EFFECTIVENESS OF SELECTED ONSITE WASTEWATER-TREATMENT SYSTEMS IN REMOVING PHARMACEUTICAL AND PERSONAL-CARE PRODUCTS

05-04/319

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PREPARED BY
BARNSTABLE COUNTY DEPARTMENT OF HEALTH
AND THE ENVIRONMENT
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BARNSTABLE, MASSACHUSETTS 02630

PREPARED FOR
MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL PROTECTION
BUREAU OF RESOURCE PROTECTION
AND
THE ENVIRONMENTAL PROTECTION AGENCY REGION I

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MASSACHUSETTS EXECUTIVE OFFICE OF ENVIRONMENTAL AFFAIRS

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DEPARTMENT OF ENVIRONMENTAL PROTECTION

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Executive Summary

A preliminary survey was conducted to determine the efficacy of selected advanced onsite septic systems for the removal of selected pharmaceuticals and personal care products (PPCPs). The following technologies were chosen for this survey: standard "Title 5" system comprised of a stone trench overlying 60 inches of sand, an aerobic treatment system that combined fixed film surfaced with activated sludge, a recirculating filter unit containing fibrous peat, a single pass filter with open-cell foam, an upflow sulfur-filled filter following an aerobic treatment unit and a recirculating sand filter designed in accordance with standard practice. A system consisting of a filter of twenty-four inches of sand was used as a surrogate measure of influent wastewater due to analytical issues with examining the matrix of raw wastewater. The results indicate that a standard system with sixty inches of sand treatment was superior to all manufactured units for the removal of the selected PPCPs. The data also called into suspicion the validity of the sand filtered wastewater as an appropriate surrogate measure of influent wastewater and further suggested the potential for soils-based treatment of PPCPs. The report underscores the need for further research into soils-based treatment for PPCPs for the possible incorporation of low-cost modifications to optimize treatment for PPCPs in the onsite setting.

This project was funded by the Massachusetts Department of Environmental Protection with funds from the United States Environmental Protection Agency under a Section 319 competitive grant. The contents of this report do not necessarily reflect the views or policies of the departments mentioned nor does the mention of any product trade name constitute and endorsement.

INTRODUCTION

In June 2004, the U.S. Geological Survey (USGS), in cooperation with the Barnstable County Department of Health and Environment performed a cursory survey of Personal Care Products and Pharmaceuticals (PCPP) concentrations at selected locations on Cape Cod, and at selected sampling locations of two types of septic systems at the Massachusetts Alternative Septic System Test Center (Zimmerman, 2005). Of particular note in that preliminary survey was the fact that a recirculating sand filter effluent exhibited higher levels of many PCPPs compared to the standard soil absorption system. These results seemed counter-intuitive, since the recirculating sand filter is considered and advanced wastewater treatment documented to remove a number of wastewater contaminants. To confirm these very initial findings and to advance our understanding of the treatment efficacy of other advanced onsite wastewater treatment systems for the removal of PCPPs, the present project was conducted in cooperation with USGS.

PURPOSE AND SCOPE OF PRESENT PROJECT

The present project proceeds from study by of Zimmerman (2005)[1] that examined the performance of two onsite wastewater technologies. Since over 25% of the wastewater in the United States is disposed of through onsite septic systems, and further since these systems are often located in proximity to private and public water supplies, it is vitally important to understand the treatment efficacy of various onsite treatment strategies in removing PCPPs.

At the outset it should be understood that a number of constraints limited the extent to which the issue of onsite treatment technology and PCPPs removal could be addressed in the present project. These constraints can be summarized as follows: expense of sampling, lack of standardized methodology for assays and matrix issues. In order to address the first two issues, Barnstable County Department of Health and Environment

[1] This project was conducted in part using treatment cells at the Massachusetts Alternative Septic System Test Center.

again corroborated with the USGS to complete the project. Somewhat subsidized costs for sample processing allowed for the ability to sample twice at each of six technologies (morning and evening). To address methodology and quality control issues, the project relies upon the sampling and quality assurance protocols of the USGS National Water Quality Laboratory (NWQL) in Denver, Colorado to ensure that data reported are of a quality that can inform future research and decisions on the issue. This laboratory used the same methodology as used in other studies, notably a national survey of streams in 1999 – 2000 (Koplin and others, 2002). The third issue (that of matrix interference) deserves particular mention here. Raw wastewater presents particular challenges to obtaining valid results of PCPP concentrations due primarily to the interference of the solids component of this matrix. Accordingly, it was decided to use a surrogate measure of the influent that represented the "minimal" treatment of filtration to remove particulate solids. In retrospect, this strategy was likely flawed for reasons discussed later.

The present project investigates six representative onsite septic system technologies for their efficacy in removing selected PPCPs. For a list of compounds examined the reader can refer to Table 1 and Table 2 of Zimmerman (2005), a copy of which is included in Appendix 1.

TECHNOLOGY SELECTION

Advanced onsite septic system technology selection for the project was based on availability and diversity of treatment methodology. The following technologies were chosen for this survey: standard "Title 5" system comprised of a stone trench overlying 60 inches of sand, an aerobic treatment system that combined fixed film surfaced with activated sludge, a recirculating filter unit containing fibrous peat, a single pass filter with open-cell foam, an upflow sulfur-filled filter following an aerobic treatment unit and a recirculating sand filter designed in accordance with standard practice. The "Control" system, which was assumed to result in little or no treatment, was a stone trench system with 24 inches of underlying sand. It was reasoned that the control sample most closely represented the influent concentrations of PCPPs, since the 24 inches of mineral sand was thought to provide only straining of solids.

Schemata of all technologies tested including design details, wastewater loading, initial holding time in pretreatment septic tank and estimated total residence time of wastewater in the system is presented in Appendix 2.

DATA COLLECTION AND PROCESSING

On December 12, 2006, samples were collected using autosamplers into three-liter Teflon® bottles from the discharge of each system at 0900 h and 2000 h and were kept chilled until processing. Field blanks and replicate samples were also collected and processed. All autosamplers used were equipped with new/unused collection tubing. After processing, samples were chilled and sent overnight delivery to the USGS NWQL in Denver, Colorado. Samples were assayed using techniques referenced in Zimmerman (2005).

SUMMARY OF RESULTS AND DISCUSSION

A summary of all compounds assayed and the number of PPCPs found at the discharge locations of all technologies is presented in Table 1.The concentrations of compounds detected with the associated treatment unit are presented in Table 2. These data suggest that a standard stone-in-pipe system designed in accordance with CMR 15.000 (Title 5) promotes higher removal efficiencies for the PCPPs assayed compared to treatment units *alone*. We could not determine from these data whether effluent from treatment units, in conjunction with a soil absorption system could have promoted increased removal efficiency compared with a soil absorption system alone (without advanced treatment). Conn and others (2006) and Wilcox and others (2009) have noted the superior treatment of advanced treatment units compared to septic tank effluent, however these studies did not examine soil absorption system percolate following the septic tank as was done in this study. A very comprehensive study examining standard and advanced treatment systems with their soil absorption systems (Hinckle and others, 2005) was conducted in LaPine Oregon; however again, the data do not allow a direct comparison of a standard soil absorption system with a combination of both treatment unit and soil absorption system.

Table 1. List of compounds assayed from effluent of onsite wastewater treatment units at the Massachusetts Alternative Septic System Test Center December 12, 2006 with the number of treatment systems having a corresponding occurrence.

Compound	Primary Use	Detected	Number of Systems Detected
Acetaminophen	analgesic	Yes	5
Azithromycin	antibiotic	No	
Caffeine	beverages, diuretic	Yes	6
Carbamazepine	anticonvulsant	Yes	7
Cimetidine	antacid	No	
Codeine	analgesic	Yes	1
Cotinine	nicotine metabolite, antianginal	Yes	1
Dehydronifedipine	metabolite	Yes	5
Diltiazem	antihypertensive	Yes	2
Diphenhydramine	antihistamine	Yes	3
Erythromycin	antibiotic	No	
Fluoxetine	antidepressant	Yes	2
Furosemide	diuretic	No	
Gemfibrozil	antihyperlipidemic, antiinflamatory	No	
Ibuprofen	analgesic	No	
Metformin	diabetes	No	
Miconazole	anti-fungal agent	No	
p-Xanthine	caffeine metabolite	Yes	4
Ranitidine	antacid	Yes	1
Salbutamol	antiasthmatic	No	
Sulfamethoxazole	antibiotic	Yes	7
Thiabendazole	insecticide	No	
Trimethoprim	antibiotic	Yes	2
Warfarin	anticoagulant	No	

Table 2. Concentrations of organic wastewater contaminants and person care products and pharmaceuticals in percolate beneath a standard soil absorption systems and effluent from advance onsite septic system treatment units. Concentrations in micrograms/liter.

Compound	"Control"	Title 5	Aerobic	Peat	Foam	Sulfur	RSF
Acetaminophen	0.170-0.392	nd	0.347-0.500	0.247-0.251	30.2-41.6		0.360-0.543
Caffeine	0.02	nd	6.57-8.64	0.310-0.340	60.9-66.7	0.250-0.420	1.73-2.37
Carbamazepine	0.047-0.054	0.071-0.089	0.025-0.026	0.024-0.026	0.008-0.009	0.019-0.029	0.063-0.068
Codeine	nd	nd	nd	nd	nd	0.0032	nd
Cotinine	nd	nd	nd	nd	0.190-0.340	nd	nd
Dehydronifedipine	0.008-0.009	0.005-0.006	nd	0.006	nd	0.004	0.008-0.009
Diltiazem	nd	nd	nd	nd	nd	0.008-0.009	0.026-0.029
Diphenhydramine	nd	nd	0.047-0.051	nd	nd	0.093-0.095	0.025-0.029
Fluoxetine	nd	nd	nd	nd	nd	0.030	0.006
p-Xanthine	nd	nd	0.780	0.056-0.057	8.06-9.12	nd	0.256-0.318
Ranitidine	nd	nd	nd	nd	nd	0.030	nd
Sulfamethoxazole	0.136-0.201	0.098-0.662	0.082-0.083	0.043-0.084	0.026	0.038-0.049	0.065-0.066
Trimethoprim	nd	nd	nd	nd	nd	0.062-0.074	0.024-0.026

nd = not detected

One unexpected result in this study bears mention. The "Control" treatment was intended to represent raw wastewater with minimal treatment, and hence should exhibit the highest number of compounds as well as higher concentrations of PCPPs. In fact, however, the Control cell percolate exhibited lower or equal numbers of OWCs than all advanced treatment units. We now believe that control cell, which is essentially a Title 5 system configuration with 36 inches less sand beneath the dispersal trench, offered significant treatment and can not be used as a surrogate measure of influent concentrations.

CONCLUSION

A majority of researchers investigating the treatment of PCPPs in onsite septic systems concur that aerobic or oxic conditions facilitate the removal of such compounds (Swartz and others, 2006, Wilcox and other, 2009, Conn and others, 2006, Hinckle and others 2009). A summary of previous research, specifically relating to onsite septic systems is presented in the PowerPoint™ Presentation in Appendix 2. Little is understood, however about the facilitating role of soil treatment systems in removing these contaminants of concern. The study here suggests that soils-based systems may have greater ability to remove certain PPCPs compared with mechanical systems alone. These initial results suggest that research on soils-based treatment potential is warranted and may lead to low-cost and simple modifications to optimize treatment potential in standard soil absorption systems.

RESEARCH OUTREACH

On September 22, 2009, Massachusetts Department of Environmental Protection held a "Forum on Pharmaceuticals, Personal Care Products and Endocrine-Disrupting Compounds (PPCPs/EDC) in Wastewater" at which the results of the study were presented.

2007 Northeast Water Science Forum, Pharmaceuticals and Personal Care Products: State of the Science Portland, Maine – Results of this project presented by Marc Zimmerman

2008 Third Northeast Onsite Wastewater Treatment Short Course and Equipment Exhibition March 11-13, 2008, Mystic Marriott Hotel & Spa – Groton, CT

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Zimmerman, M.J., 2005, Occurrence of organic wastewater contaminants, pharmaceuticals, and personal care products in selected water supplies, Cape Cod, Massachusetts, June 2004: U.S. Geological Survey Open-File Report 2005-1206, 16 p.

Appendix 1

Table 1 and 2 from Zimmerman, M.J., 2005, Occurrence of organic wastewater contaminants, pharmaceuticals, and personal care products in selected water supplies, Cape Cod, Massachusetts, June 2004: U.S. Geological Survey Open-File
Report 2005-1206, 16 p.

Table 1. Nitrate and organic wastewater-contaminant concentrations in samples collected on Cape Cod, Massachusetts, June 1–2, 2004.

[Possible use or source: Listings are not exhaustive. All concentrations in micrograms per liter except nitrate, which is in milligrams per liter. Shading indicates analytes that were detected in this study. E, estimated value; MRL, minimum reporting level; NS, not sampled; SED, suspected endocrine disruptor; <, actual value is less than value shown; --, not applicable]

Analyte	Possible use or source	SED	MRL	Quality-control samples		Wastewater sources					
						Monitoring wells				Recir-culating sand filter	Septic tank test system
				Blank water	Blank water	92B	C2	B1	B2		
Date sampled	--	--	--	6-01-04	6-02-04	6-01-04	6-01-04	6-01-04	6-01-04	6-02-04	6-02-04
Time sampled	--	--	--	1344	1114	1130	1230	1345	1400	1545	1600
Nitrate	wastewater	--	--	NS	NS	3	<0 .1	4.9	1.6	28	9.8
1,4-Dichlorobenzene	moth repellent, fumigant, deodorant	Yes	0.5	< 0.5	0.5	E .200	E .120	E .0250	< .5	< .5	< .5
1-Methylnaphthalene	gasoline, diesel fuel, crude oil	No	.5	< .5	< .5	< .5	E .0280	E .0330	< .5	< .5	< .5
2,6-Dimethylnaphthalene	diesel fuel, kerosene	No	.5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
2-Methylnaphthalene	gasoline, diesel fuel, crude oil	No	.5	< .5	< .5	E .0290	E .0430	E .0550	< .5	< .5	< .5
3-beta-Coprostanol	carnivore fecal indicator	No	2	<2.0	<2.0	<2.0	E .810	<2.0	<2.0	2	E .720
3-Methyl-1(*H*)-indole (Skatole)	fragrance, stench in feces or coal tar	No	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
3-*tert*-Butyl-4-hydroxyanisole (BHA)	antioxidant, preservative	Yes	5	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
4-Cumylphenol	nonionic detergent metabolite	Yes	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
4-*n*-Octylphenol	nonionic detergent metabolite	Yes	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
4-*tert*-Octylphenol	nonionic detergent metabolite	Yes	1	<1.0	<1.0	<1.0	E .190	<1.0	<1.0	<1.0	<1.0
5-Methyl-1(*H*)-benzotriazole	antioxidant in antifreeze and deicers	No	2	<2.0	<2.0	E .690	E .680	E .690	<2.0	<2.0	<2.0
Acetophenone	fragrance, flavor	No	.5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Acetylhexamethyltetrahydronaphthalene (AHTN)	musk fragrance	No	.5	< .5	< .5	E .220	E .160	< .5	< .5	1.5	< .5
Anthracene	wood preservative, tar, diesel, crude oil	No	.5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Anthraquinone	dyes, seed treatment, bird repellent	No	.5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Benzo[*a*]pyrene	combustion product, cancer research	Yes	.5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Benzophenone	fixative for perfumes and soaps	Yes	.5	< .5	< .5	E .150	E .130	E .110	E .100	E .200	< .5
beta-Sitosterol	plant sterol	No	2	<2.0	<2.0	<2.0	E1.10	<2.0	<2.0	E1.50	E .940
beta-Stigmastanol	plant sterol	No	2	<2.0	<2.0	<2.0	E1.20	<2.0	<2.0	E1.40	E .940
Bisphenol A	flame retardant, antioxidant	Yes	1	<1.0	<1.0	1.2	<1.0	E .140	<1.0	<1.0	E .530
Bromacil	herbicide	No	.5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Bromoform	ozonation biproduct, explosives	No	.5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Caffeine	beverages, diuretic	No	.5	< .5	< .5	E .100	< .5	< .5	< .5	2.6	< .5
Camphor	flavor, fragrance, ointments	No	.5	< .5	< .5	< .5	< .5	< .5	< .5	E .260	< .5

Table 1. Nitrate and organic wastewater-contaminant concentrations in samples collected on Cape Cod, Massachusetts, June 1–2, 2004.—Continued

[Possible use or source: Listings are not exhaustive. All concentrations in micrograms per liter except nitrate, which is in milligrams per liter. Shading indicates analytes that were detected in this study. E, estimated value; MRL, minimum reporting level; NS, not sampled; SED, suspected endocrine disruptor; <, actual value is less than value shown; --, not applicable]

Analyte	Possible use or source	SED	MRL	Quality-control samples		Wastewater sources					
						Monitoring wells				Recir-culating sand filter	Septic tank test system
				Blank water	Blank water	92B	C2	B1	B2		
Carbaryl	herbicide	Yes	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Carbazole	insecticide, dyes, explosives, lubricants	No	.5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Chlorpyrifos	insecticide	Yes	.5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Cholesterol	fecal indicator, plant sterol	No	2	<2.0	<2.0	<2.0	E1.00	<2.0	<2.0	E3.40	E .900
Cotinine	nicotine metabolite	No	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	E .440	<1.0
Diazinon	insecticide	Yes	.5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Dichlorvos	insecticide	Yes	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Diethoxynonylphenol (total)	nonionic detergent metabolite	Yes	5	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	E1.50	<5.0
Diethoxyoctylphenol	nonionic detergent metabolite	Yes	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
d-Limonene	antimicrobial, antiviral, aerosol fragrance	No	.5	< .5	E .110	< .5	< .5	< .5	< .5	< .5	< .5
Fluoranthene	coal tar, asphalt	No	.5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Hexahydrohexamethylcyclopenta-benzopyran (HHCB)	musk fragrance	No	.5	< .5	< .5	< .5	< .5	< .5	< .5	E .310	E .170
Indole	pesticide ingredient, fragrance in coffee	No	.5	< .5	< .5	< .5	< .5	< .5	< .5	E .0730	< .5
Isoborneol	fragrance	No	.5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Isophorone	solvent for lacquer, plastic, oil, resin	No	.5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Isopropylbenzene (cumene)	fuels, paint thinner	No	.5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Isoquinoline	flavors and fragrances	No	.5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Menthol	cigarettes, cough drops, mouthwash	No	.5	< .5	< .5	< .5	< .5	< .5	< .5	E .350	< .5
Metalaxyl	general-use pesticide	No	.5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Methyl salicylate	liniment, food, beverage	No	.5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Metolachlor	herbicide	No	.5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Monoethoxyoctylphenol	nonionic detergent metabolite	Yes	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
N,N-diethyl-meta-toluamide (DEET)	mosquito repellent	No	.5	< .5	< .5	E .110	E .140	E .220	E .150	.63	E .110
Naphthalene	fumigant, moth repellent, gasoline	No	.5	< .5	< .5	E .0330	E .0300	E .0580	< .5	< .5	< .5
Para-Nonylphenol (total)	nonionic detergent metabolite	Yes	5	<5.0	<5.0	E 2.70	E1.80	<5.0	E1.10	E2.40	<5.0

Table 1. Nitrate and organic wastewater-contaminant concentrations in samples collected on Cape Cod, Massachusetts, June 1–2, 2004.—Continued

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Analyte	Possible use or source	SED	MRL	Quality-control samples		Wastewater sources					
						Monitoring wells				Recir-culating sand filter	Septic tank test system
				Blank water	Blank water	92B	C2	B1	B2		
p-Cresol	wood preservative	No	1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Pentachlorophenol	herbicide, fungicide, wood preservative	Yes	2	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Phenanthrene	explosives, tar, diesel fuel, crude oil	No	.5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Phenol	disinfectant	No	.5	E .370	0.54	0.98	< .5	E .330	< .5	< .5	.97
Prometon	herbicide	No	.5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Pyrene	coal tar, asphalt	No	.5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Tetrachloroethylene	solvent, degreaser, anthelmintic	No	.5	< .5	< .5	E .0640	E .0490	E .0380	< .5	< .5	E .0190
Tri(2-butoxyethyl) phosphate	flame retardant	No	.5	< .5	< .5	E .410	< .5	< .5	< .5	3.7	< .5
Tri(2-chloroethyl) phosphate	plasticizer, flame retardant	Yes	.5	< .5	< .5	E .190	E .220	E .240	E .0810	.51	E .110
Tri(dichlorisopropyl) phosphate	flame retardant	Yes	.5	< .5	< .5	E .370	E .370	E .220	< .5	E .390	E .140
Tributyl phosphate	flame retardant, antifoaming agent	No	.5	< .5	< .5	E .200	E .190	E .200	< .5	< .5	< .5
Triclosan	disinfectant, antimicrobial	Yes	1	<1.0	<1.0	E .170	E .180	<1.0	<1.0	E .280	<1.0
Triethyl citrate (ethyl citrate)	cosmetics, pharmaceuticals	No	.5	< .5	< .5	< .5	< .5	< .5	< .5	E .260	< .5
Triphenyl phosphate	plasticizer, resin, wax	No	.5	< .5	< .5	E .0600	< .5	< .5	< .5	< .5	< .5

Table 1. Nitrate and organic wastewater-contaminant concentrations in samples collected on Cape Cod, Massachusetts, June 1–2, 2004.—Continued

[Possible use or source: Listings are not exhaustive. All concentrations in micrograms per liter except nitrate, which is in milligrams per liter. Shading indicates analytes that were detected in this study. E, estimated value; MRL, method reporting level; NS, not sampled; SED, suspected endocrine disruptor; <, actual value is less than value shown; --, not applicable]

Analyte	Possible use or source	Drinking-water wells: Public supplies Well 1	Public supplies Well 2	Public supplies Well 3	Semi-public supply well	Private supplies Well 1	Private supplies Well 2	Private supplies Well 3	Private supplies Well 3 (replicate)	Private supplies Well 4	Private supplies Well 4 (replicate)
Date sampled	--	6-01-04	6-01-04	6-01-04	6-02-04	6-02-04	6-02-04	6-02-04	6-02-04	6-02-04	6-02-04
Time sampled	--	1530	1600	1615	0945	0915	1000	1115	1116	1145	1146
Nitrate	Wastewater	3.9	5.9	0.2	6.4	8.8	7.4	4.5	NS	6.4	NS
1,4-Dichlorobenzene	moth repellent, fumigant, deodorant	< .5	< .5	< .5	< .5	< .5	< .5	< .5	<0.5	<.5	<0.5
1-Methylnaphthalene	gasoline, diesel fuel, crude oil	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
2,6-Dimethylnaphthalene	diesel fuel, kerosene	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
2-Methylnaphthalene	gasoline, diesel fuel, crude oil	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
3-beta-Coprostanol	carnivore fecal indicator	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
3-Methyl-1(*H*)-indole (Skatole)	fragrance, stench in feces or coal tar	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
3-*tert*-Butyl-4-hydroxyanisole (BHA)	antioxidant, preservative	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
4-Cumylphenol	nonionic detergent metabolite	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
4-*n*-Octylphenol	nonionic detergent metabolite	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
4-*tert*-Octylphenol	nonionic detergent metabolite	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
5-Methyl-1(*H*)-benzotriazole	antioxidant in antifreeze and deicers	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Acetophenone	fragrance, flavor	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Acetylhexamethyltetrahydronaphthalene (AHTN)	musk fragrance	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Anthracene	wood preservative, tar, diesel, crude oil	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Anthraquinone	dyes, seed treatment, bird repellent	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Benzo[*a*]pyrene	combustion product, cancer research	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Benzophenone	fixative for perfumes and soaps	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
beta-Sitosterol	plant sterol	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
beta-Stigmastanol	plant sterol	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Bisphenol A	flame retardant, antioxidant	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Bromacil	herbicide	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Bromoform	ozonation biproduct, explosives	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Caffeine	beverages, diuretic	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Camphor	flavor, odorant, ointments	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5

Table 1. Nitrate and organic wastewater-contaminant concentrations in samples collected on Cape Cod, Massachusetts, June 1–2, 2004.—Continued

[Possible use or source: Listings are not exhaustive. All concentrations in micrograms per liter except nitrate, which is in milligrams per liter. Shading indicates analytes that were detected in this study. E, estimated value; MRL, method reporting level; NS, not sampled; SED, suspected endocrine disruptor; <, actual value is less than value shown; --, not applicable]

Analyte	Possible use or source	Drinking-water wells									
		Public supplies			Semi-public supply well	Private supplies					
		Well 1	Well 2	Well 3		Well 1	Well 2	Well 3	Well 3 (replicate)	Well 4	Well 4 (replicate)
Carbaryl	herbicide	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Carbazole	insecticide, dyes, explosives, lubricants	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Chlorpyrifos	insecticide	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Cholesterol	fecal indicator, plant sterol	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Cotinine	nicotine metabolite	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Diazinon	insecticide	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Dichlorvos	insecticide	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Diethoxynonylphenol (total)	nonionic detergent metabolite	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Diethoxyoctylphenol	nonionic detergent metabolite	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
d-Limonene	antimicrobial, antiviral, aerosol fragrance	< .5	< .5	< .5	< .5	< .5	< .5	E .300	< .5	< .5	< .5
Fluoranthene	coal tar, asphalt	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Hexahydrohexamethylcyclopenta-benzopyran (HHCB)	musk fragrance	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Indole	pesticide ingredient, fragrance in coffee	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Isoborneol	fragrance	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Isophorone	solvent for lacquer, plastic, oil, resin	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Isopropylbenzene (cumene)	fuels, paint thinner	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Isoquinoline	flavors and fragrances	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Menthol	cigarettes,cough drops, mouthwash	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Metalaxyl	general use pesticide	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Methyl salicylate	liniment, food, beverage	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Metolachlor	herbicide	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Monoethoxyoctylphenol	nonionic detergent metabolite	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
N,N-diethyl-meta-toluamide (DEET)	mosquito repellent	< .5	< .5	< .5	< .5	E .0740	< .5	< .5	< .5	< .5	< .5
Naphthalene	fumigant, moth repellent, gasoline	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Para-Nonylphenol (total)	nonionic detergent metabolite	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0

Table 1. Nitrate and organic wastewater-contaminant concentrations in samples collected on Cape Cod, Massachusetts, June 1–2, 2004.—Continued

[Possible use or source: Listings are not exhaustive. All concentrations in micrograms per liter except nitrate, which is in milligrams per liter. Shading indicates analytes that were detected in this study. E, estimated value; MRL, method reporting level; NS, not sampled; SED, suspected endocrine disruptor; <, actual value is less than value shown; --, not applicable]

Analyte	Possible use or source	Drinking-water wells									
		Public supplies			Semi-public supply well	Private supplies					
		Well 1	Well 2	Well 3		Well 1	Well 2	Well 3	Well 3 (replicate)	Well 4	Well 4 (replicate)
p-Cresol	wood preservative	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Pentachlorophenol	herbicide, fungicide, wood preservative	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Phenanthrene	explosives, tar, diesel fuel, crude oil	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Phenol	disinfectant	< .5	E .420	< .5	< .5	E .300	E .280	E .210	< .5	E .180	E .480
Prometon	herbicide	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Pyrene	coal tar, asphalt	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Tetrachloroethylene	solvent, degreaser, anthelmintic	E .0340	E .0390	< .5	< .5	< .5	< .5	< .5	< .5	E .0170	E .0120
Tri(2-butoxyethyl) phosphate	flame retardant	< .5	< .5	< .5	E .300	< .5	< .5	< .5	< .5	< .5	< .5
Tri(2-chloroethyl) phosphate	plasticizer, flame retardant	< .5	< .5	< .5	< .5	E .110	< .5	< .5	< .5	< .5	< .5
Tri(dichlorisopropyl) phosphate	flame retardant	< .5	< .5	< .5	< .5	E .240	< .5	< .5	< .5	< .5	< .5
Tributyl phosphate	flame retardant, antifoaming agent	< .5	< .5	< .5	E .190	< .5	< .5	< .5	< .5	< .5	< .5
Triclosan	disinfectant, antimicrobial	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Triethyl citrate (ethyl citrate)	cosmetics, pharmaceuticals	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Triphenyl phosphate	plasticizer, resin, wax	< .5	< .5	< .5	E .0460	< .5	< .5	< .5	< .5	< .5	< .5

Table 2. Concentrations of pharmaceutical and personal care products in samples collected on Cape Cod, Massachusetts, June 1–2, 2004.

[All concentrations are in micrograms per liter. Shading indicates analytes that were detected in this study. E, estimated value; MDL, method detection limit; MRL, minimum reporting level; N/D, not determined; *, not detected, minimum reporting level not determined; <, actual value is less than value shown; --, not applicable]

Analyte	Possible use or source	Provisional MDL	Provisional MRL	Quality-control samples		Wastewater sources					
						Monitoring wells					
				Blank water	Blank water	92B	C2	B1	B2	Recirculating sand filter	Septic tank test system
Date sampled	--	--	--	6-1-2004	6-2-2004	6-1-2004	6-1-2004	6-1-2004	6-1-2004	6-2-2004	6-2-2004
Time sampled	--	--	--	1344	1114	1130	1230	1345	1400	1545	1600
1,7-Dimethylxanthine	caffeine metabolite	0.072	0.144	<0.144	<0.144	<0.144	<0.144	<0.144	<0.144	4.5	<0.144
Acetaminophen	analgesic	.018	.036	< .036	E .01	E .0283	< .036	E .0172	E .0138	6.4	< .036
Azithromycin	antibiotic	.002	.004	< .004	< .004	< .004	< .004	< .004	< .004	< .004	< .004
Caffeine	beverages, diuretic	.008	.016	< .016	< .016	.17	< .016	< .016	< .016	4.6	< .016
Carbamazapine	antidepressant	.005	.011	< .011	< .011	.71	.59	.55	< .011	< .011	< .011
Cimetidine	antacid	.006	.012	< .012	< .012	< .012	< .012	< .012	< .012	E .0076	< .012
Codeine	analgesic	.008	.015	< .015	< .015	< .015	< .015	< .015	< .015	< .015	< .015
Cotinine	nicotine metabolite	.007	.014	< .014	< .014	< .014	E .0046	< .014	< .014	.49	< .014
Dehydronifedipine	antianginal metabolite	.008	.015	< .015	< .015	E .013	< .015	< .015	< .015	< .015	< .015
Diltiazem	antihypertensive	.008	.016	< .016	< .016	< .016	< .016	< .016	< .016	E .0076	< .016
Diphenhydramine	antihistamine	.007	.015	< .015	< .015	< .015	< .015	< .015	< .015	.045	< .015
Erythromycin	antibiotic	.005	.009	< .009	< .009	< .009	< .009	< .009	< .009	.11	< .009
Fluoxetine	antidepressant	.007	.014	< .014	< .014	< .014	< .014	< .014	< .014	< .014	< .014
Furosemide	diuretic	N/D	N/D	*	*	*	*	*	*	*	*
Gemfibrozil	antihyperlipidemic	.006	.013	< .013	< .013	< .013	< .013	< .013	< .013	< .013	< .013
Ibuprofen	anti-inflammatory, analgesic	.021	.042	< .042	< .042	< .042	< .042	< .042	< .042	< .042	< .042
Metformin	diabetes treatment	N/D	N/D	*	*	*	*	*	*	.033	*
Miconazole	antifungal agent	.009	.018	< .018	< .018	< .018	< .018	< .018	< .018	< .018	< .018
Ranitidine	antacid	.006	.013	< .013	< .013	< .013	< .013	< .013	< .013	E .0073	< .013
Salbutamol	antiasthmatic	.012	.023	< .023	< .023	< .023	< .023	< .023	< .023	< .023	< .023
Sulfamethoxazole	antibiotic	.032	.064	< .064	< .064	.47	.27	1.3	< .064	< .064	E .0101
Thiabendazole	insecticide	.005	.011	< .011	< .011	< .011	< .011	< .011	< .011	< .011	< .011
Trimethoprim	antibiotic	.006	.013	< .013	< .013	< .013	< .013	< .013	< .013	.016	E .0036
Warfarin	anticoagulant	.006	.012	< .012	< .012	< .012	< .012	< .012	< .012	< .012	< .012

Table 2. Concentrations of pharmaceutical and personal care products in samples collected on Cape Cod, Massachusetts, June 1–2, 2004.—Continued

[All concentrations are in micrograms per liter. Shading indicates analytes that were detected in this study. E, estimated value; MDL, method detection limit; MRL, minimum reporting level; N/D, not determined; *, not detected, minimum reporting level not determined; <, actual value is less than value shown; --, not applicable]

Analyte	Possible use or source	Drinking-water supplies									
		Public supplies			Semi-public supply well	Private supplies					
		Well 1	Well 2	Well 3		Well 1	Well 2	Well 3	Well 3 (replicate)	Well 4	Well 4 (replicate)
Date sampled	--	6-1-2004	6-1-2004	6-1-2004	6-2-2004	6-2-2004	6-2-2004	6-2-2004	6-2-2004	6-2-2004	6-2-2004
Time sampled	--	1530	1600	1615	945	915	1000	1115	1116	1145	1146
1,7-Dimethylxanthine	caffeine metabolite	<0.144	<0.144	<0.144	<0.144	<0.144	<0.144	<0.144	<0.144	<0.144	<0.144
Acetaminophen	analgesic	< .036	< .036	< .036	.052	E .0037	< .036	< .036	< .036	E .0064	E .0229
Azithromycin	antibiotic	< .004	< .004	< .004	< .004	< .004	< .004	< .004	< .004	< .004	< .004
Caffeine	beverages, diuretic	< .016	< .016	< .016	< .016	E .0121	< .016	< .016	< .016	< .016	< .016
Carbamazapine	antidepressant	< .011	< .011	< .011	< .011	< .011	< .011	< .011	< .011	E .0041	E .0053
Cimetidine	antacid	< .012	< .012	< .012	< .012	< .012	< .012	< .012	< .012	< .012	< .012
Codeine	analgesic	< .015	< .015	< .015	< .015	< .015	< .015	< .015	< .015	< .015	< .015
Cotinine	nicotine metabolite	< .014	< .014	< .014	< .014	< .014	< .014	< .014	< .014	< .014	< .014
Dehydronifedipine	antianginal metabolite	< .015	< .015	< .015	< .015	< .015	< .015	< .015	< .015	< .015	< .015
Diltiazem	antihypertensive	< .016	< .016	< .016	< .016	< .016	< .016	< .016	< .016	< .016	< .016
Diphenhydramine	antihistamine	< .015	< .015	< .015	< .015	< .015	< .015	< .015	< .015	< .015	< .015
Erythromycin	antibiotic	< .009	< .009	< .009	< .009	< .009	< .009	< .009	< .009	< .009	< .009
Fluoxetine	antidepressant	< .014	< .014	< .014	< .014	< .014	< .014	< .014	< .014	< .014	< .014
Furosemide	diuretic	*	*	*	*	*	*	*	*	*	*
Gemfibrozil	antihyperlipidemic	< .013	< .013	< .013	< .013	< .013	< .013	< .013	< .013	< .013	< .013
Ibuprofen	anti-inflammatory, analgesic	< .042	< .042	< .042	< .042	< .042	< .042	< .042	< .042	< .042	< .042
Metformin	diabetes treatment	*	*	*	*	*	*	*	*	*	*
Miconazole	antifungal agent	< .018	< .018	< .018	< .018	< .018	< .018	< .018	< .018	< .018	< .018
Ranitidine	antacid	< .013	< .013	< .013	< .013	< .013	< .013	< .013	< .013	< .013	< .013
Salbutamol	antiasthmatic	< .023	< .023	< .023	< .023	< .023	< .023	< .023	< .023	< .023	< .023
Sulfamethoxazole	antibiotic	E .0138	E .0576	< .064	E .0123	E .0093	< .064	< .064	< .064	< .064	< .064
Thiabendazole	insecticide	< .011	< .011	< .011	< .011	< .011	< .011	< .011	< .011	< .011	< .011
Trimethoprim	antibiotic	< .013	< .013	< .013	< .013	< .013	< .013	< .013	< .013	< .013	< .013
Warfarin	anticoagulant	< .012	< .012	< .012	< .012	< .012	< .012	< .012	< .012	< .012	< .012

Appendix 2

Presentation- September 22, 2009, Massachusetts Department of Environmental Protection held a “Forum on Pharmaceuticals, Personal Care Products and Endocrine-Disrupting Compounds (PPCPs/EDC) in Wastewater” Boston, Massachusetts

Pharmaceuticals, Personal Care Products and other Organic Wastewater Contaminants and Septic Systems

What we know

What we don't know

What we need to find out

George Heufelder, MS, RS

Barnstable County Department of Health and Environment

Septic Systems are only one potential source of conveyance of PPCPs to general environment

Septic Systems

Wastewater Treatment Plants

Animal waste “recycling”
Manure spreading

Animal Operations
(feed lots, etc)

Wastewater residuals use

Septic Systems are only one potential source of conveyance of PPCPs to general environment

Septic Systems

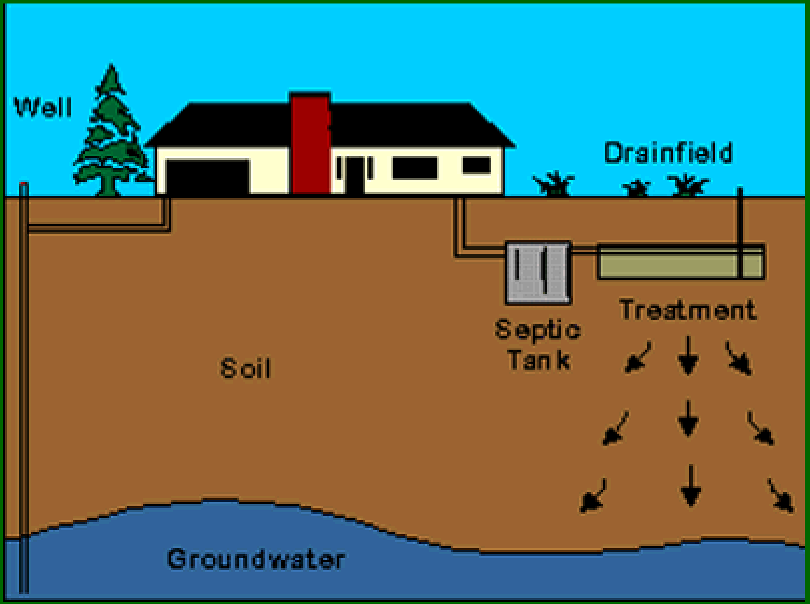
Wastewater Treatment Plants

Animal waste “recycling”
Manure spreading

Animal Operations (feed lots, etc)

Wastewater residuals use

Organic Wastewater Contaminants and Septic System Treatment



Research Review

Studies from Cape Cod

Silent Spring (1998, 2006, 2008)
USGS (2005,2006,2008)
Barnstable County Department of Health and Environment (continuing)

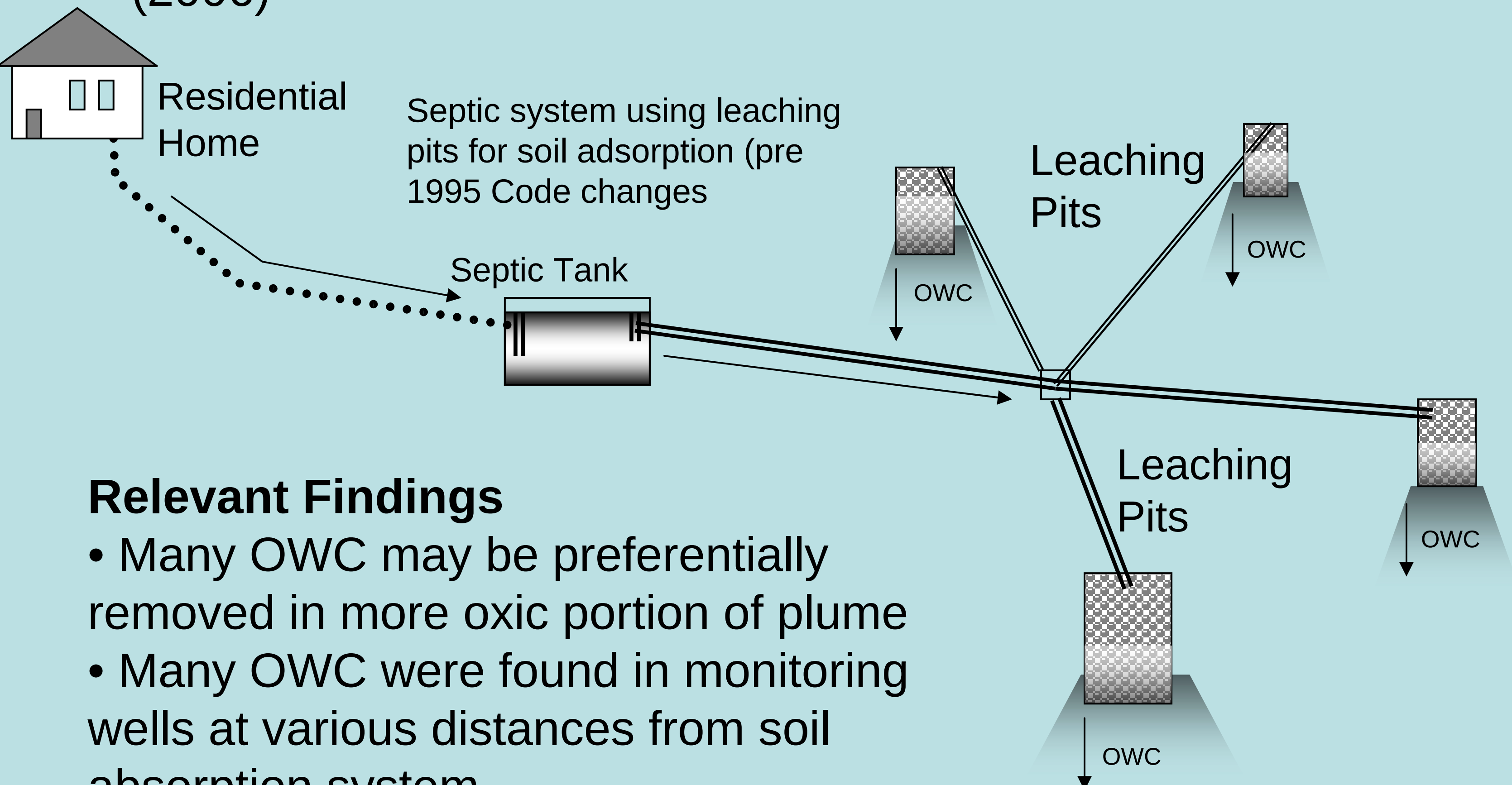
Organic Wastewater Contaminants, Pharmaceuticals, and Personal Care Products in Selected Water Supplies, Cape Cod, Massachusetts, June 2004,

- Of 85 compounds analyzed for, 43 were detected.
- 13 detected in low concentrations (less than 1 microgram per liter) from drinking-water supplies thought to be affected by wastewater because of previously detected high nitrate concentrations (wells on same lot as septic system)
- of two systems tested at the Massachusetts Alternative Septic System Test Center, a standard septic tank-soil absorption system was better at removing PPCP than recirculating sand filter

Zimmerman, M.J., 2005, U.S. Geological Survey Open-File Report 2005-1206, 16 p. [http://pubs.usgs.gov/of/2005/1206/]

Only available online

STEROID ESTROGEN, NONYLPHENOL ETHOXYLATE METABOLITES, AND OTHER WASTEWATER CONTAMINANTS IN GROUNDWATER AFFECTED BY A RESIDENTIAL SEPTIC SYSTEM ON CAPE COD, MA (Environ. Sci. Technology Vol. 40, pp 4894-4902. (2006)



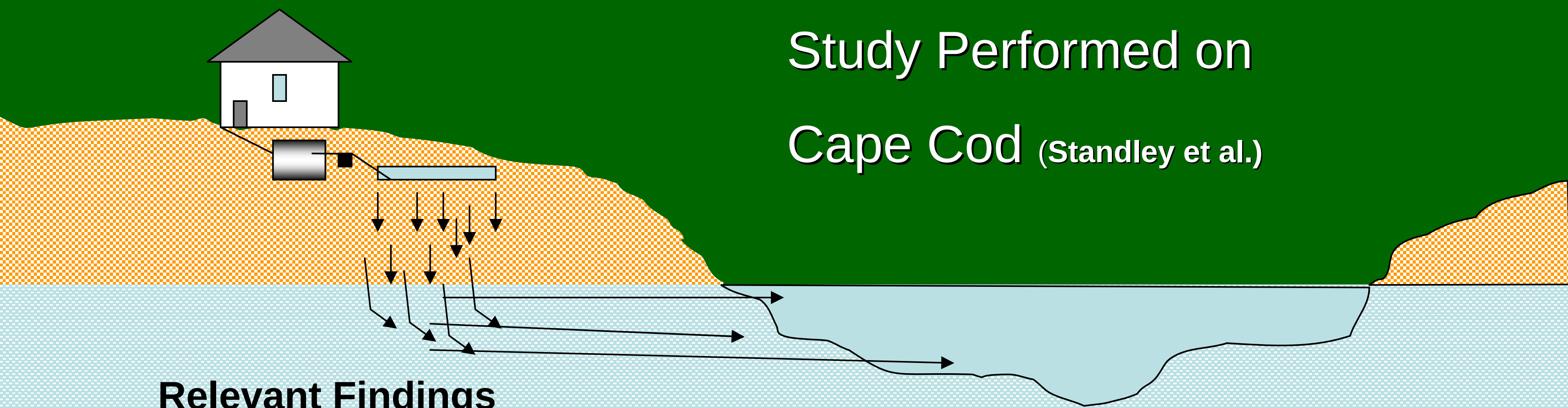
Relevant Findings

- Many OWC may be preferentially removed in more oxic portion of plume
- Many OWC were found in monitoring wells at various distances from soil absorption system

(Swartz et al, 2006)

WASTEWATER-CONTAMINATED GROUNDWATER AS A SOURCE OF ENDOGENEOUS HORMONES AND PHARMACEUTICALS TO SURFACE WATER ECOSYSTEMS (Env. Toxicology and Chemistry, Vol27(12), pp 2457-2468. (2008)

Septic systems studied of various and unspecified designs



Study Performed on

Cape Cod **(Standley et al.)**

Relevant Findings

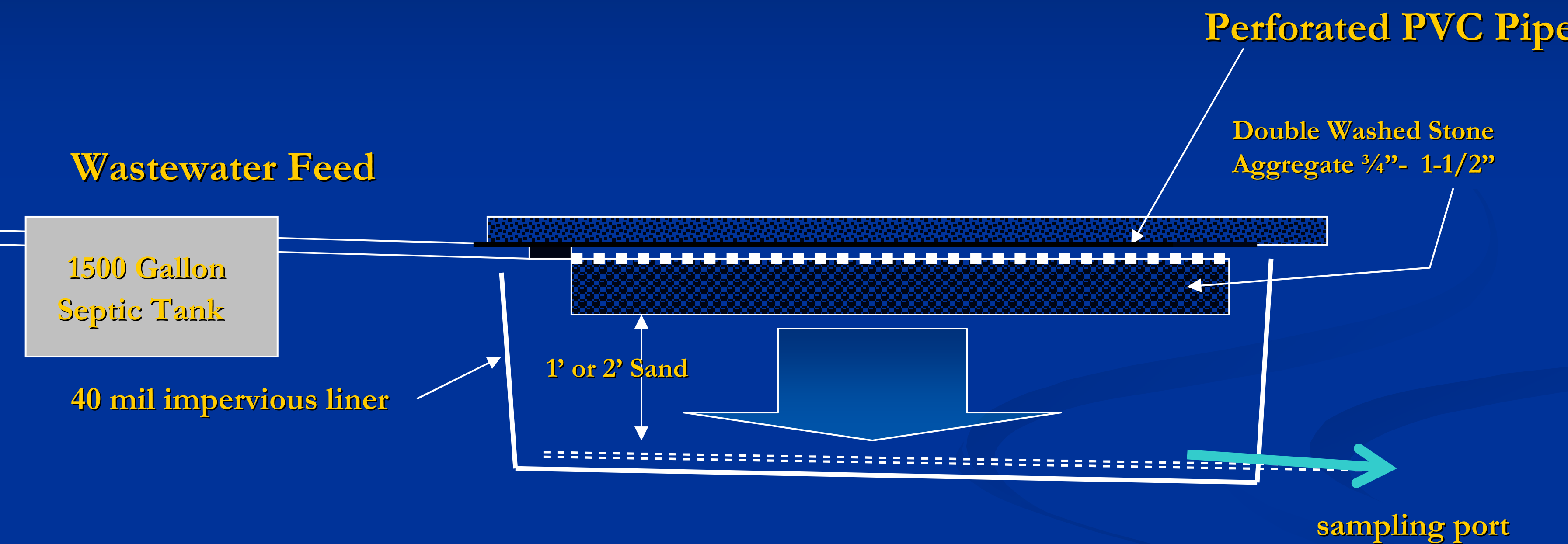
- **PPCP present in ponds in proportion to residential density in watershed**
- **Estrogenic hormones present at concentrations approaching those that induce physiological responses in fish.**

Effectiveness of Selected Onsite Wastewater-Treatment Systems in Removing Pharmaceutical and Personal-Care Products

Marc Zimmerman
USGS MA-RI Water Science Center
and
George Heufelder
Barnstable County Department of Health and Environment

Onsite Systems Studied

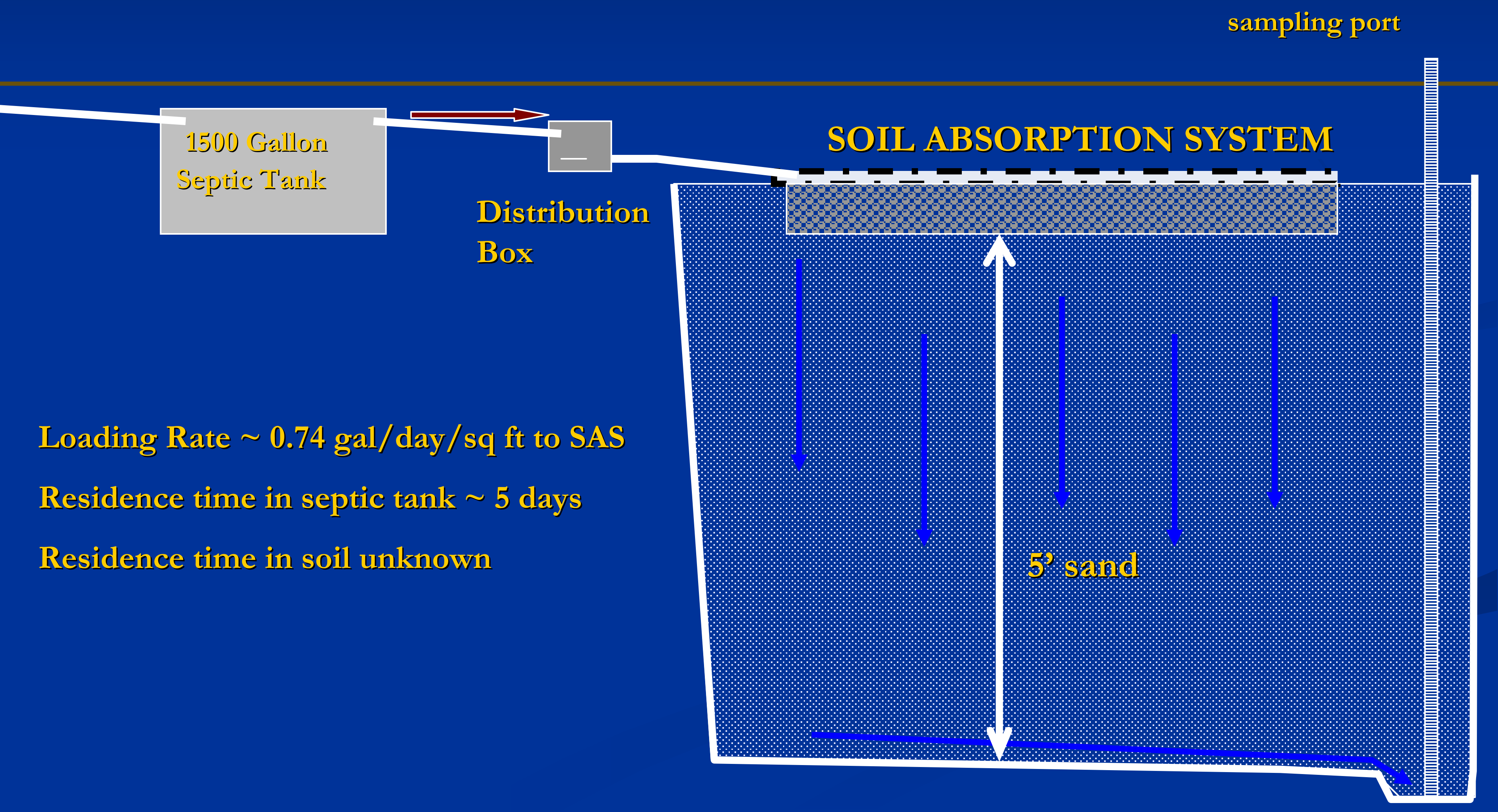
“Control” system



Hydraulic Loading 1.42 gal/sq ft/day

Origin of influent - 1500 gallon septic tank with 1.7 day residence time (900 gal/day influent feed).

Standard "Massachusetts Title 5" Septic System



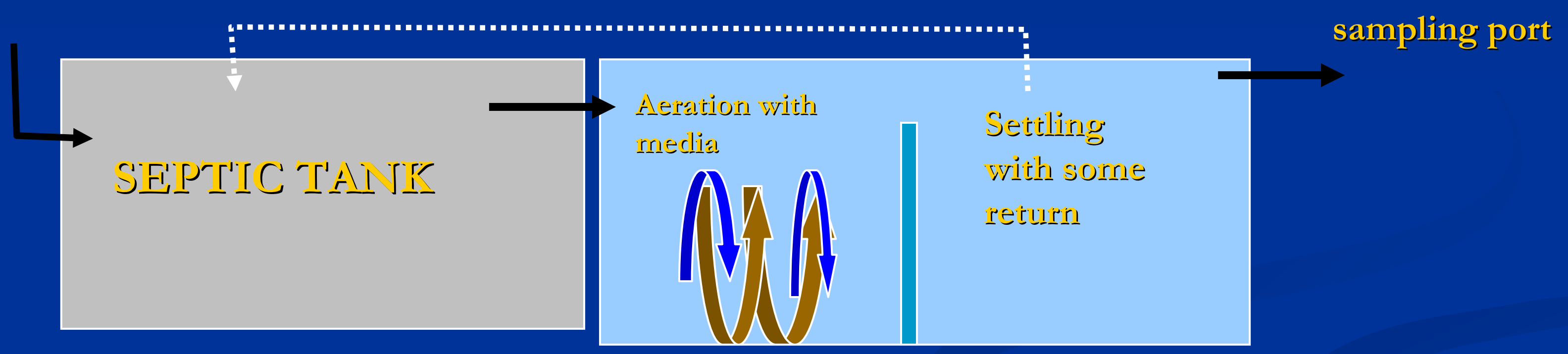
Loading Rate ~ 0.74 gal/day/sq ft to SAS

Residence time in septic tank ~ 5 days

Residence time in soil unknown

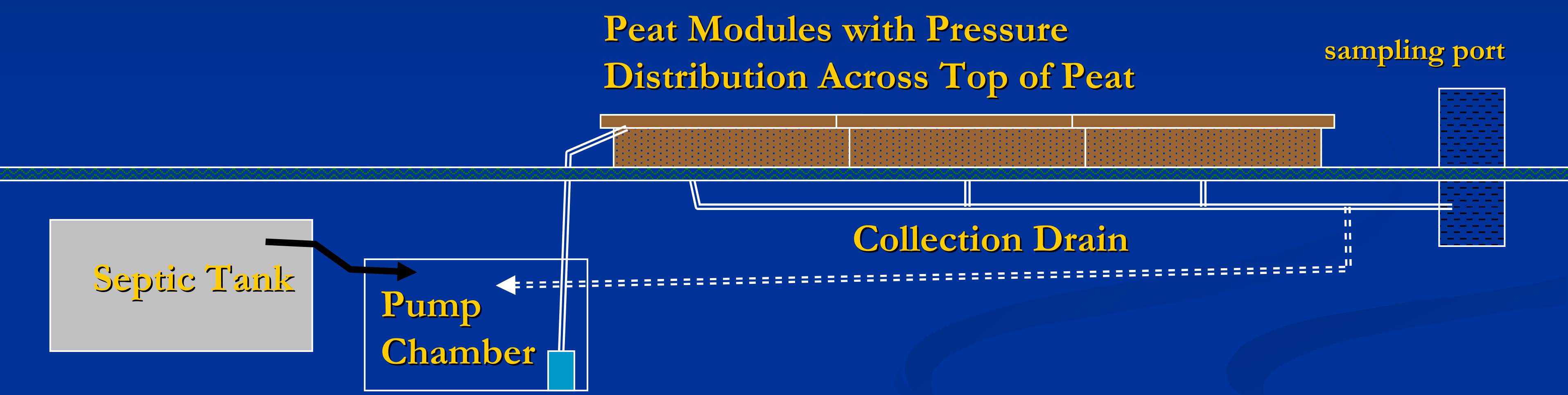
Aerobic Treatment Unit

(fixed film and activated sludge process)



Average Total Residence Time ~ 5 days

Peat Treatment System



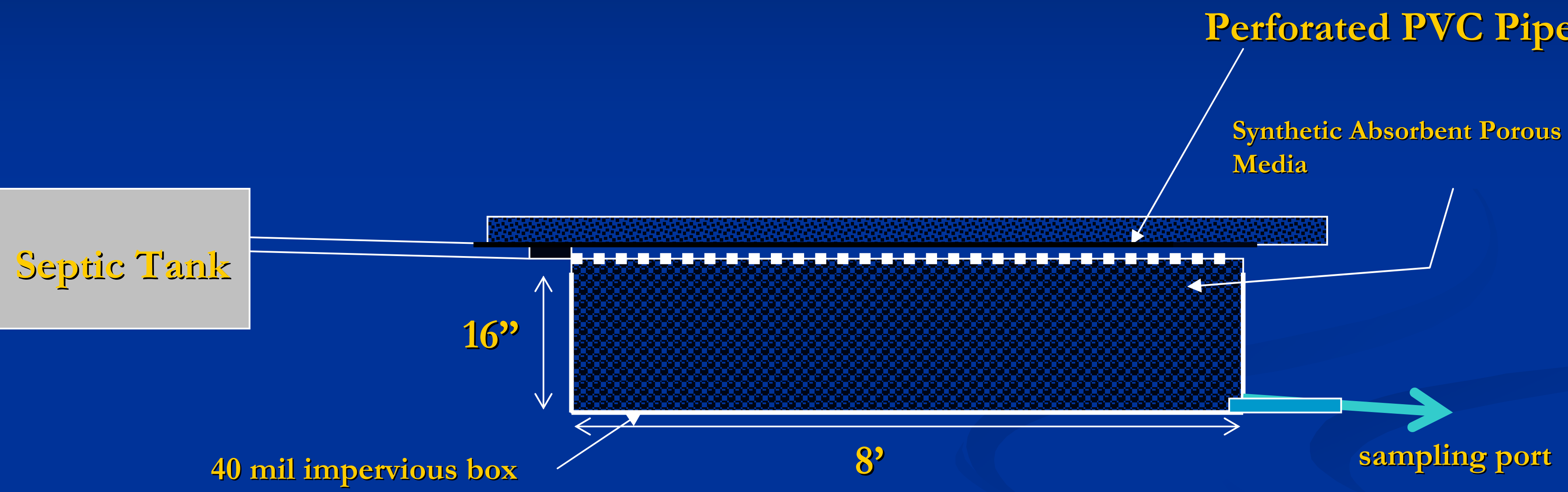
1500 Gallon Septic Tank – Residence Time ~ 3 days

1000 Gallon Pump Chamber – Residence Time ~ 1 day

Peat Modules – Residence Time estimated at 1 day

Total Residence Time ~ 5 days

Absorbent synthetic porous media bed (foam)

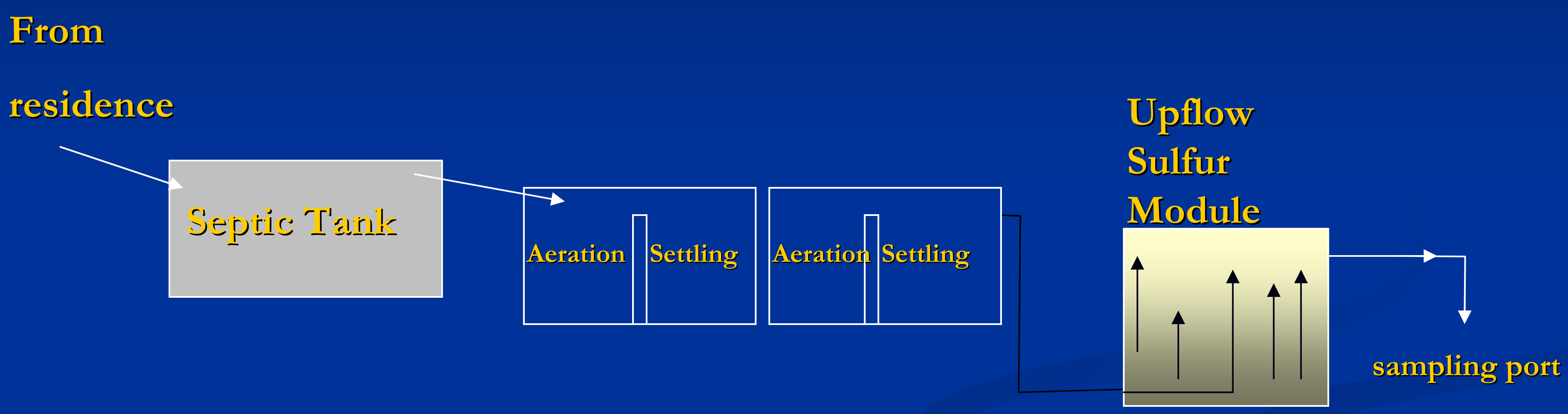


Origin of influent - 1500 gallon septic tank with 2.3 day residence time (660 gal/day influent feed).

Residence time in Media ~ 1/4 -1/3 day

Average Total Residence Time ~ 3 days

Sulfur Denitrification System



1500 Gallon Septic Tank – Residence Time ~ 3 days

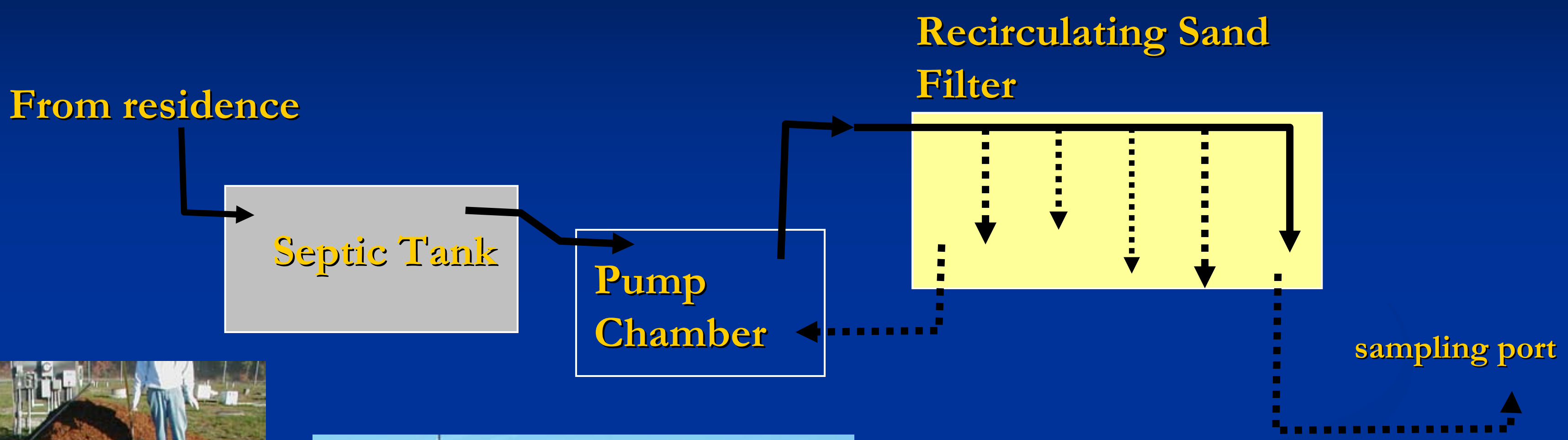
1000 Gallon Treatment Tank – Residence Time ~ 2 days

1000 Gallon Treatment Tank – Residence Time ~ 2 days

Sulfur upflow filter – Residence Time ~ ½ day

Total Residence Time ~ 7.5 days

Recirculating Sand Filter (RSF)



Total Residence Time Estimated ~ 5 days

Study Results

USGS analytical schedule and PPCPs detected

PPCP	Primary use	PPCP	Primary use
p-Xanthine *	caffeine metabolite	Fluoxetine	antidepressant
Acetaminophen ✔	analgesic	Furosemide	diuretic
Azithromycin	antibiotic	Gemfibrozil	antihyperlipidemic
Caffeine ✔	beverages, diuretic	Ibuprofen	anti-inflammatory, analgesic
Carbamazepine ✔	anticonvulsant	Metformin	diabetes treatment
Cimetidine	antacid	Miconazole	anti-fungal agent
Codeine	analgesic	Ranitidine	antacid
Cotinine *	nicotine metabolite	Salbutamol	antiasthmatic
Dehydronifedipine*	antianginal metabolite	Sulfamethoxazole ✔	antibiotic
Diltiazem	antihypertensive	Thiabendazole	insecticide
Diphenhydramine	antihistamine	Trimethoprim	antibiotic
Erythromycin	antibiotic	Warfarin	anticoagulant

Detected or Not Detected; *, metabolite; ✔ detected in drinking-water in 2004

Concentrations of PPCPs detected

(Concentrations in µg/L)

PPCP	Control	Title 5	Aerobic	Peat	Foam	Sulfur	RSF
Acetaminophen	0.170-0.392	-	0.347-0.500	0.247-0.251	30.2-41.6	-	0.360-0.543
Caffeine	0.020	-	6.57-8.64	0.310-0.340	60.9-66.7	0.250-0.420	1.73-2.37
Carbamazepine	0.047-0.054	0.071-0.089	0.025-0.026	0.024-0.026	0.008-0.009	0.019-0.029	0.063-0.068
Codeine	-	-	-	-	-	0.032	-
Cotinine*	-	-	-	-	0.190-0.340	-	-
Dehydronifedipine*	0.008-0.009	0.005-0.006	-	0.006	-	0.004	0.008-0.009
Diltiazem	-	-	-	-	-	0.046-0.066	0.026-0.029
Diphenhydramine	-	-	0.047-0.051	-	-	0.093-0.095	0.025-0.029
Fluoxetine	-	-	-	-	-	0.030	0.006
p-Xanthine*	-	-	0.780	0.056-0.057	8.06-9.12	-	0.256-0.318
Ranitidine	-	-	-	-	-	0.030	-
Sulfamethoxazole	0.136-0.201	0.098-0.662	0.082-0.083	0.043-0.084	0.026	0.038-0.049	0.065-0.066
Trimethoprim	-	-	-	-	-	0.062-0.074	0.024-0.026

Disclaimer: All data presented are provisional and subject to revision prior to publication.

Numbers of PPCPs detected by system

	Control	Title 5	Aerobic	Peat	Foam	Sulfur	RSF
Number of PPCPs detected	5	3	5	5	5	10	9

Number of systems with specific PPCPs (or metabolites) detected

PPCP	Number of systems
Acetaminophen	5
Caffeine	6
Carbamazepine	7
Codeine	1
Cotinine*	1
Dehydronifedipine*	5
Diltiazem	2
Diphenhydramine	3
Fluoxetine	2
p-Xanthine*	4
Ranitidine	1
Sulfamethoxazole	7
Trimethoprim	2

Summary

- Standard septic tank – soil absorption systems seem relatively effective
- Recirculation may increase concentrations and numbers of detections
- Individual compound and substrate chemistries and physical properties may affect their interactions.
- A simple survey such as this may raise far more questions than it provides answers.

December – 2008 "mini-study"

Barnstable County in Cooperation with USGS (Unpublished)

Raw Wastewater

Drip Dispersal (modified following an aerobic treatment unit)

Ozone-Peroxide unit (following an aerobic treatment unit)

	Raw Influent	Drip (modified following ATU)	Ozone following ATU
1,4-Dichlorobenzene	0.1	0.04	0.04
1,7-Dimethylxanthine	11.1	<.12	<.12
3-beta-Coprostanol	E50	M	M
3-Methyl-1H-indole	5	<.04	<.04
4-Nonylphenol (sum of all isomers)	26	<2	E2
4-Nonylphenol diethoxylate (sum of all isomers),	16	<5	<5
Acetaminophen	109	<.8	<.8
Acetophenone	0.6	<.4	<.4
beta-Sitosterol	23	<4	<4

All values micrograms/Liter

	Raw Influent	Drip (modified following ATU)	Ozone following ATU
beta-Stigmastanol	E4	<2	<2
Caffeine,	62.4	M	0.6
Camphor	1.6	<.1	E.1
Carbamazepine	E.021	E.003	E.012
Cholesterol	E109	<2	M
Cotinine	0.348	0.026	0.026
DEET	2.2	E.1	0.1
Dehydronifedipine	<.08	E.003	<.08
D-Limonene	E3	<.1	<.1
Hexahydrohexamethyl cyclopentabenzopyran	3.7	<.5	0.6
Indole,	0.2	<.1	<.1
Isophorone	0.2	<.1	<.1
Menthol	24.7	<.4	E2

All values micrograms/Liter

	Raw Influent	Drip (modified following ATU)	Ozone following ATU
Methyl salicylate	0.9	<.1	<.1
p-Cresol	36	<.18	M
Phenol	13.8	<1.4	E.4
Sulfamethoxazole	E.084	E.114	E.016
Triclosan	8	<.2	<.2
Triethyl citrate	1.1	E.1	E.2
Trimethoprim	0.072	<.02	0.104
Triphenyl phosphate	0.3	<.1	M
Tris(2-butoxyethyl) phosphate	20.9	E.7	0.6
Tris(2-chloroethyl) phosphate	E.8	E.2	E.5
Tris(dichloroisopropyl) phosphate	1.2	M	0.4

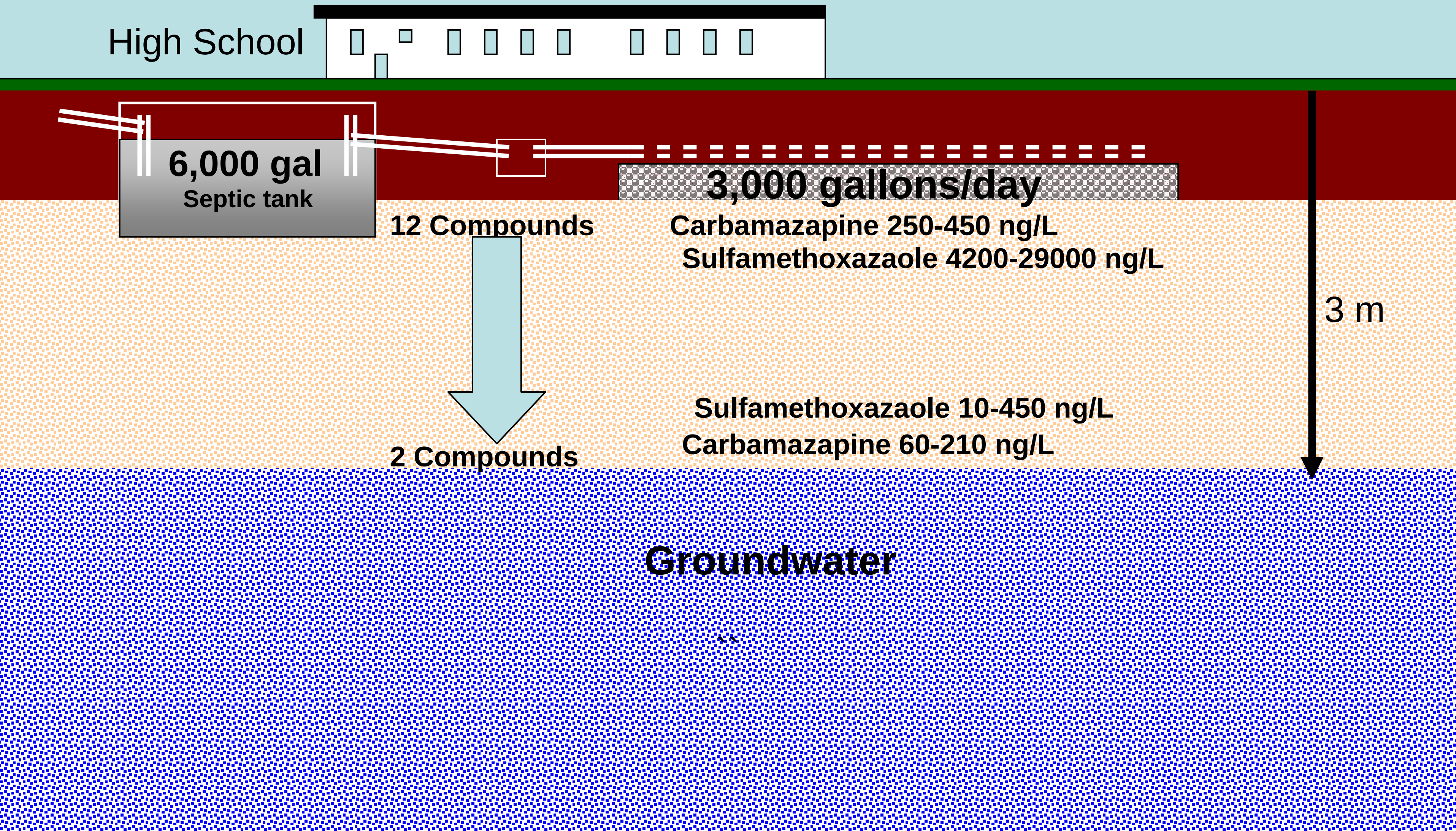
All values micrograms/Liter

Take home message

For many of the compounds investigated, a drip dispersal unit (which presumably incorporates plants to some degree into the wastewater treatment), reduced the majority of these compounds to the detection limit.

Studies from other states

PHARMACEUTICALS IN ON-SITE SEWAGE EFFLUENT AND GROUNDWATER, WESTERN MONTANA (Ground Water May-June 2007 (pp263-271)



science for a changing world

Prepared in cooperation with Oregon Department of Environmental Quality and Deschutes County Environmental Health Division

Organic Wastewater Compounds, Pharmaceuticals, and Coliphage in Ground Water Receiving Discharge from Onsite Wastewater Treatment Systems near La Pine, Oregon: Occurrence and Implications for Transport

Scientific Investigations Report 2005–5055
Version 1.1, July 2009

U.S. Department of the Interior
U.S. Geological Survey

Partial Analysis of Data from LaPine Project

The green blocks indicate the reduction of compound from the indicated value to a value below the detection limit at the drainfield monitoring well

	3-beta-coprostanol	3-Methyl-1H-indole (FRAGRENCE OF STENCH)	Caffeine	Camphor (odor in ointments)	Cholesterol	D-Limonene (anti-microbial, anti-viral;a fragrance in	Indole coffee fragrance, inert ingredient in pesticides)	Menthol	Methyl salicylate (used in liniments, food, beverages, and U-V absorbing lotions)	DEET	Phenol	p-Cresol
Standard	11	82	140	3	33	2.8	220	24	0.9	14	630	820
Standard	2	7	2.2	NS	3	NS	NS	8.2	NS	NS	NS	3
Pressure	16	120	5.1	0.9	33	14	38	30	1.2	1.7	160	520
Pressure	38	57	90	0.5	110	0.8	38	NS	1.5	NS	88	340
Sand Filter	33	82	99	1.1	52	1.9	72	72	1.3	0.9	180	640
Sand Filter	12	28	8.8	1	24	0.8	7.6	16	NS	0.8	98	640
Textile Filter	NS	11	3.8	3.4	2	2	0.9	29	NS	NS	32	73
Rotating Biological Contactor	6	NS	9.2	NS	20	NS	4.1	5.9	NS	NS	42	93
Rotating Biological Contactor	15	4	1	NS	20	1.1	17	5.3	NS	NS	44	89
Enviroserver	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	2
Enviroserver	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
FAST	53	24	34	NS	46	0.8	12	25	2	2.9	78	370
FAST	44	19	17	NS	48	1.2	19	24	NS	0.6	53	200
NAYADIC	11	52	18	0.8	32	8.9	34	62	NS	0.6	240	730
NAYADIC	10	17	9	0.9	15	2.7	14	4.3	0.7	52	74	200
Nitrex	7	28	4.7	4.1	16	NS	13	8.8	NS	3.6	56	310
Nitrex	11	66	12	0.6	36	NS	23	21	5.6	0.6	140	540
Puraflo	14	44	21	1.9	28	1.1	24	13	NS	1.4	84	310
Wert B	28	NS	320	19	46	2.9	90	160	6.7	1.1	550	1300
Wert B	12	NS	68	1.9	16	NS	11	24	1.1	NS	94	330

Partial Analysis of Data from LaPine Project

3-beta-coprostanol

3-Methyl-1H-indole (FRAGRENCE OF STENCH)

Caffeine

Camphor (odor in ointments)

Cholesterol

D-Limonene (anti-microbial, anti-viral;a fragrance in aerosols)

Indole coffee fragrance, inert ingredient in pesticides)

Menthol

Methyl salicylate (used in liniments, food, beverages, and U-V absorbing lotions)

DEET

Phenol

p-Cresol

For a number of OWCs, standard and alternative onsite septic systems, combined with their soil absorption systems, reduce the concentrations to below present detection limits

Wisconsin Study

Aerobic Treatment and Sand Filter Treatment

- OWC concentrations significantly less in aerobic (six suspended growth aerobic systems) or sand filter systems (seven single-pass sand filters) compared with septic tank effluent.
- Systems were *not* sampled below soil absorption system.

Wilcox, Jeffrey D. J.M. Bahr, C.J. Hedmen, Hemming, J D.C., and Barman, M.A.E. 2009. Removal of Organic Wastewater Contaminants in Septic Systems Using Advanced Treatment Technologies. J. Environ. Qual. 38:149-156.

Colorado Study

Septic tank, textile ("biofilter") filter and wetland-based Treatment

- Biofilter-based systems had better removal of OWC with compared septic tank effluent.
- Systems were *not* sampled below soil absorption system.

Conn, Kathleen E., L.B. Barber, G.K. Brown, and R. Siegrist. 2006. Occurrence and fate of Organic Contaminants during Onsite Wastewater Treatment. J. Environ. Qual. 40:7358-7366.

Florida Study

USGS
science for a changing world

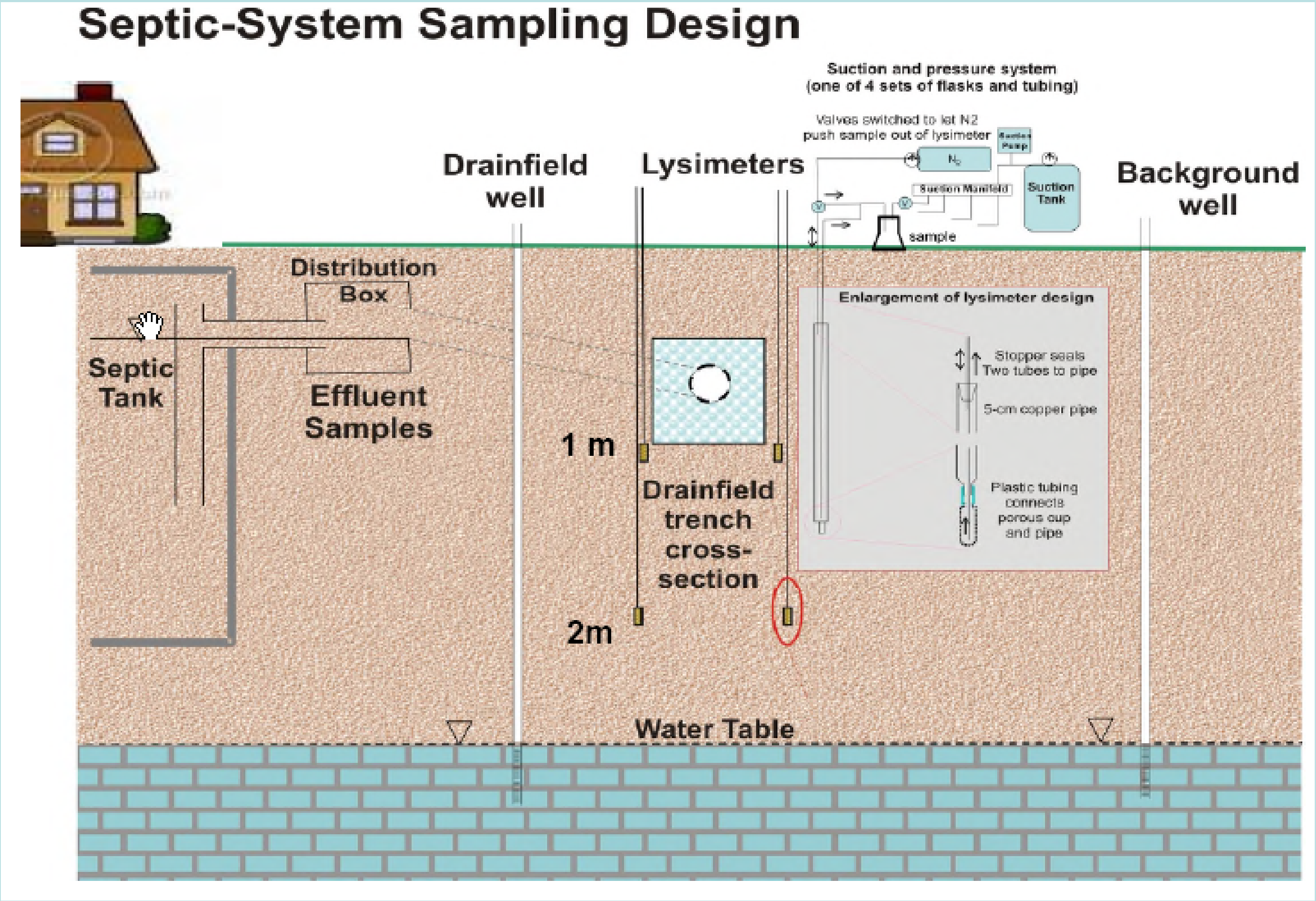
Nutrients, Organic Wastewater Compounds, Pharmaceuticals, and Microorganisms Beneath Septic Tank Drainfields in the Woodville Karst Plain, Florida

B.G. Katz[1], D.W. Griffin[1], P.B. McMahon[1], R.W. Hicks[2], E.Wade[2], H.S. Harden[3] and J.P. Chanton[3]

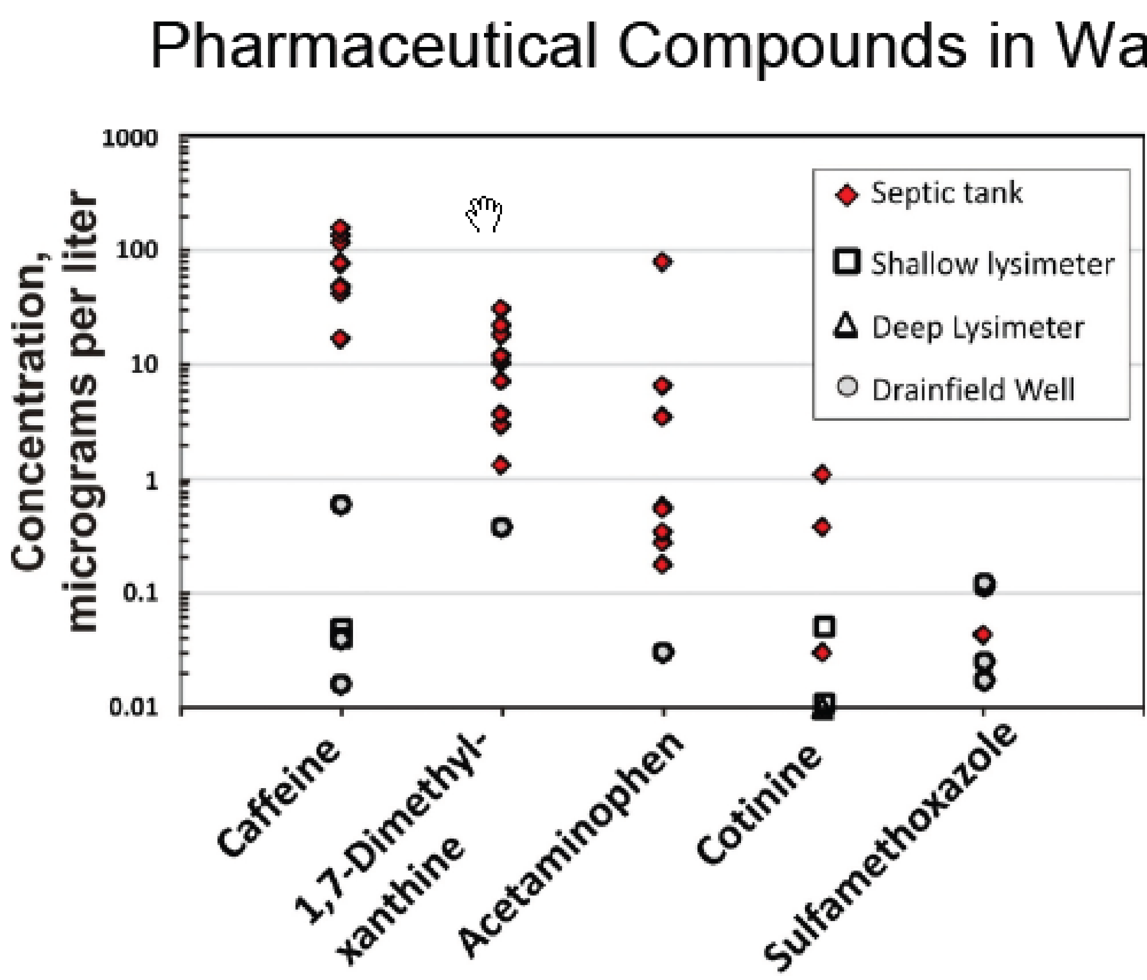
[1]U.S. Geological Survey
[2]Florida Department of Environmental Protection
[3]Florida State University, Department of Oceanography

Wakulla Springshed Workshop
Tallahassee, Florida
February 25-26, 2009

Florida Study

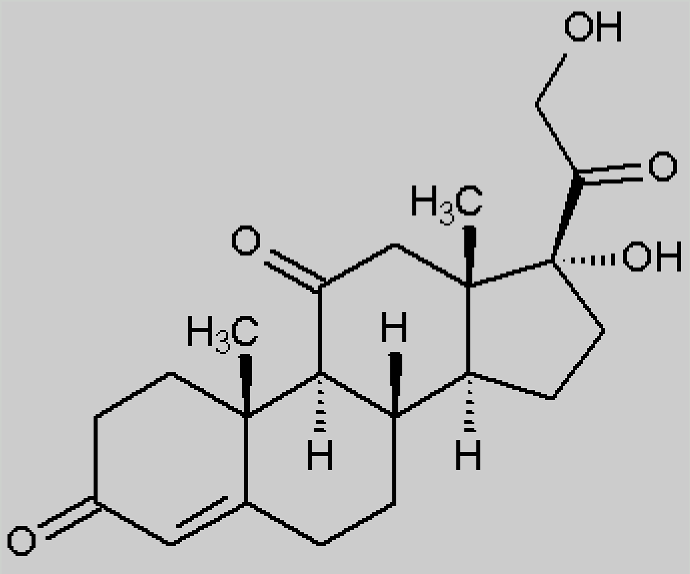


Florida Study

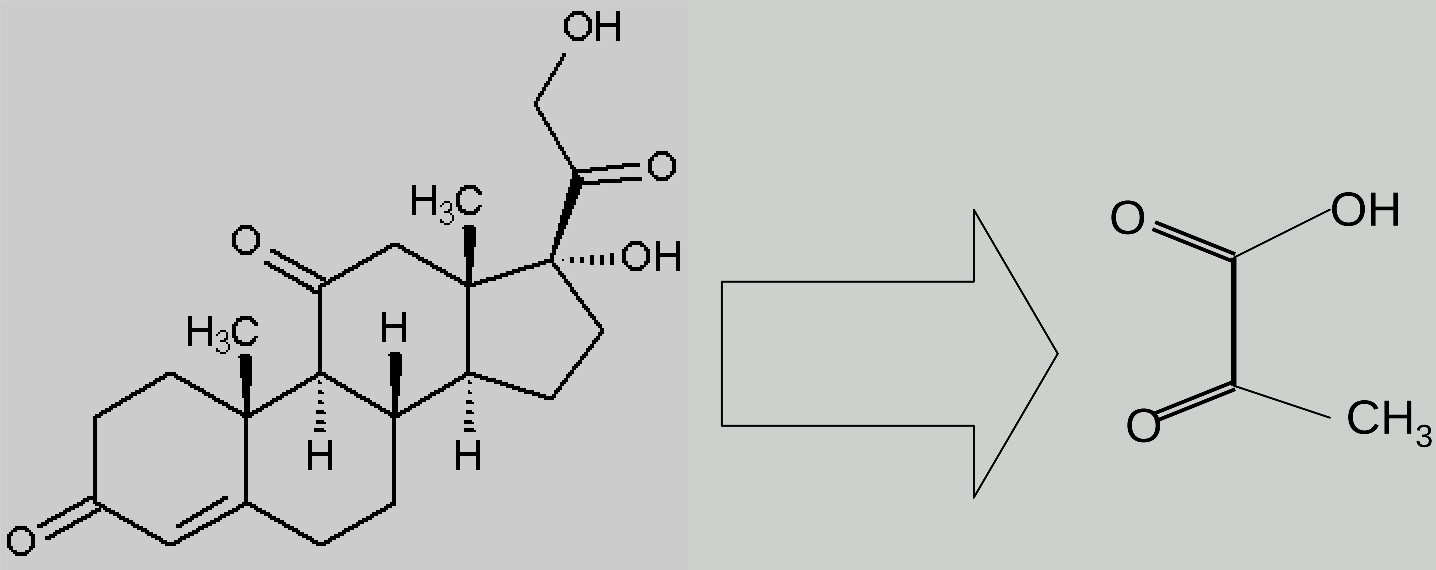


- Much lower concentrations of pharmaceutical compounds in lysimeter and drainfield well water samples than in septic tank effluent

- Sulfamethoxazole found in drainfield well samples at all sites, but only in septic tank effluent at 1 site

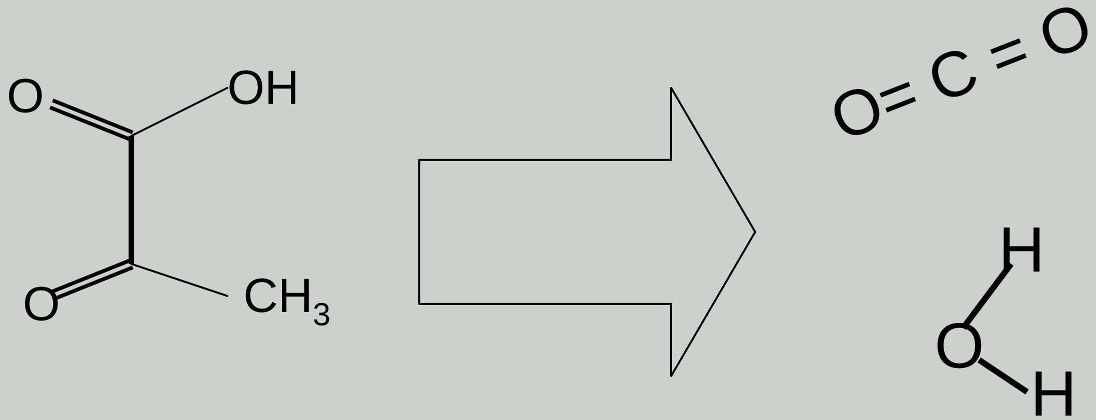


Collectively, what are all these studies telling us about the ability and potential ability of onsite septic systems to treat for organic wastewater contaminants ?



Perhaps there are metabolic pathways of bacteria, algae, plants and fungi that can be exploited to reduce OWC to harmless byproducts.

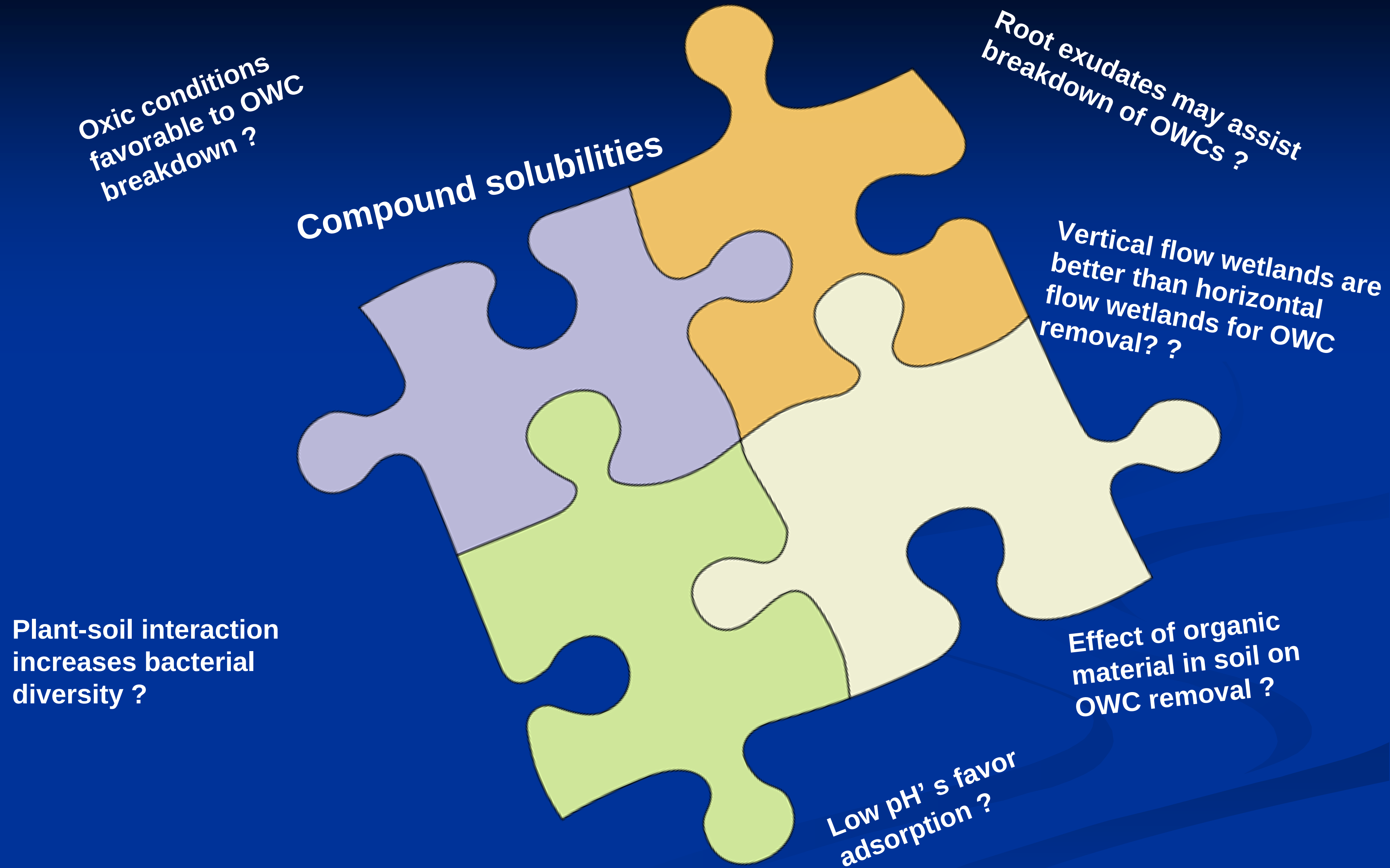
And........



And perhaps the environments to encourage organisms and physical conditions that promote these organisms can be engineered into onsite systems.

What we know about the community of organisms and the environment in the standard septic system

It is a complex environment with shifting pH, potentials and physical characteristics inhabited by a complex array of organisms that fortunately break down our wastewater


Oxic conditions favorable to OWC breakdown ?
Compound solubilities
Root exudates may assist breakdown of OWCs ?
Vertical flow wetlands are better than horizontal flow wetlands for OWC removal? ?
Plant-soil interaction increases bacterial diversity ?
Effect of organic material in soil on OWC removal ?
Low pH' s favor adsorption ?

Concentrations of PPCPs detected

(Concentrations in µg/L)

PPCP	Control	Title 5	Aerobic	Peat	Foam	Sulfur	RSF
Acetaminophen	0.170-0.392	-	0.347-0.500	0.247-0.251	30.2-41.6	-	0.360-0.543
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Carbamazepine	0.047-0.054	0.071-0.089	0.025-0.026	0.024-0.026	0.008-0.009	0.019-0.029	0.063-0.068
Codeine	-	-	-	-	-	0.032	-
Cotinine*	-	-	-	-	0.190-0.340	-	-
Dehydronifedipine*	0.008-0.009	0.005-0.006	-	0.006	-	0.004	0.008-0.009
Diltiazem	-	-	-	-	-	0.046-0.066	0.026-0.029
Diphenhydramine	-	-	0.047-0.051	-	-	0.093-0.095	0.025-0.029
Fluoxetine	-	-	-	-	-	0.030	0.006
p-Xanthine*	-	-	0.780	0.056-0.057	8.06-9.12	-	0.256-0.318
Ranitidine	-	-	-	-	-	0.030	-
Sulfamethoxazole	0.136-0.201	0.098-0.662	0.082-0.083	0.043-0.084	0.026	0.038-0.049	0.065-0.066
Trimethoprim	-	-	-	-	-	0.062-0.074	0.024-0.026

Disclaimer: All data presented are provisional and subject to revision prior to publication.

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Codeine	-	-	-	-	-	0.032	-
Cotinine*	-	-	-	-	0.190-0.340	-	-
Dehydronifedipine*	0.008-0.009	0.005-0.006	-	0.006	-	0.004	0.008-0.009
Diltiazem	-	-	-	-	-	0.046-0.066	0.026-0.029
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Ranitidine	-	-	-	-	-	0.030	-
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Trimethoprim	-	-	-	-	-	0.062-0.074	0.024-0.026

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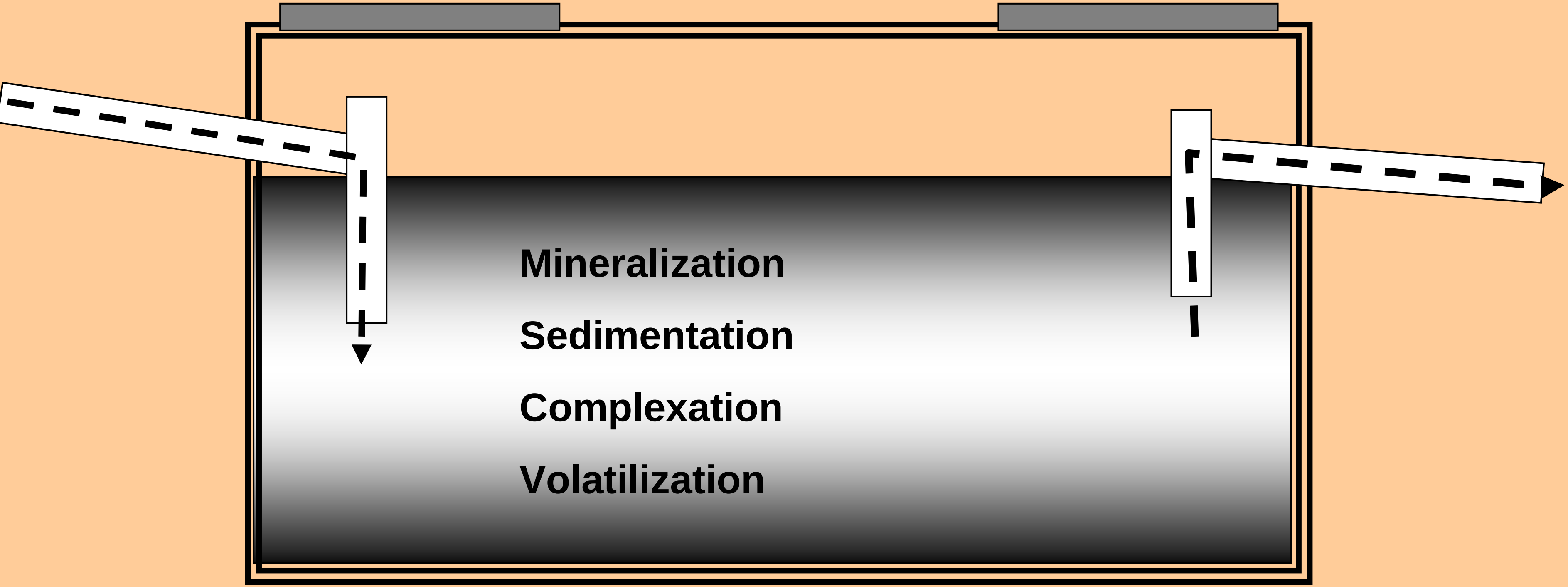
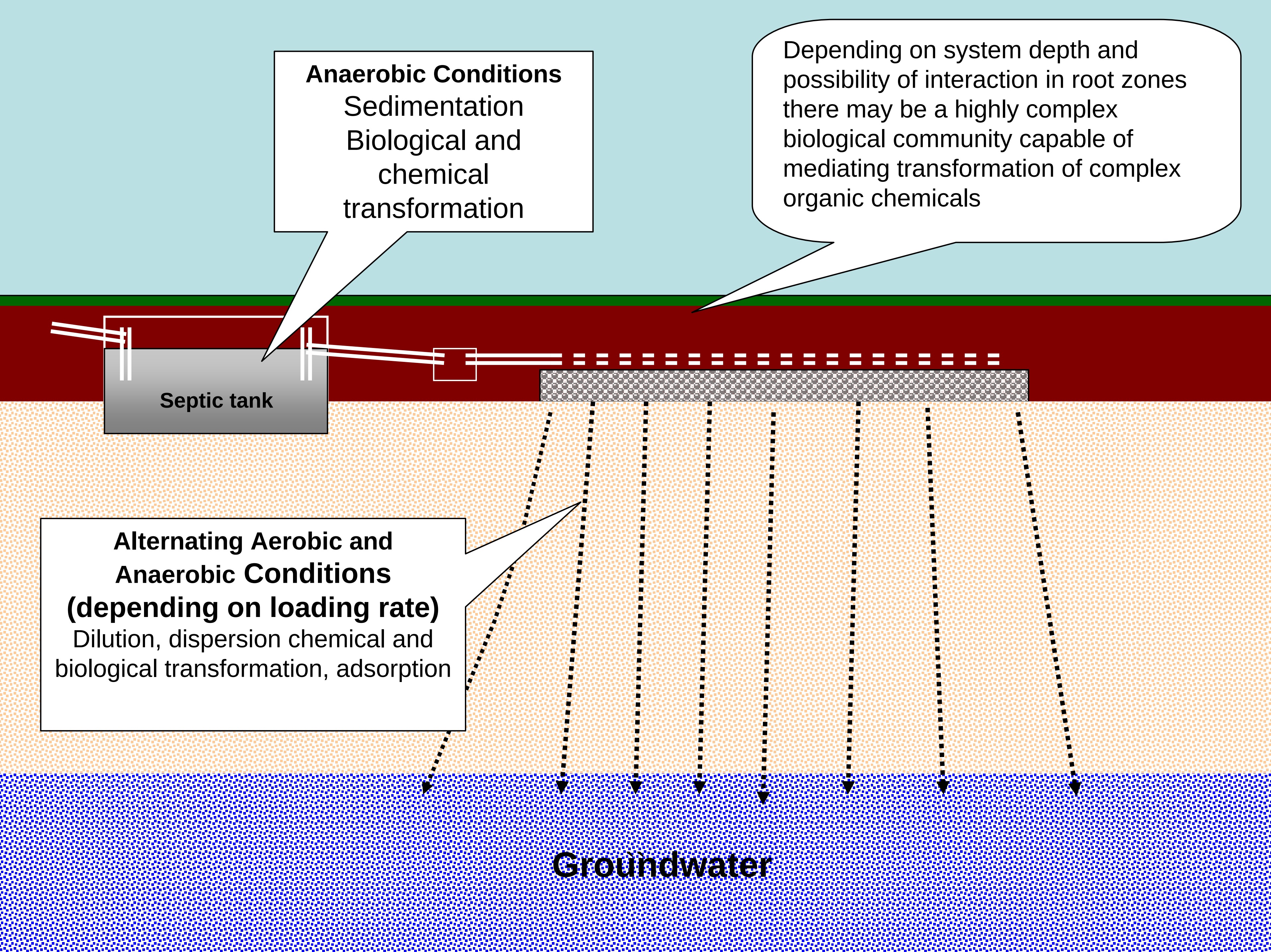
Septic Tank

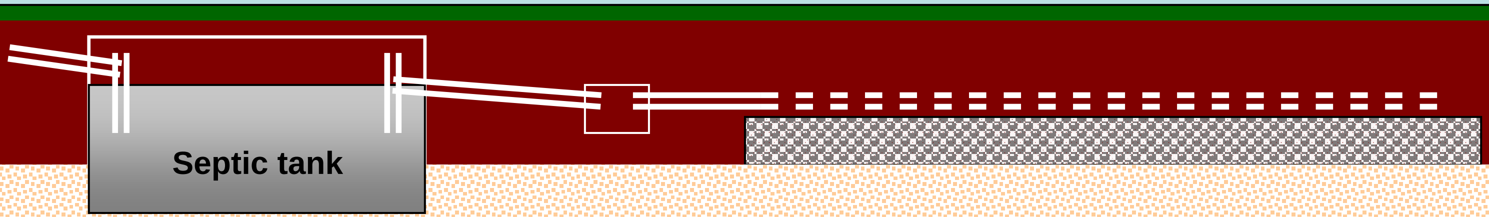


Septic Tank Environment Variables

- Hydraulic retention time
- redox potential
- flow path (sedimentation potential)

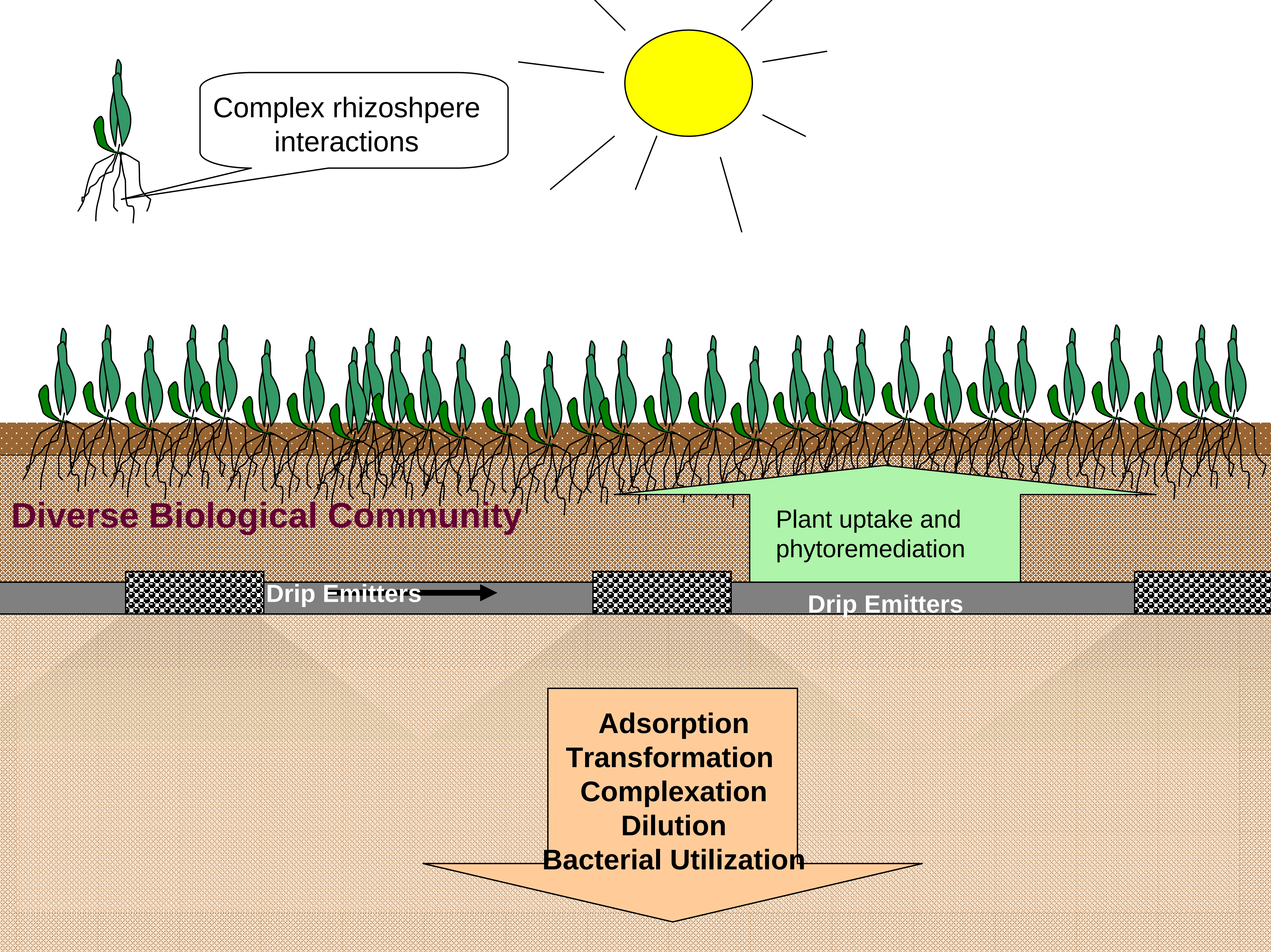

Anaerobic Conditions
Sedimentation
Biological and chemical transformation
Depending on system depth and possibility of interaction in root zones there may be a highly complex biological community capable of mediating transformation of complex organic chemicals
Septic tank
Alternating Aerobic and Anaerobic Conditions (depending on loading rate)
Dilution, dispersion chemical and biological transformation, adsorption
Groundwater

Variables in the subsurface environment in the soil absorption system might be able to be optimized to encourage the breakdown of PPCPs



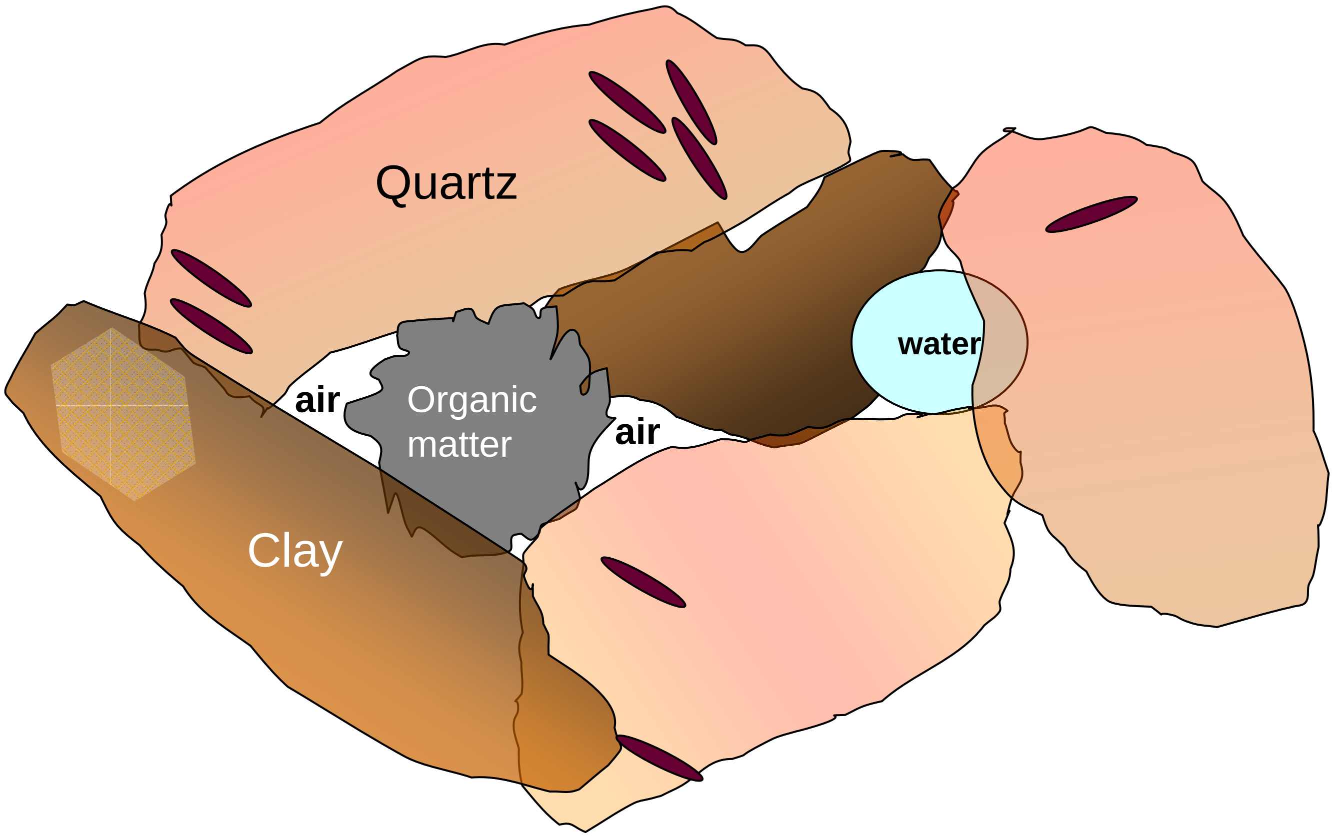
Variables in subsurface (not exhaustive list)

- **clay content (affects adsorption, moisture, pH)**
- **Soil texture (affects degree of saturation and oxic conditions)**
- **mineral content**
- **pH (affects dissociation, adsorption, chemical and biological mediated transformations.**
- **Carbon availability (affects biological community diversity and propensity to “need” carbon from wastewater organic compounds)**
- **Oxygen availability (affects numerous biologically-mediated transformations)**

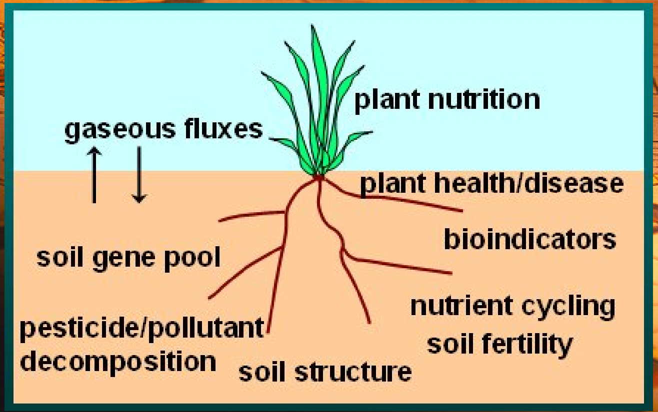


Complex rhizoshpere interactions
Diverse Biological Community
Plant uptake and phytoremediation
Drip Emitters
Drip Emitters
Adsorption
Transformation
Complexation
Dilution
Bacterial Utilization

Soil structure can offer a wide variety of microcosms that may provide conditions that are conducive to various modes of OWC reduction.



The diversity of the soil layers and the ability of those biological communities to process of assimilate many man-made compounds is largely unexplored



Steps

1. Prioritize a class of compounds based on what is known about potential risks
2. Conduct a series of experiments that have the promise of yielding useful and applicable conclusions regarding soil treatment.
3. Investigate the feasibility and the practicality of incorporating design features that use the discovered information into design changes for onsite systems in sensitive areas.

Where would this author begin ? Or

The opinion of a neophyte.

- Application changes (does pressure distribution facilitate removal of contaminants?)
- Soil preferences (are finer grained soils better for contaminant removal?)
- Vertical positioning (can root zone installations enhance contaminant removal)
- Can addition of organics enhance contaminant removal?
- Can the introduction of textural breaks enhance removal of contaminants as effluent passes through the vadose zone?


Questions?