The fate of pharmaceutical residues

- during sludge hygienization and in soil fertilized with sludge

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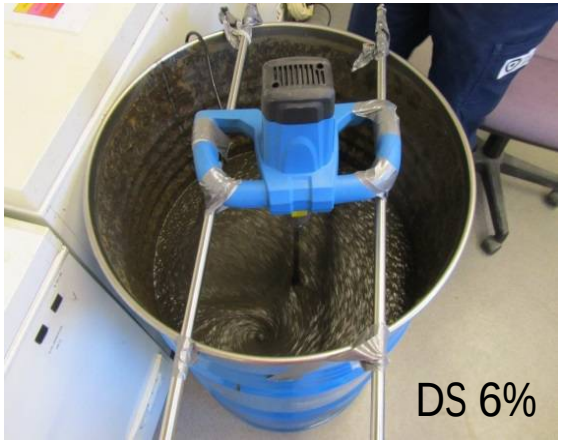
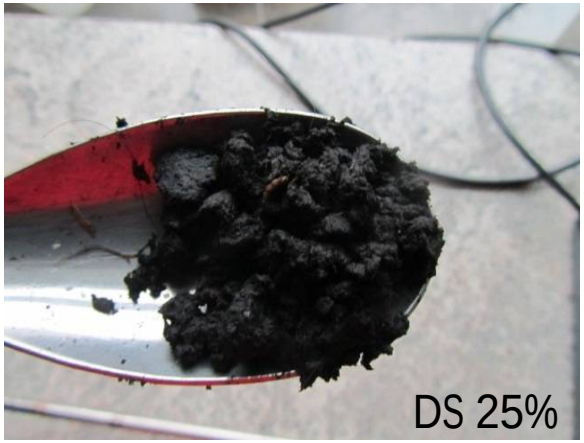
Pharmaceutical residues in sewage sludge

- Effect of sanitization and anaerobic digestion

Technologies	Process parameters
Mesophilic anaerobic digestion	38 °C, 60 days
Thermophilic anaerobic digestion	55 °C, 60 days
Pasteurization	70°C, 30 min
Advanced oxidation (AOP)	H_2SO_4, H_2O_2, 10 min
Ammonia treatment	Urea > 100mM, 10 days
Thermophilic dry digestion	55°C, 31 days
Thermal hydrolysis	165°C, 6 bar, 30 min



- Anaerobic digestion
- Thermal hydrolysis
- Pasteurization
- Advanced Oxidation



- Ammonia treatment
- Dry digestion

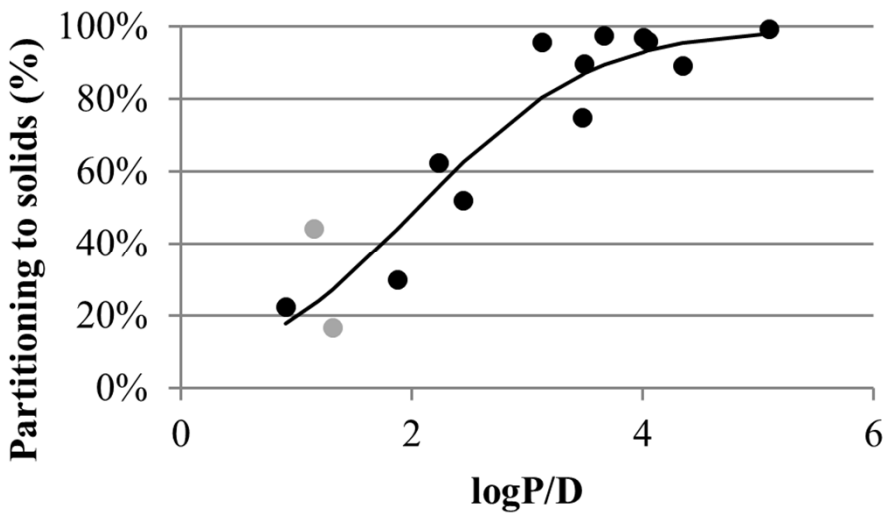
Reference: *Malmborg J, Magnér J. (2015) Pharmaceutical residues in sewage sludge: Effect of sanitization and anaerobic digestion. J Environ Manage. 153:1-10.*

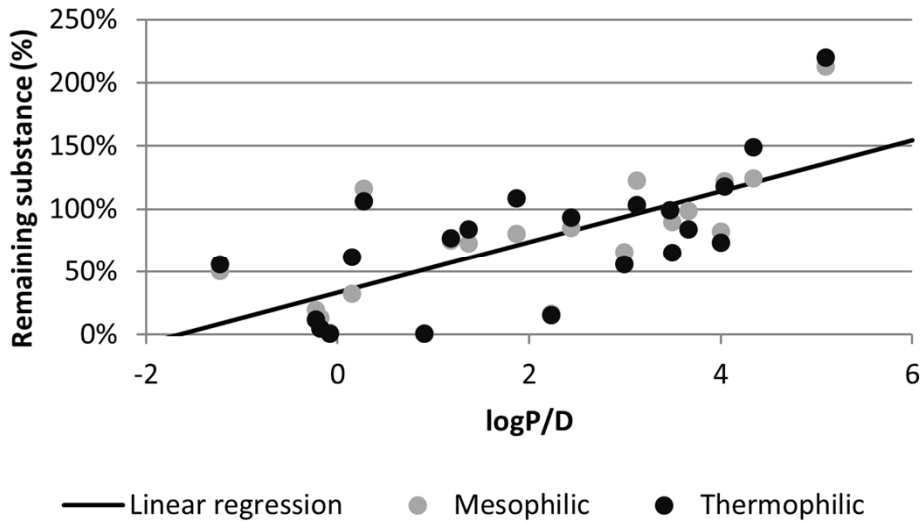
Investigated pharmaceuticals

Substance		Ion class
Spiked substances	Carbamazepine	Neutral
	Citalopram	Base
13	Diclofenac	Acid
	E2	Acid
	EE2	Acid
	Fluoxetine	Base
	Ibuprofen	Acid
	Metoprolol	Base
	Oxazepam	Acid
	Propranolol	Base
	Sertraline	Base
	Tetracycline	Base
	Trimethoprim	Base
Unspiked substances	Atenolol	Base
	Amlodipine	Base
10	Caffeine	Base
	E1	Acid
	Furosemide	Acid
	Hydrochloroth.	Acid
	Ketoconazole	Base
	Naproxen	Acid
	Progesterone	Neutral
	Warfarin	Acid

Result from the study

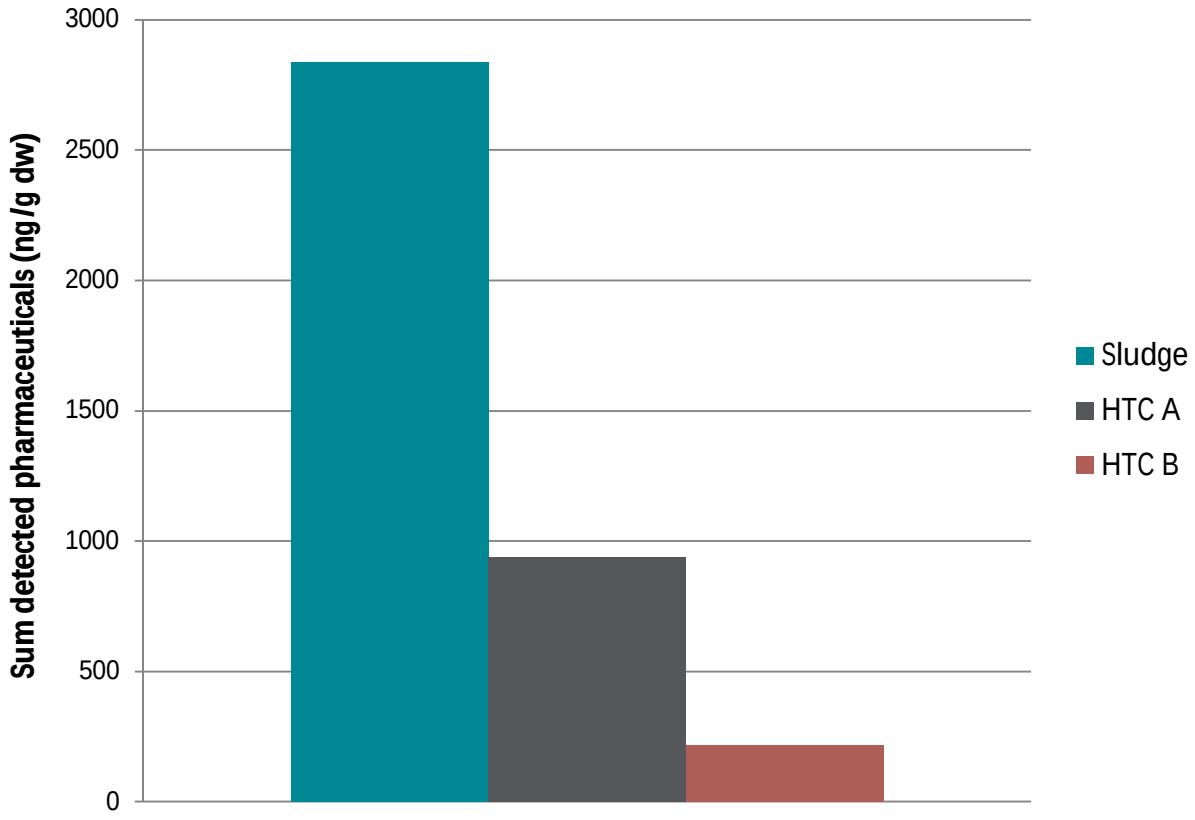
Technologies	Process parameters	Reduction	
		Out of 23	Estrogens
Mesophilic anaerobic digestion	38 °C, 60 days	12	Stable
Thermophilic anaerobic digestion	55 °C, 60 days	14	Stable
Pasteurization	70°C, 30 min	9	Stable
Advanced oxidation (AOP)	H_2SO_4, H_2O_2, 10 min	12	Stable
Ammonia treatment	Urea > 100mM, 10 days	12	Stable
Thermophilic dry digestion	55°C, 31 days	6	Stable
Thermal hydrolysis	165°C, 6 bar, 30 min	10	Reduction





Hydrothermal carbonization

- HTC A - 200°C for 2 hours
- HTC B - 220°C for 4 hours

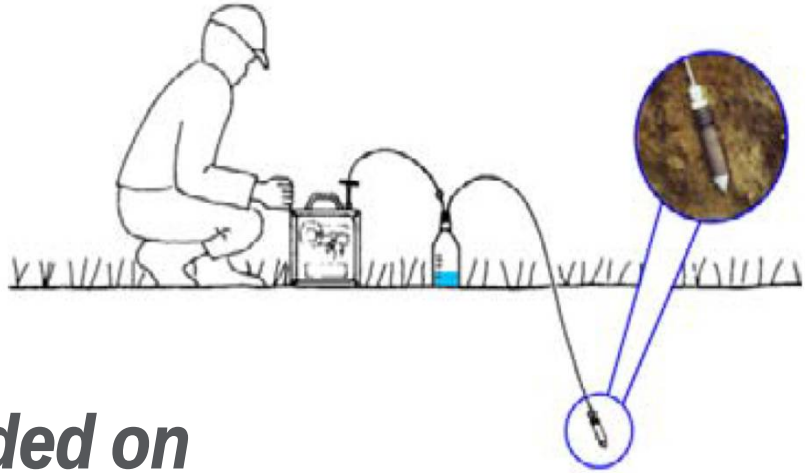


Fate of pharmaceutical residues

- in sewage treatment and on farmland fertilized with sludge

Samples from the fields at Petersborgs farm, Skåne

- Sludge
- Soil
- Soil water (Lysimeter)



Overall aim: ***if sludge amended on farmland could be a significant source for emission of pharmaceuticals to the environment***

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Reference: *Magnér J, Rosenqvist L, Rahmberg M, Graae L, Eliaeson K, Örtlund L, Fång J, Brorström-Lundén E. (2016) Fate of pharmaceutical residues - in sewage treatment and on farmland fertilized with sludge. IVL report B2284.*

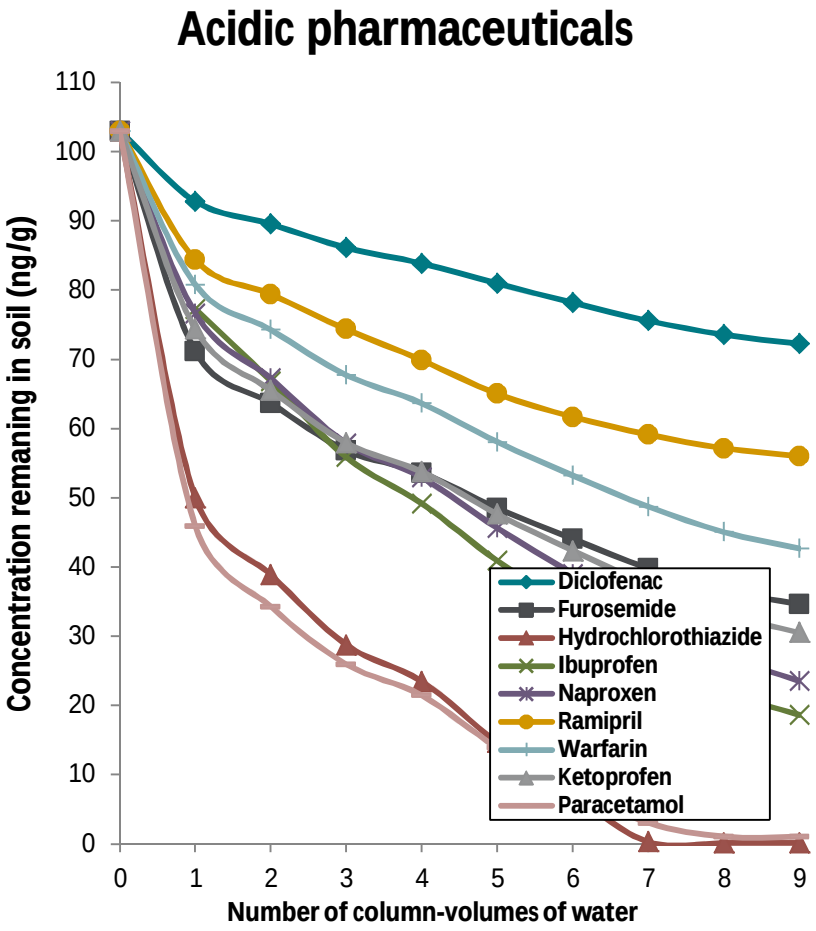
Investigated pharmaceuticals

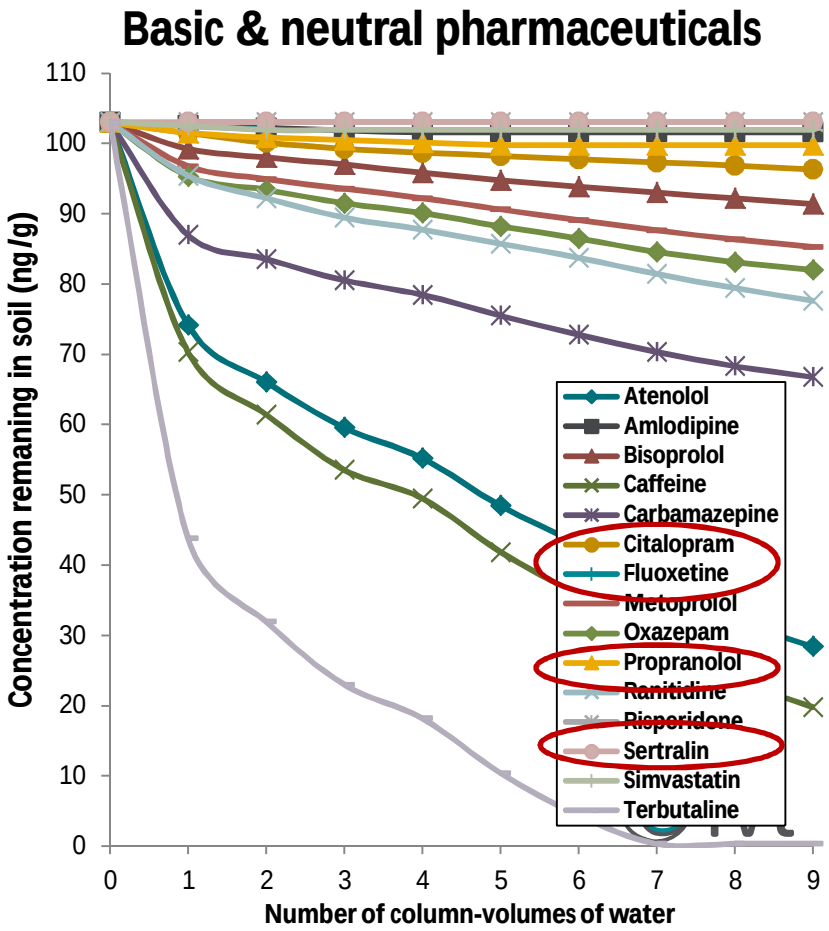
Substance	Mode of action	Chemical properties		
		Acid/Base	Log K_{ow} [1)]	Log $D_{pH7.4}$ [2)]
Diclofenac	*Anti-inflammatories*	Acid	4.06	1.37
Furosemide	*Diuretics*	Acid	3.10	-0.78
Hydrochlorothiazide	*Antihypertensives*	Acid	-0.07	-0.01
Ibuprofen	*Anti-inflammatories*	Acid	3.72	0.45
Naproxen	*Anti-inflammatories*	Acid	3.00	0.45
Ramipril	*Antihypertensives*	Acid	3.41	-0.13
Warfarin	*Anticoagulants*	Acid	3.42	0.30
Atenolol	*Antihypertensives*	Base	0.10	-1.85
Amlodipine	*Antihypertensives*	Base	4.16	1.91
Bisoprolol	*Antihypertensives*	Base	2.14	0.12
Caffeine	*Stimulant*	Neutral	-0.13	0.28
Carbamazepine	*Sedatives*	Neutral	2.67	2.28
Citalopram	*Antidepressants*	Base	2.51	1.27
Fluoxetine	*Antidepressants*	Base	4.09	1.75
Ketoprofen	*Anti-inflammatories*	Acid	2.81	0.06
Metoprolol	*Antihypertensives*	Base	1.79	-0.25
Oxazepam	*Sedatives*	Neutral	2.31	2.06
Paracetamol	*Anti-inflammatories*	Acid	1.08	0.74
Propranolol	*Antihypertensives*	Base	3.10	1.15
Ranitidine	*Antiulcers*	Base	1.23	-0.63
Risperidone	*Antipsychotic*	Base	2.88	1.81
Sertralin	*Antidepressants*	Base	4.81	3.14
Simvastatin	*Lipid-regulating*	Neutral	4.41	4.60
Terbutaline	*Asthma medication*	Base	0.48	-1.61

Result from the study

Detected levels of pharmaceuticals residues in the samples

- Sludge – 15 of 24 pharmaceuticals (1.9 – 1000 ng/g dw)
- Soil – 4 of 24 pharmaceuticals (0.4-4.9 ng/g dw)
- Soil water (Lysimeter) – only Caffeine in one sample (69 ng/L)





Conclusions

- Sludge amended on farmland is a insignificant source for emissions

- Study implies that the investigated pharmaceuticals are **retained** and eventually **degraded** at the surface of the soil.

Thank you for your attention