SETAC Europe 29th Annual Meeting, Helsinki, 26-30 May 2019

# Towards global LCI data on urban wastewater discharges

# WW LCI v3

Ivan Muñoz, 2.-0 LCA consultants

Ivan.munoz@lca-net.com



### Content

- WW LCI
- Developments in WW LCI v3
- Example of application to 81 countries

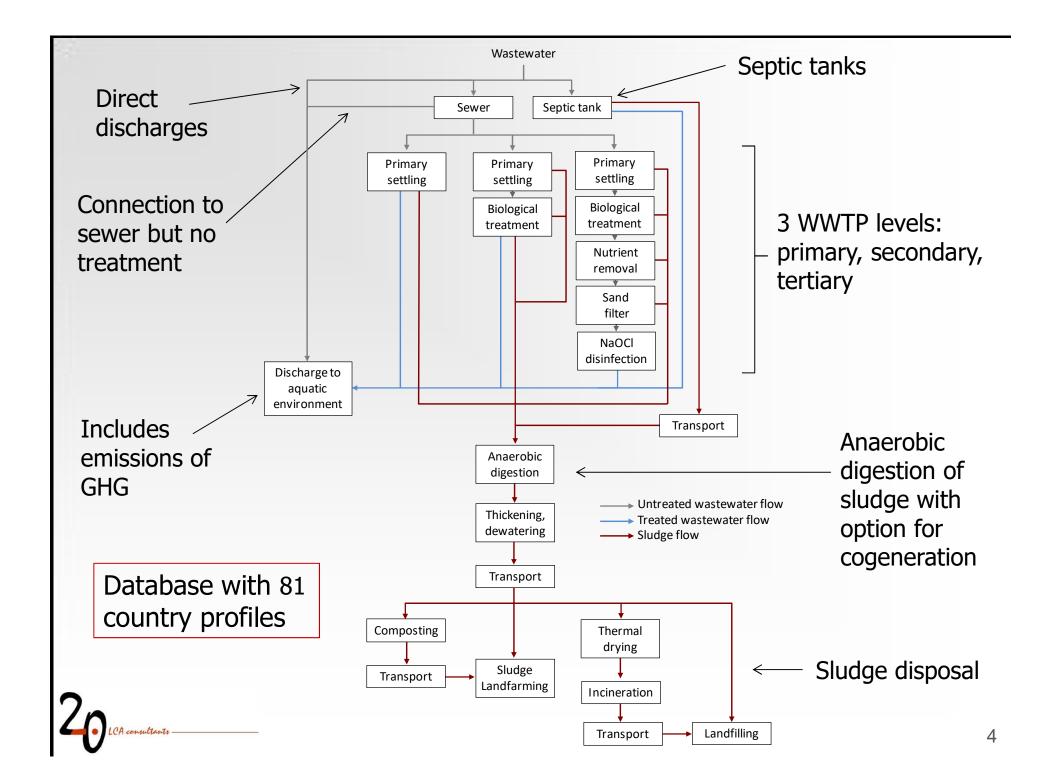


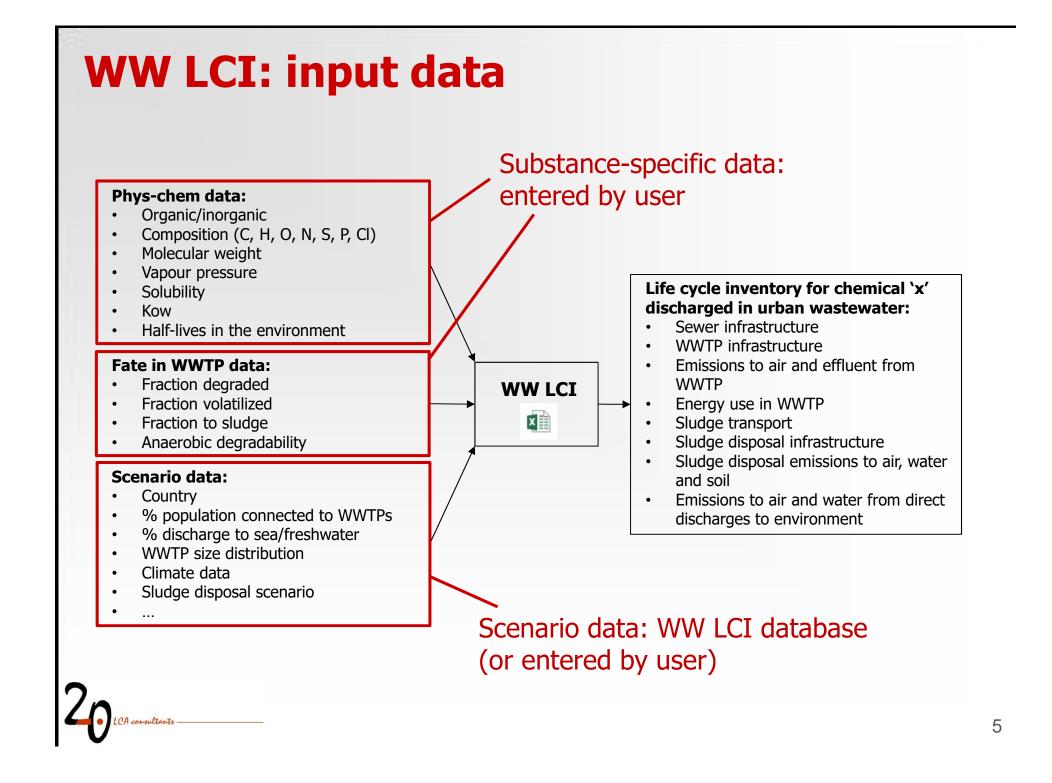
# **WW LCI**

- WW LCI is an excel-based model to calculate chemical-specific LCIs for chemicals discharged in urban wastewater
- Originally focused on specific substances rather than generic pollution descriptors:
  - Ethanol ✓
     Nitrate ✓

- N-total ×
- BOD ➤
   Suspended solids ➤
   Diclofenac ✓







Bit out out out out out out out out out ou	ll colour code		B C I	DEFGHI	J K L	M N O	Р	Q F	R S	Т	U	V 🔺	
Intro         NL         NL         Important set of the reference of the r	ooloal ooao	s	Green cells not to be filled in	Brown cells can be filled in or chan	ged								
Intro- concretor         Nu         Nu         Nu           concretor         Nu         Nu<													
Details       Details       Details       Oracle to uchn welweder collecting systems - which thatmatter (%)       Details         devolution collection and the set of the third wellweder collecting systems - which thatmatter (%)       0.96,					NI	28							
Connection to undra vasiowater collecting systems - with catavant (%) Undra wasiowater		y data set											
Bitwater collection and minimit scenario         Under westoweder collecting systems - with readment (%)         0.0% 0.0%           Stewater collecting systems - with readment (%)         0.0% <td< td=""><td></td><td></td><td></td><td></td><td>yes</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></td<>					yes								
arrowser         B         C           Interfere         100%           Interfere         10%			Urban wastewater collecting s Urban wastewater collecting s Urban wastewater treatment Urban wastewater treatment Urban wastewater treatment Connection to independent was	ystems - without treatment (%) ystems - with treatment (%) - primary treatment (%) - secondary treatment (%) - tertiary treatment (%) tewater collecting systems - total (%)	99.4% 0.0% 99.4% 0.0% 1.0% 98.4% 0.6% 0.6%	Eurostat, data from 2015		0% 0% 09 09 09 100% 100%	% % % 6 D%				
natio       LC for WWTP-sludge disposal-environme         stewater       2         3       CCSVmaker         3       Cost         6       0					0.0%			0%					
name     A     B     C       1     LC1 for WWTP-sludge disposal+environme     CSVmaker       2     A     B     C       1     1     1     1     1     0       2     A     B     CSVmaker     0       3     Polyscientify ta consult     CSVmaker       1     0     0     0     0       1     0     0     0     0     0       1     0     0     0     0     0     0       1     1     1     1     0     0     0       1     0     0     0     0     0     0     0       1     0     0     0     0     0     0     0       1     0     0     0     0     0     0     0       1     0     0     0     0     0     0     0       1     0     0     0     0     0     0     0       1     0     0     0     0     0     0     0       1     0     0     0     0     0     0     0     0       1     1     1     0     0     0		harge			1000 C	Calculated from coactal verinland noreon-	aquivalant discharges rar	ct	100%				
Image: stewater	nario	A						н	1	J	К	LL	М
1       Image: Constraint of the second secon								1	Dodecylbenze				
denvlar set 5       0			LCI for WWTP+	sludge disposal+environme	C1/100					Diclofenac	Ibuprofen	Atrazine	0
deriver a schry set 5 6 7 7 8 8 8	1			Reference flow (kg)	. <b>SV</b> []]	oker				1	1	1	0
edity St: 4       6       0       0.0018/077       0.0024034       0.4294E-05       0         Ammonium, from wast       Methanol (kg)       Prosphete, from wast       Methanol (kg)       0	stewater							)	0	0	0	0	-
6       7       -0.00289227       -0.0020722       -0.0031723       0.0031723       0	4			Polyelectrolyte consul									
7       0	-												
8       9       0	-												
ient ren       9       0								,		•		<u> </u>	
inent refit       10         ing refit       10 </td <td>9</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td>5E-06</td> <td></td> <td></td> <td></td> <td></td> <td></td>	9							5E-06					
Ige treat         12           TPs         14           Wastewater         WWTP infrastructure           WWTP infrastructure         WWTP infrastructure           WWTP infrastructure         Sever 1.610 L/year           Sever 1.610 L/year         Sever 1.610 L/year	ient rem 10								1.724419142	0.262375783	1.614825599	0.028282605	0
MTPS       13         Wastewater       WWTP infrastructure         WWTP infrastructure       WWTP infrastructure         WWTP infrastructure       Excel         Sever 1.1E10 L/year       Sever 1.1E10 L/year         Sever 1.8E0 L/year (in       Sever 1.8E0 L/year (in         Sever 1.8E0 L/year (in       Sever 1.8E0 L/year (in         Polyethylene, high density (kg)       1.74050E-00       1.74050E-00 <td> 11</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td>4E-05</td> <td>0.000483131</td> <td>0.342140409</td> <td>4.8024E-05</td> <td></td> <td></td>	11							4E-05	0.000483131	0.342140409	4.8024E-05		
Wastewater         WwrTP infrastructure         WerTP infrastructur													
Wastewater         WWTP infrastructure         WWTP infrastructure         Excel         SimaPtro         88-12         1.43933E-12         1.4262E-12         1.42732E-12         0           16         17         16         Sewer 1.1E10 L/year         Excel         SimaPtro         14         4.3093E-13         4.49024E-13         4.490274E-13         4.49576E-13         0           19         Sewer 1.1E10 L/year         Sewer 1.1E10 L/year         Sewer 1.6E3 L/year (kn         Sewer 1.6E3 L/year (kn         Sewer 1.6E3 L/year (kn         Sewer 1.6E3 L/year (kn         1.49000E-00         1.74000E-00								OL IO					
16 17 18 18 19 20 20 21 22 22 23 24 23 24 25         treatment         WWTP infrastructure Sewer 1.E1D L/year (n Sewer 1.E1D L/year (n Sewer 1.E1D L/year)         Excel         SimaPiro S			10/										
19       Sewer 5E9 L/year (kn       i7E-11       7.82687E-11				WWTP infrastructure	_	<b>C</b> ·		2E-13					
19       Sewer 5E9 L/year (kn       i7E-11       7.82687E-11			actuation	Sewer 4.7E10 L/year	-vcol	Sima	<b>ארר</b> ו	3E-11					
20       Sewer 1E9 L/year (kn       4E-11       1.51194E-11       1.51194E-11       1.51194E-11       1.51194E-11       1.51194E-11       1.51194E-11       1.51194E-11       1.51194E-11       0         21       Sewer 1.0E8 L/year (       961979E-13       9.61979E-13       9.61979E-13 <td>18</td> <td></td> <td></td> <td>Sewer 1.1E10 L/year</td> <td></td> <td></td> <td>1 F I U</td> <td>7E-11</td> <td>4.19687E-11</td> <td>4.19687E-11</td> <td>4.19687E-11</td> <td>4.19687E-11</td> <td>0</td>	18			Sewer 1.1E10 L/year			1 F I U	7E-11	4.19687E-11	4.19687E-11	4.19687E-11	4.19687E-11	0
21       Sewer 1.6E8 L/year (       96:1979E-13       9.61979E-13       9.61978E-13								37E-11	7.82687E-11	7.82687E-11	7.82687E-11		
22       Polyvinylchloride, bulk       1/4030E-00       1/4030E-00       1/4030E-00       1/4030E-08       6.31456E-08       6.31456E-08       6.31456E-08       6.31456E-08       0         23       Polyethylene, high densny (kg)       1/4030E-00       1/4030E-00       1/4030E-08       1/4658E-08       1/4658E-													
23       Polyethylene, high density (kg)       1.74030E-00       1.74030E-00       1.74038E-08       1.74658E-08       1.7465													
24         Extrusion, plastics (kg)         8.06114E-08													
25       Excavation, hydraulic digger (m3)       8 46994E-09       10 5205E-07       1 95205E-07       1 95													
26       Sand (kg)       1.95205E-07       1													
27         Gravel, crushed (kg)         5.45651E-06	25												
28         Fibre glass (kg)         1.58818E-05         <						10-10-10-10-10-10-10-10-10-10-10-10-10-1							
30         Sludge transport         transport to sludge disposal facilities, lorry (kgkm)         25.2786096         44.45124693         69.03759354         0         36.16061245         46.65768154         40.55356131         1.901974431         0           31         Compost plant infrastructure (units)         0	26												
31         Compost plant infrastructure (units)         0	26 27					1.58818E-05 1.58818E-05	1.58818E-05	1.58818E-05	1.58818E-05	1.58818E-05	1.58818E-05	1.58818E-05	0
	26 27 28 29			Fibre glass (kg) Sodium hydroxide, 50% in H2O, pr		7.34064E-06 7.34064E-06	6 7.34064E-06	7.34064E-06	7.34064E-06	7.34064E-06	7.34064E-06	7.34064E-06	0
32 Sludge Electricity (XVb) 0 0 0 0 0 0 0 0 0	26 27 28 29 30		Sludge transp	Fibre glass (kg) Sodium hydroxide, 50% in H2O, pr ort transport to sludge disposal facilitie	s, lorry (kgkm)	7.34064E-06 7.34064E-06 25.2786096 44.45124693	6 7.34064E-06 3 69.03759354	7.34064E-06 0	7.34064E-06 36.16061245	7.34064E-06 46.65768154	7.34064E-06 40.55356131	7.34064E-06 1.901974431	0 0

20 LCA consultants -

6

# **Coverage of wastewater components**

Wastewater component	WW LCI v2	WW LCI v3	Examples
Organics	$\checkmark$	$\checkmark$	Surfactants, pesticides, solvents
Inorganics (non-metals)	$\checkmark$	$\checkmark$	Phosphates, carbonates, zeolite
Generic pollution descriptors	×	✓	COD, TSS, N-total, P-total
Inorganics (metals)	×	~	Ag, Al, As, Cd, Cr, Cu, Hg, Mn, Ni, Pb, Zn, Ba, Co, Fe, Mg, Sb, Va

- WW LCI v3 covers all main chemical content in urban wastewater:
  - Organic matter (COD/BOD)
  - Nutrients (N/P)
  - Organic micropollutants (e.g. Pesticides)
  - Inorganic micropollutants (metals)

#### **Geographical-technological coverage:** Methane emissions from open sewers



\* Source: https://www.crookedbrains.net/2008/01/open-sewers-of-world.html

- IPCC's Methane correction factor (MCF): expresses anaerobic conditions
- MCF for open-stagnant sewers according to IPCC: 0.5 (0.4 0.8)

Same for all countries?

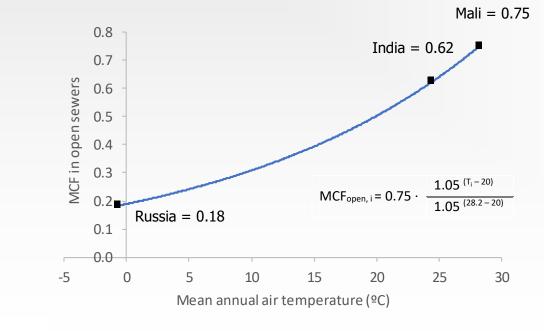


#### **Geographical-technological coverage:** Methane emissions from open sewers

Michiel Doorn, author of IPCC-wastewater report:

"... You are right that a hot climate would enhance anaerobic conditions... I agree that Russia would be very different than India for reasons of climate and perhaps infrastructure"

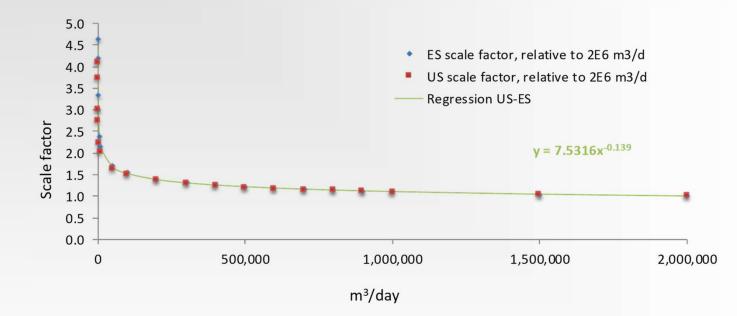
We introduce a climate-dependent MCF\*:



\*Partly based on: Chaosakul T et al. (2014) A model for methane production in sewers. J Environ Sci Heal A, 49 (11): 1316-1321

# **Geographical-technological coverage: Electricity demand vs. size in WWTPs**

Unitary electricity consumption as a function of plant capacity:



#### Example: WWTP 2E+06 m<sup>3</sup>/d = 0.27 kWh/m<sup>3</sup> WWTP 2E+04 m<sup>3</sup>/d = $0.27 \times 1.9 = 0.51$ kWh/m<sup>3</sup>

Stillwell AS et al. (2010) Energy Recovery from Wastewater Treatment Plants in the United States: A Case Study of the Energy-Water Nexus. Sustainability 2010, 2, 945-962.

Albadelejo A et al. (2015) Parametrización del consumo energético en las depuradoras de aguas residuales urbanas de la Comunidad Valenciana. Tecnoacqua, nº 11-15 Enero-Febrero 2015.

#### **Geographical-technological coverage:** Climate-dependent heat balance in WWTPs

- Of special relevance for WWTPs with anaerobic digestion of sludge
- Monthly heat balance at the digester, as a function of local T:

Heat demand (MJ/d) = Losses (wall, floor, roof) + Sludge heating

Month		WWTP in Russ	ia	WWTP in Thailand			
Month	Mean T (°C)	Without CHP	With CHP	Mean T (°C)	Without CHP	With CHP	
January	-18	Fuel input needed	Fuel input needed	24	Self-sufficient	Self-sufficient	
February	-16	Fuel input needed	Fuel input needed	26	Self-sufficient	Self-sufficient	
March	-10	Self-sufficient	Fuel input needed	28	Self-sufficient	Self-sufficient	
April	-1	Self-sufficient	Fuel input needed	29	Self-sufficient	Self-sufficient	
May	7	Self-sufficient	Fuel input needed	29	Self-sufficient	Self-sufficient	
June	13	Self-sufficient	Self-sufficient	28	Self-sufficient	Self-sufficient	
July	16	Self-sufficient	Self-sufficient	28	Self-sufficient	Self-sufficient	
August	14	Self-sufficient	Self-sufficient	27	Self-sufficient	Self-sufficient	
September	9	Self-sufficient	Fuel input needed	27	Self-sufficient	Self-sufficient	
October	0	Self-sufficient	Fuel input needed	27	Self-sufficient	Self-sufficient	
November	-9	Self-sufficient	Fuel input needed	26	Self-sufficient	Self-sufficient	
December	-15	Fuel input needed	Fuel input needed	24	Self-sufficient	Self-sufficient	

Example: WWTPs in Thailand and Russia

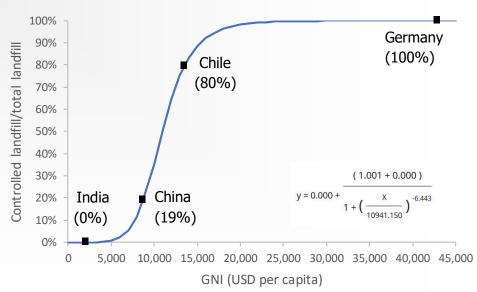
CHP: cogeneration of heat and power

### **Geographical-technological coverage:** Uncontrolled landfill and landfill mix

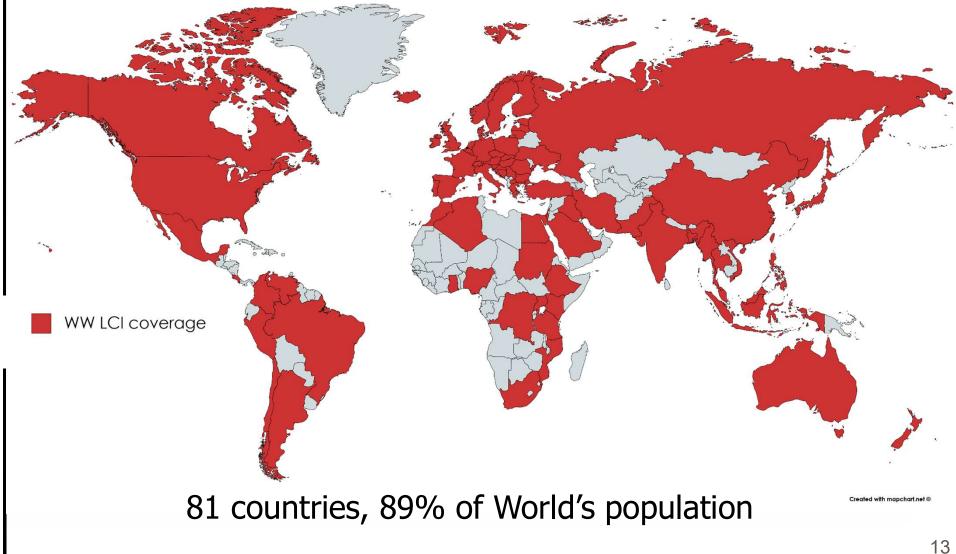
#### • Two landfill options in WW LCI v3:

Model features	Controlled	Uncontrolled
Infrastructure inputs	Yes	No
Methane correction factor	1	0.8
Methane capture	Yes	No
Leachate collection	Yes	No

- Attempting a country-specific landfill mix:
  - We assume controlled landfilling is proportional to gross national income (GNI, \$ per capita)
  - GNI>35,000  $\rightarrow$  100% controlled
  - GNI<2,500  $\rightarrow$  0% controlled



### **Geographical-technological coverage:** WW LCI database country coverage

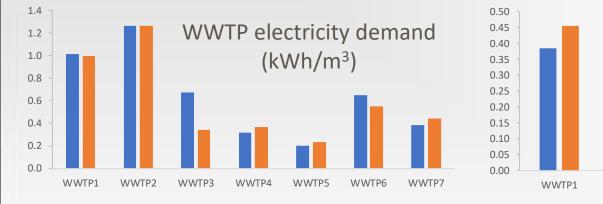


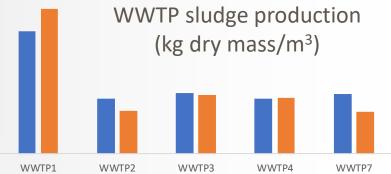
### **Geographical-technological coverage:** Content of WW LCI database

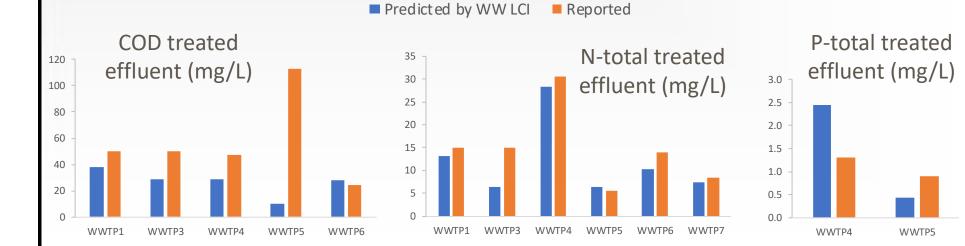
- For each country:
  - % population connected to sewer, treatment (primary, secondary, etc.)
  - Distribution of WWTP capacity by size
  - % WWTP with anaerobic digestion of sludge
  - % WWTP with CHP
  - % wastewater discharged to inland waters or sea
  - % sludge to landfill, composting, incineration, agriculture
  - Mean annual and monthly temperatures
  - GNI and landfill mix estimate
  - Estimate of MCF for open sewers

# Validating parts of the model: Electricity, sludge production, effluent

 Comparing WW LCI prediction to reported data for 7 WWTPs of different size, wastewater composition and treatment level



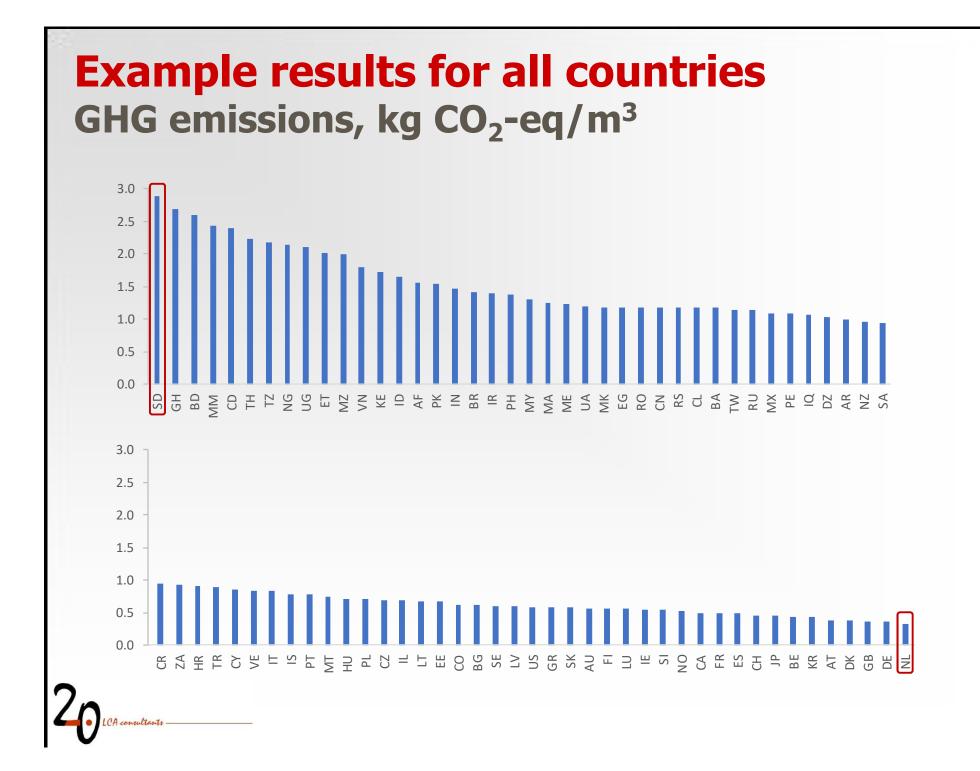




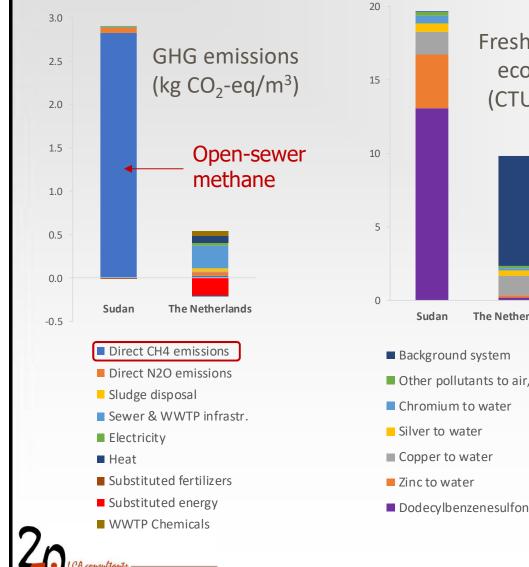
#### **Example results for all countries** Hypothetical wastewater

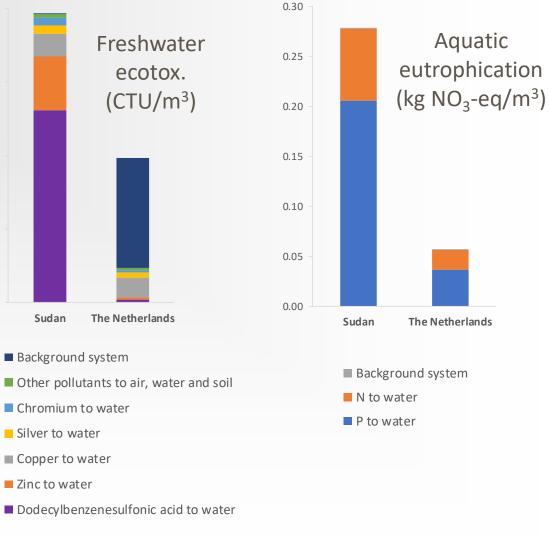
Wastewater component	mg/L
Chemical oxygen demand (COD)	500
Total suspended solids (TSS)	250
Total nitrogen	30
Total phosphorus	6
Dodecylbenzenesulfonic acid	5
Ibuprofen	0.012
Zinc	0.1
Diclofenac	6.5E-04
Copper	0.03
Silver	0.003
Lead	0.025

- Enter composition and substance-specific data in WW LCI
- Get LCI results per country (one by one)
- Export LCIs to SimaPro as CSV file



### **Example results for all countries** Contribution analysis SD and NL





# **Thank you!**

More info and documentation about WW LCI v3: http://lca-net.com/projects/show/wastewater-lciinitiative/

#### **References:**

Muñoz I (2019) *WW LCI version 3: changes and improvements to WW LCI v2*. 2.-0 LCA consultants, Aalborg, Denmark. <u>http://lca-net.com</u>

Kalbar P, Muñoz I, Birkved M. (2018) *WW LCI v2: a second-generation inventory model for chemicals discharged to wastewater*. Sci Total Environ. 2018 May 1;622-623:1649-1657

Muñoz I, Otte N, Van Hoof G, Rigarlsford G. *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