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# Consequential LCI modeling of chemicals in wastewater: including avoided nutrient treatment

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 Nowadays most urban wastewater treatment systems rely on biological treatment

Organic matter +  $O_2$  + N + P  $\rightarrow$  Biomass +  $CO_2$ 

 Urban wastewaters contain (more than) enough nutrients for microorganisms to thrive



Table	3.7	Typical	content	of	nutrients	in	raw	municipal
waster	wate	r with m	inor cont	ribu	tions of in	dust	rial w	/astewater
(in g/m	1 <sup>3</sup> )							

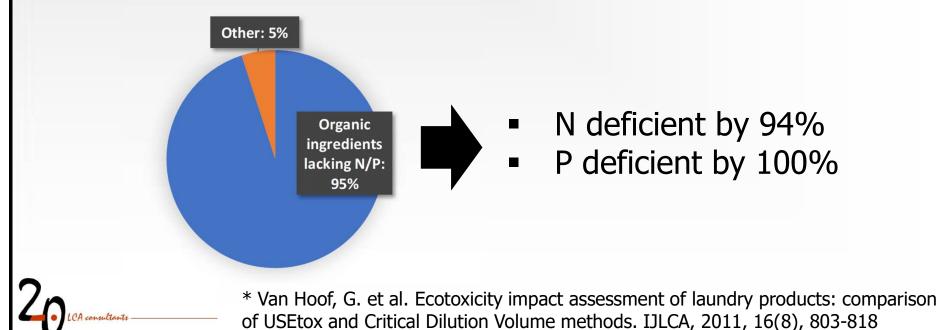
Parameter	High	Medium	Low
N total	100	60	30
Ammonia N	75	45	20
Nitrate + Nitrite N	0.5	0.2	0.1
Organic N	25	10	15
Total Kjeldahl N	100	60	30
P total	25	15	6
Ortho-P	15	10	4
Organic P	10	5	2

Henze M. et al. (Eds.) Biological Wastewater Treatment: Principles Modelling and Design. IWA Publishing, London.

- In LCA we often need to model the impact of wastewaters with specific compositions and not the 'average'
- Such specific wastewaters are often N and/or P deficient
   Example: washing machine detergent

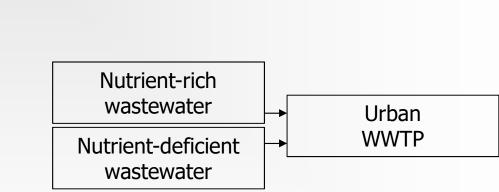
Mass of ingredients in a concentrate washing detergent formulation, excl. water\*





- How to model this deficiency?
  - Industrial WWTP:

Urban WWTP:



External N source External P source

Industrial

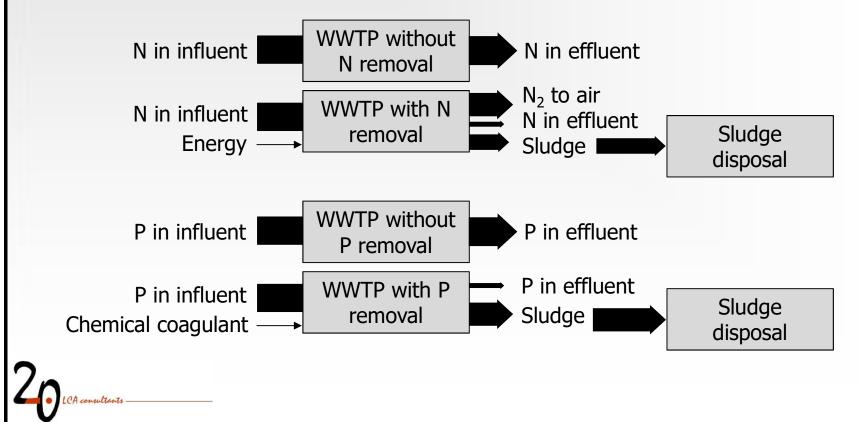
**WWTP** 

- in urban wastewater, N and P are 'freely' available
- Does that mean the impact of consuming this N and P is zero (i.e. Waste materials are `burden-free')?

Nutrient-deficient

wastewater

- Nutrients in urban wastewater are an example of `not fully utilized' materials
- Additional demand for these nutrients displaces their disposal:



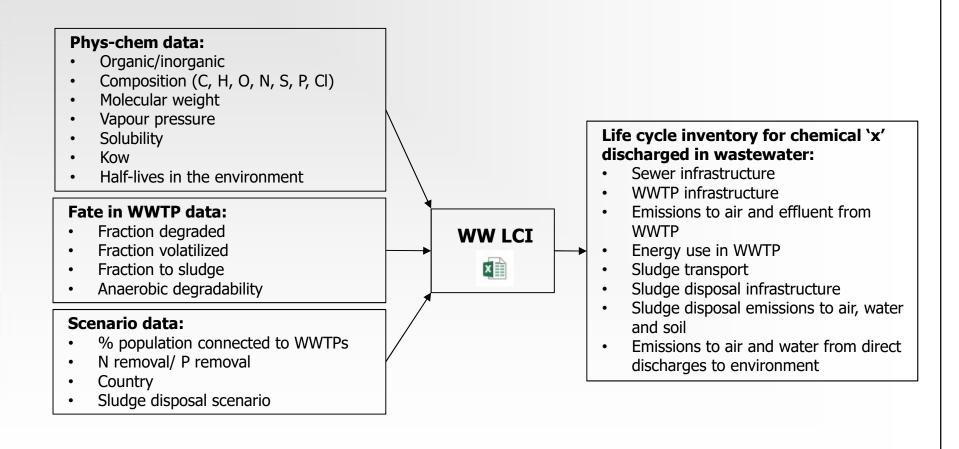
## **Goal and scope**

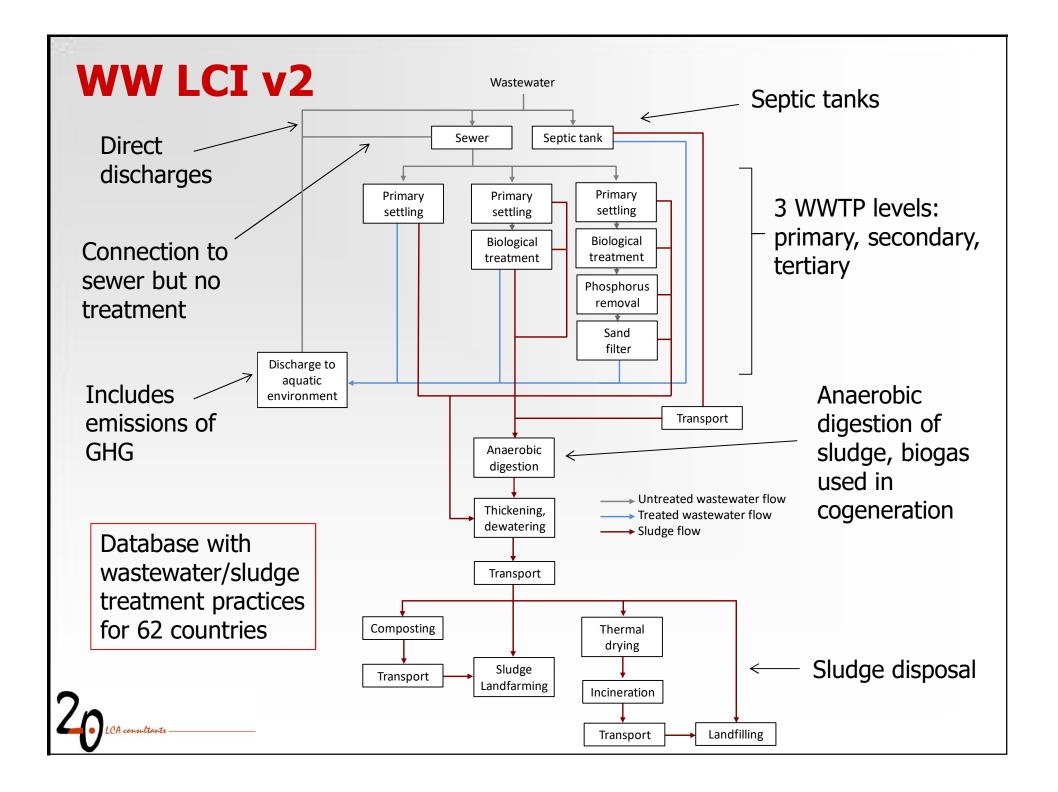
- Our goal is to quantify the environmental effects of a marginal discharge of nutrient-deficient wastewater to urban wastewater systems
- As a case study, we assess the effects of discharging
   **1 kg ethanol** (C<sub>2</sub>H<sub>6</sub>O) to the sewer:
  - In Denmark
  - In India
- We use the model WW LCI v2 to quantify the environmental effects of an ethanol discharge and those of nutrient consumption



## WW LCI v2

 WW LCI calculates chemical-specific LCIs of chemicals discharged in wastewater

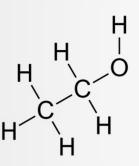




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e of country data		on to urban wastev	water collecting systems -	total (%)	Database 85% 100%							-
	Conne	action to urban was	tewater collecting system	s - without treatment (%)	8% 0%		6					
water treatment	Cor	nnection to urban w	tewater collecting system astewater treatment - prin	nary treatment (%)	2% 0	1%						
rio	A Cor	nnection to urban w B	vastewater treatment - sec	condarv treatment (%)	30% 1	00%	F	G	Н	1		K
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									acid, bis 2-			
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cal mixture				Methanol (kg) FeCl3 (kg)		0	0	0.002936072	0	0	0	0
ical-specific				Electricity (kWh)		0.001492698	0.311109633	0.005228534	0.018422938	0.000022444	5.25866E-05	0
				Heat (MJ)		0.003620335	0.067179499	0 00525724	0.29087883	0.00005643	0.000526878	0
Name				WWTP infrastructure ( Sewer infrastructure (				-13	8.78414E-13 8.0444E-11	3.37175E-13 8.0444E-11	3.37175E-13 8.0444E-11	0
nac				Polyvinylchloride, bulk				292	0.016807292	0.016807292	0.016807292	ŏ
len Ie			Wastewater	Polyethylene, high der	CSVm			313	0.015695313	0.015695313	0.015695313	0
nonic acid, b			treatment	Injection moulding (GL Excavation, hydraulic	CJVIN	uker		504 813	0.032502604 0.006507813	0.032502604 0.006507813	0.032502604	0
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				Gravel, crushed {GLO				5	0.459375	0.459375	0.459375	0
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				Occupation, industrial				9	1.7125E-09	1.7125E-07	6.85E-09 1.7125E-07	U 0
				Building, hall, steel co				9	6.85E-09	6.85E-09	6.85E-09	0
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				Compost plant infrastr				-11	3.5581E-10	9.40404E-13	Ō	0
			Sludge composting	Electricity (kWh)				-06	9.38943E-05	2.48162E-07	0	0
4.4.4				Diesel (MJ) Transport to landfarmi				708 134	0.006804866 0.905585868	1.79852E-05 0.00239346	0	0
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5	1000			process-specific burde	FXCPL		Idr	0 -06 07 -09	<u>o</u>	0	0	0
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1	⊃ Fro	m		iron (III) chloride, 40%					0	0	0	0
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	and the second sec	>> WV	WTP input USESL	CA input   LCI output /		Ready to CSV output				e / Parameters	Env deg calc	Pri calc
	Norm											

## **Case study**

- Test chemical:
  - Ethanol, bio-based
  - Ethanol, fossil-based



	Fate of ethanol in wastewater treatment						
Treatment	Fair Fdeg		Fsludge	Feffluent			
WWTP with secondary or tertiary treatment *	0.4%	87.1%	0.0%	12.5%			
WWTP with primary treatment **	0.0%	26.1%	0.0%	73.9%			
Septic tank **	0.0%	26.1%	0.0%	73.9%			
<ul><li>* Simulation with Simpletr</li><li>** Assumption in WW LCI:</li></ul>		= 30% of the	value in Simpletreat	; Fair = 0			

 $C_{2}H_{6}O + 1.96 O_{2} + 0.22 NH_{4} + 0.016 P-PO_{4} \rightarrow 0.22 C_{5}H_{7}NO_{2}P_{0.074} + 0.9 CO_{2} + 2.7 H_{2}O$ 

## **Case study**

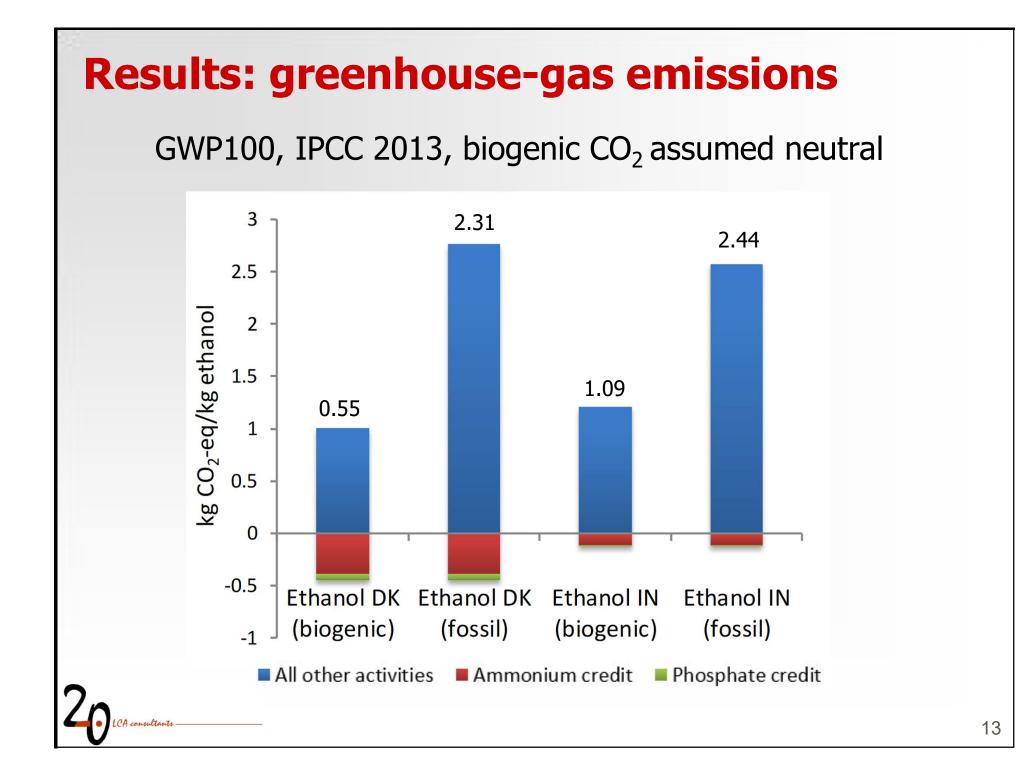
 Wastewater and sludge treatment in DK and IN according to WW LCI's database:

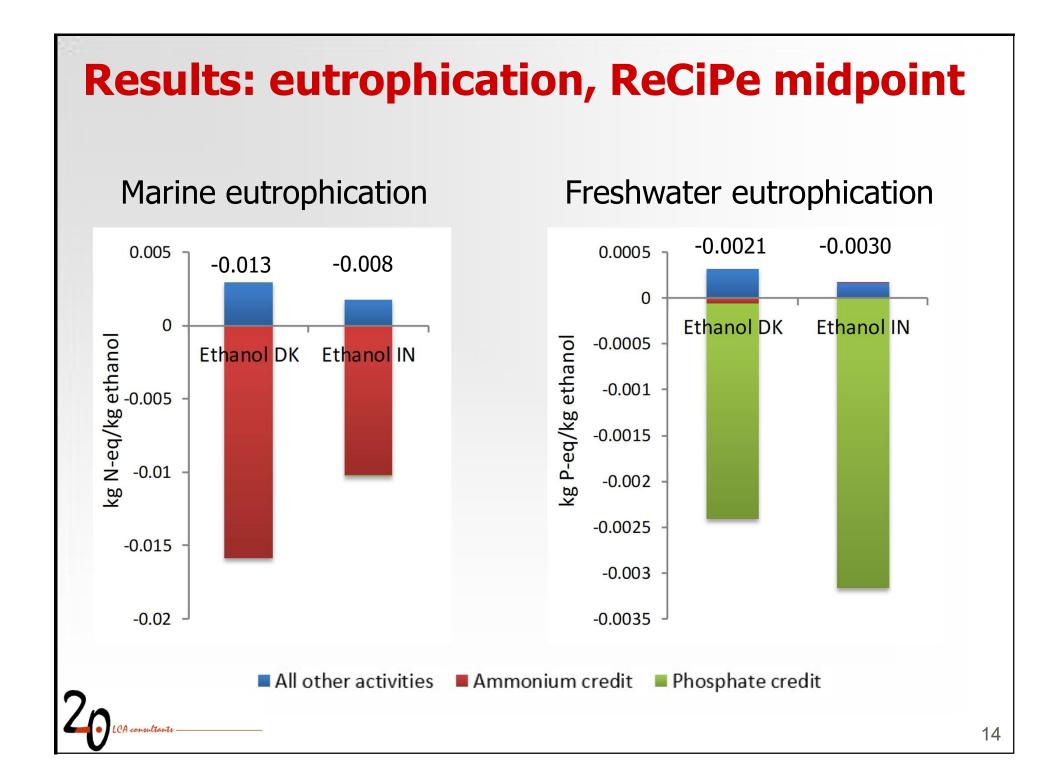
Wastewater tre	eatment and sludge disposal scenario	Denmark	India
	Connection to WWTP - primary treatment	2%	
Wastewater	Connection to WWTP - secondary treatment	3%	21%
treatment	Connection to WWTP - tertiary treatment	84%	
scenario	Connection to septic tank	11%	39%
	Direct discharge (no treatment)		39%
	Composting	6%	
Sludge disposal	Agriculture	50%	100%
scenario	Landfilling		
	Incineration	44%	

#### **Case study**

- WW LCI does not provide a systematic calculation of credits associated to consumption of nutrients
- They can be calculated `manually' by:
  - 1. Obtaining the LCIs for treating ammonium, phosphate, and ethanol, separately
  - 2. Linking to the LCI of ethanol the inputs of -X kg ammonium and -Y kg phosphate consumed

Denmark	Primary WWTP	Secondary WWTP	Tertiary WWTP	Septic tank	Total
NH4 cons. (kg/kg ethanol)	0.00045	0.0022	0.0629	0.0025	0.068
PO4 cons. (kg/kg ethanol)	0.00017	0.0009	0.0245	0.0009	0.027
India	Primary WWTP	Secondary WWTP	Tertiary WWTP	Septic tank	Total
India NH4 cons. (kg/kg ethanol)	-				Total 0.025





# Conclusions

- Consumption of available N and P in urban wastewater by organic chemicals avoids the disposal of these nutrients
- Credits for this avoided disposal are higher than those from by-products (energy recovery, sludge fertilizer, etc.)
- The magnitude of these credits is dependent on the local wastewater treatment situation, as seen for DK and IN
- These credits only apply for organic chemicals which:
  - Are expected to degrade in WWTPs
  - Do not contain N and/or P



#### **Thank you!**

More info about WW LCI: <u>http://lca-</u> <u>net.com/projects/show/wastewater-lci-initiative/</u>

#### **WW LCI** References:

Kalbar P, Muñoz I, Birkved M. (2017) *WW LCI v2: a secondgeneration inventory model for chemicals discharged to wastewater systems*. Science of the Total Environment, https://doi.org/10.1016/j.scitotenv.2017.10.051

Muñoz I, Otte N, Van Hoof G, Rigarlsford G. (2016) *A model and tool to calculate life cycle inventories of chemicals discharged down the drain.* International Journal of Life Cycle Assessment. DOI: 10.1007/s11367-016-1189-3

