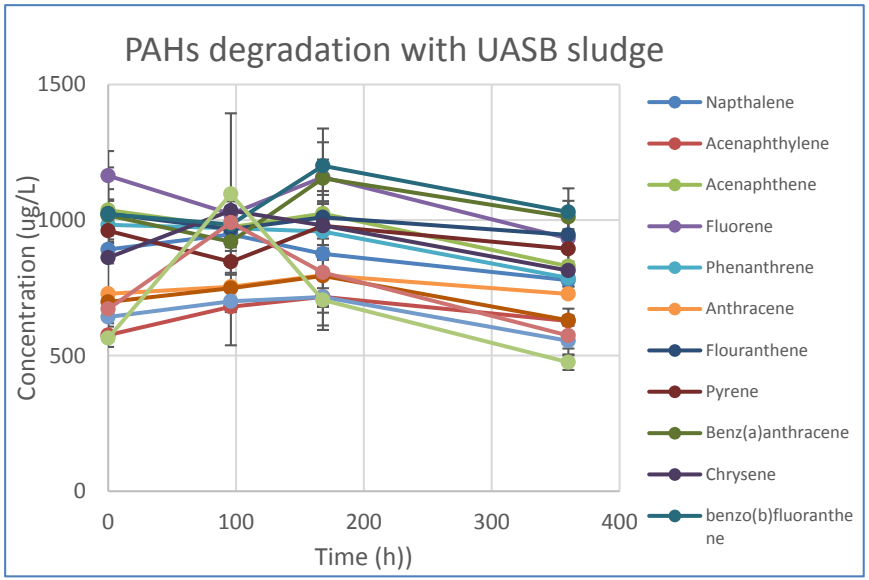
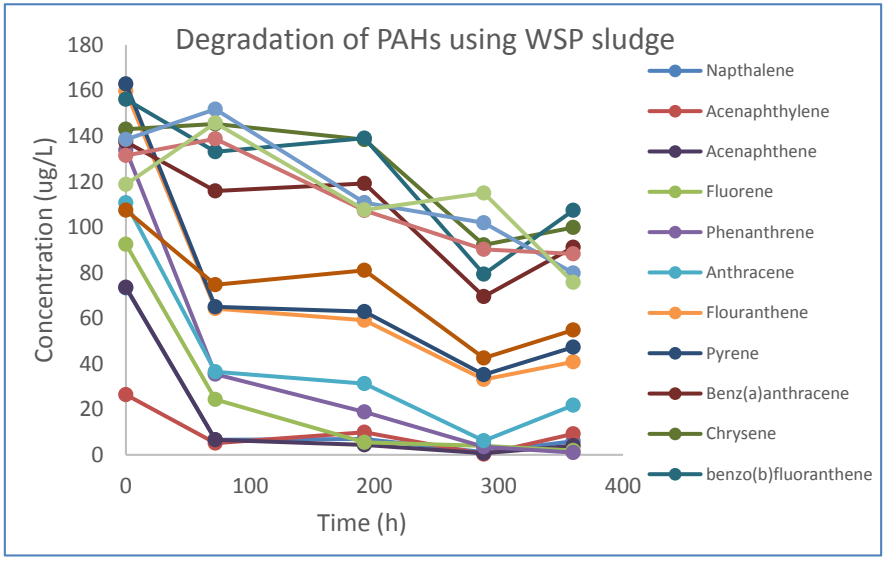
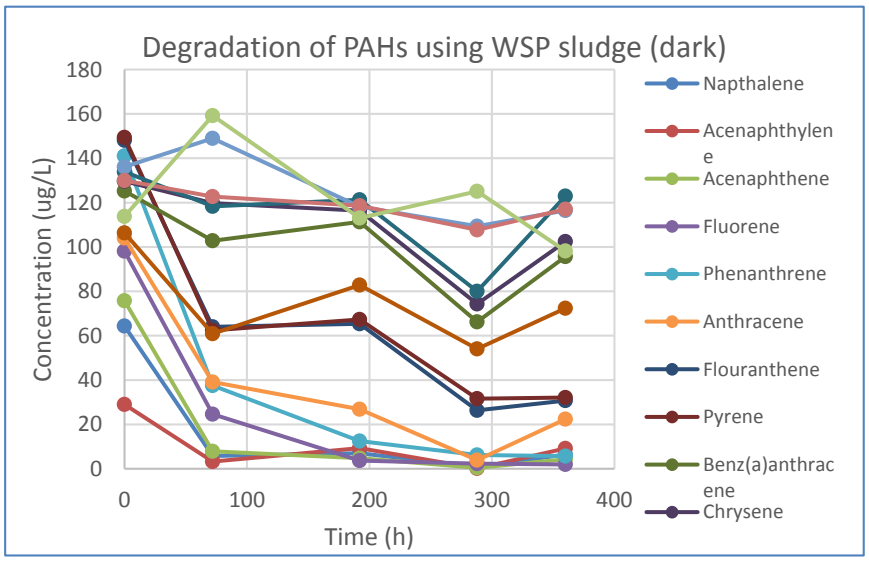
Degradation of PAHs









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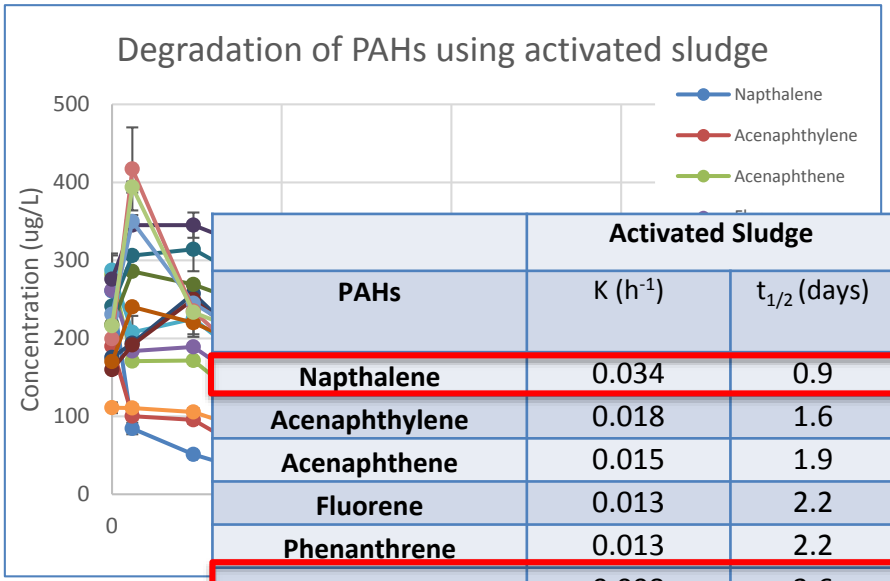
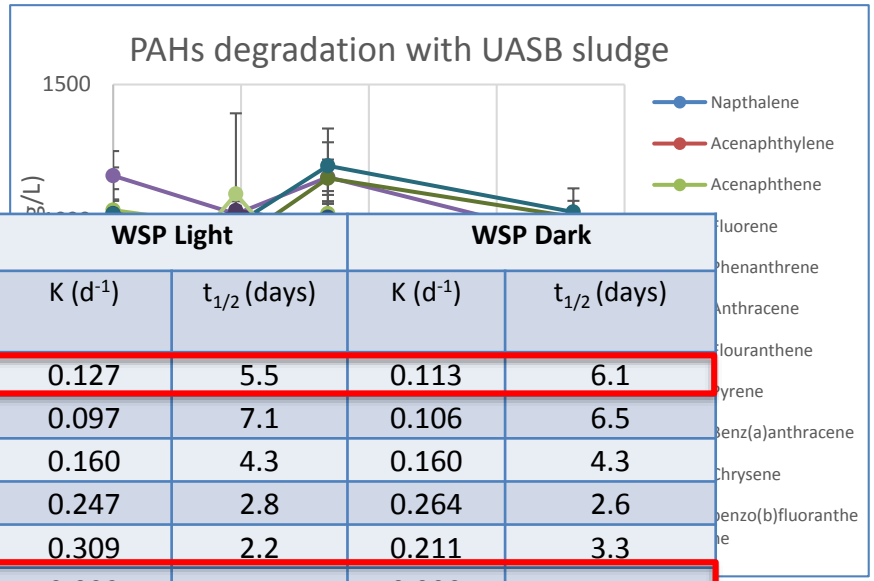
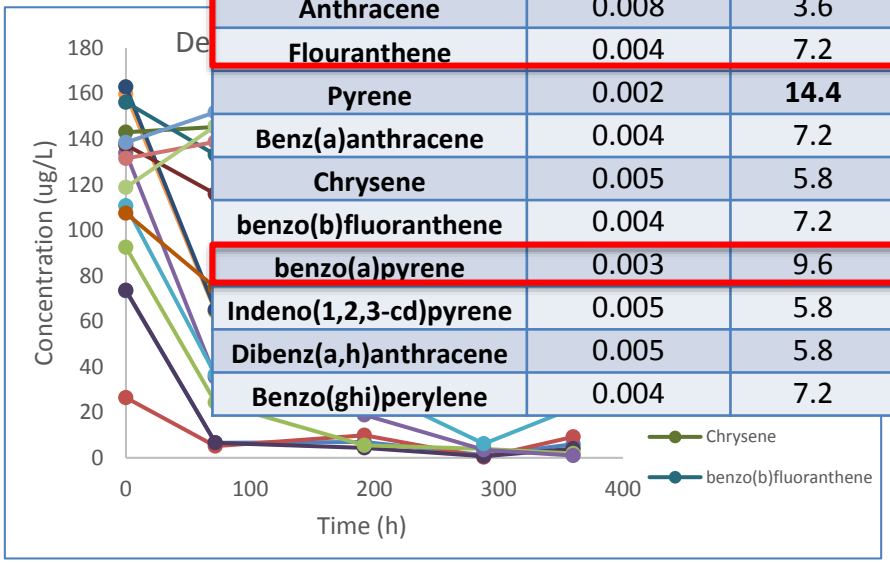
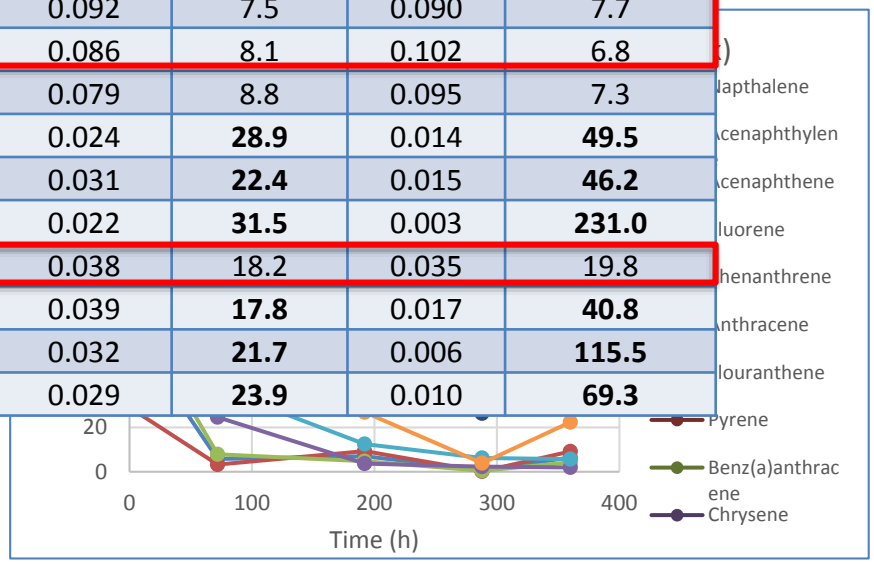
Degradation of PAHs





PAHs	Activated Sludge		WSP Light		WSP Dark	
	K (h^{-1})	$t_{1/2}$ (days)	K (d^{-1})	$t_{1/2}$ (days)	K (d^{-1})	$t_{1/2}$ (days)
Napthalene	0.034	0.9	0.127	5.5	0.113	6.1
Acenaphthylene	0.018	1.6	0.097	7.1	0.106	6.5
Acenaphthene	0.015	1.9	0.160	4.3	0.160	4.3
Fluorene	0.013	2.2	0.247	2.8	0.264	2.6
Phenanthrene	0.013	2.2	0.309	2.2	0.211	3.3
Anthracene	0.008	3.6	0.092	7.5	0.090	7.7
Flouranthene	0.004	7.2	0.086	8.1	0.102	6.8
Pyrene	0.002	**14.4**	0.079	8.8	0.095	7.3
Benz(a)anthracene	0.004	7.2	0.024	**28.9**	0.014	**49.5**
Chrysene	0.005	5.8	0.031	**22.4**	0.015	**46.2**
benzo(b)fluoranthene	0.004	7.2	0.022	**31.5**	0.003	**231.0**
benzo(a)pyrene	0.003	9.6	0.038	18.2	0.035	19.8
Indeno(1,2,3-cd)pyrene	0.005	5.8	0.039	**17.8**	0.017	**40.8**
Dibenz(a,h)anthracene	0.005	5.8	0.032	**21.7**	0.006	**115.5**
Benzo(ghi)perylene	0.004	7.2	0.029	**23.9**	0.010	**69.3**





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Conclusion

- Reliable analytical methods were developed/validated
- Micropollutant levels and removal capabilities have been compared between different biological systems
- Most of the chemicals were founds in all WWTP investigated and WSP was observed to worked better in removing these chemicals.
- Concentration of the chemicals in final effluent was still above EQS standards or PNEC
- None of the chemicals degraded anaerobically. Therefore, removal rates obtained in the UASB plant were either due to sorption to sludge or volatilization.

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On-going work

- Analysing PBDEs samples from the plant survey and degradation experiments

- Putative identification of changes in taxa associated with the degradation of these chemicals.

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Acknowledgement

Supervisors: Dr. Paola Meynet, Dr. Jan Dolfing, Dr. Wojciech Mrozik, and Dr. Russell Davenport (Newcastle University)

Partners in Brazil: Dr. Cesar Mota (UFMG, Belo Horizonte), Mr. Thiago Bressani

Sponsors

EPSRC Engineering and Physical Sciences Research Council

PETROLEUM TECHNOLOGY DEVELOPMENT FUND PTDF

Thank you. Any questions?