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Towards global LCI data on urban wastewater discharges

WW LCI v3

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Content

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


https://en.wikipedia.org/wiki/Wastewater_treatment

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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 ✓
  - BOD ✗
  - Nitrate ✓
  - Suspended solids ✗
  - N-total ✗
  - Diclofenac ✓

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Direct discharges

Connection to sewer but no treatment

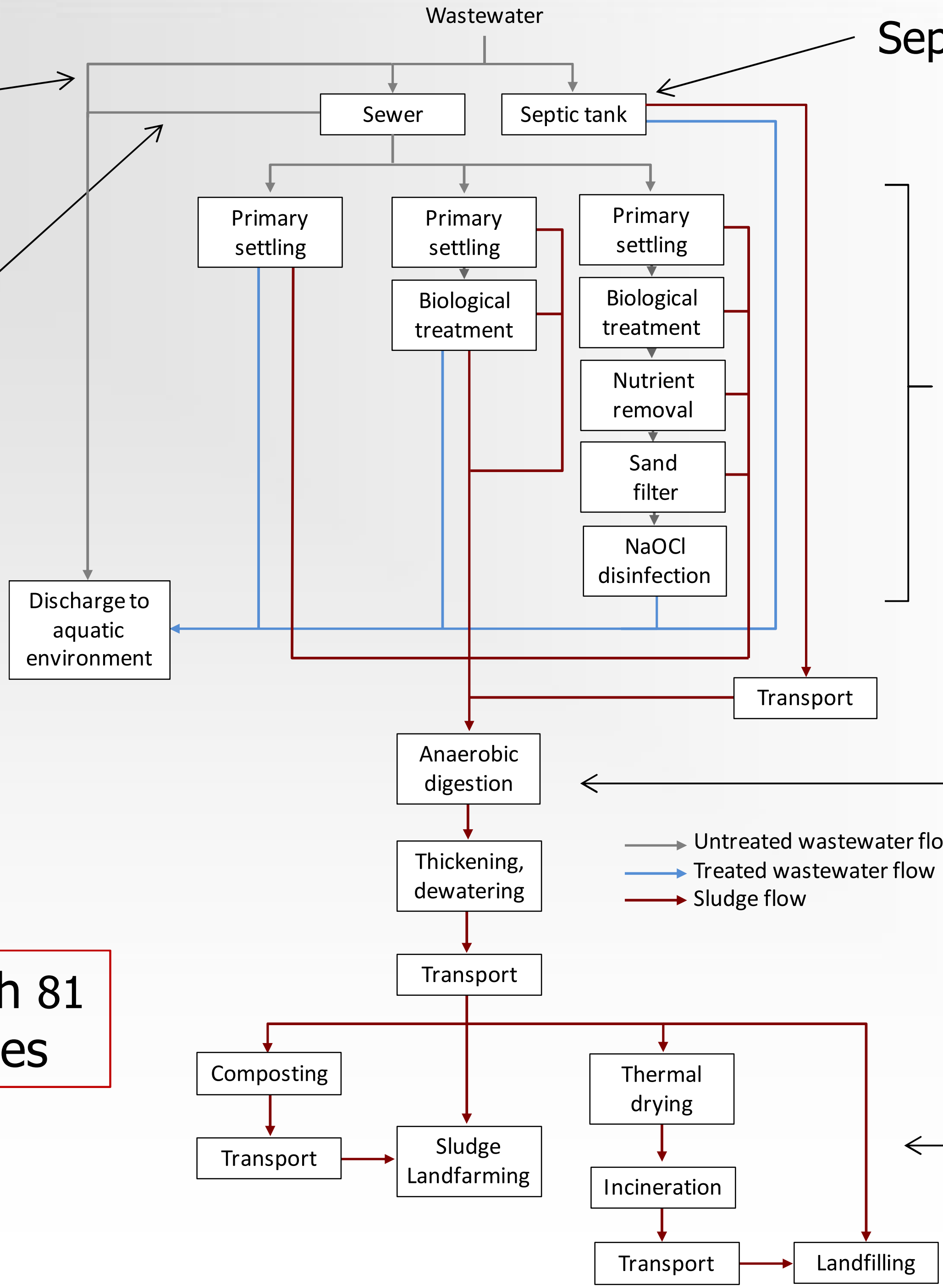
Includes emissions of GHG

Septic tanks

3 WWTP levels: primary, secondary, tertiary

Anaerobic digestion of sludge with option for cogeneration

Sludge disposal



Database with 81 country profiles

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WW LCI: input data

Phys-chem data:
- Organic/inorganic
- Composition (C, H, O, N, S, P, Cl)
- Molecular weight
- Vapour pressure
- Solubility
- Kow
- Half-lives in the environment

Fate in WWTP data:
- Fraction degraded
- Fraction volatilized
- Fraction to sludge
- Anaerobic degradability

Scenario data:
- Country
- % population connected to WWTPs
- % discharge to sea/freshwater
- WWTP size distribution
- Climate data
- Sludge disposal scenario
- …

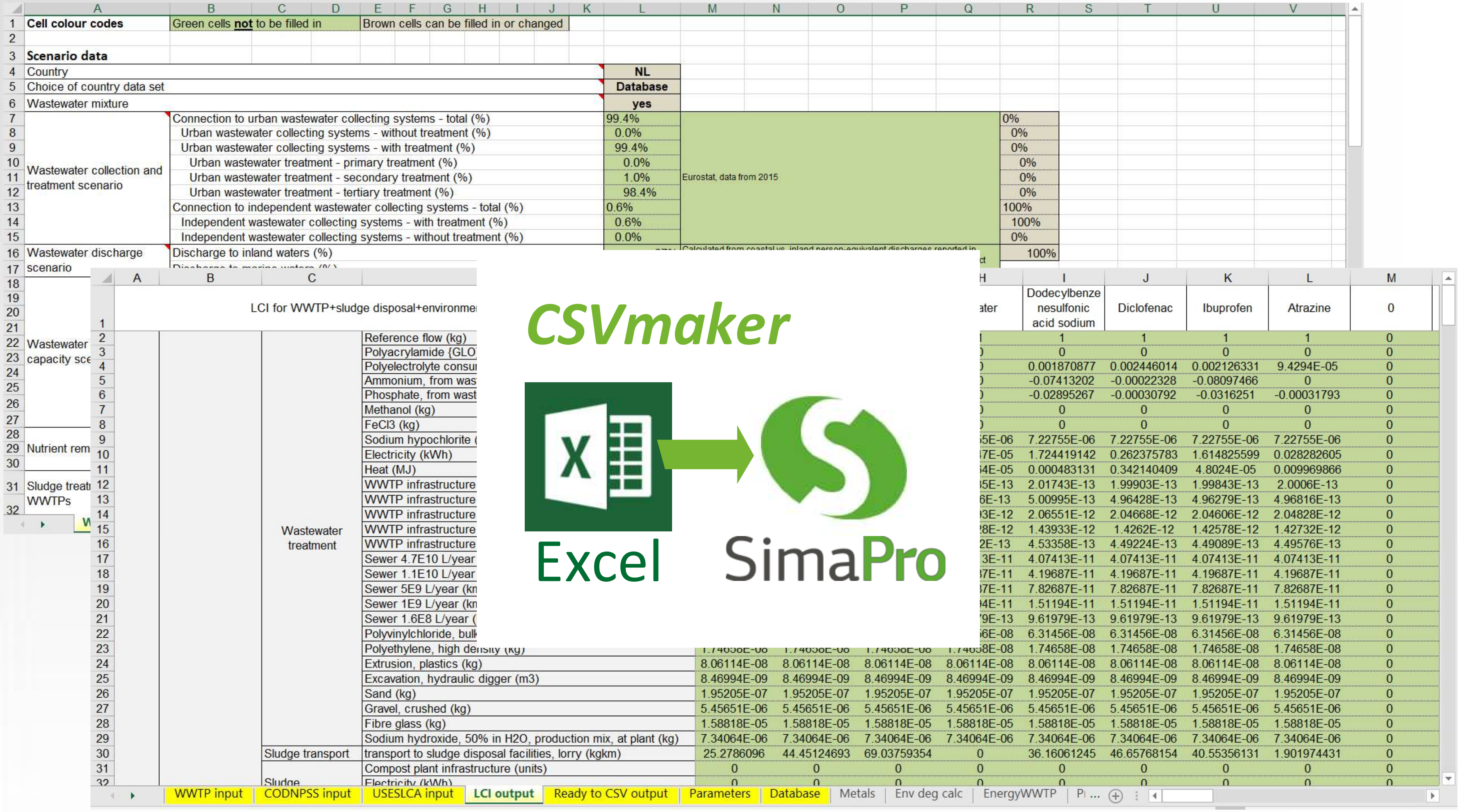
Substance-specific data: entered by user

WW LCI

Life cycle inventory for chemical 'x' discharged in urban wastewater:
- Sewer infrastructure
- WWTP infrastructure
- Emissions to air and effluent from WWTP
- Energy use in WWTP
- Sludge transport
- Sludge disposal infrastructure
- Sludge disposal emissions to air, water and soil
- Emissions to air and water from direct discharges to environment

Scenario data: WW LCI database (or entered by user)

WW LCI in Excel



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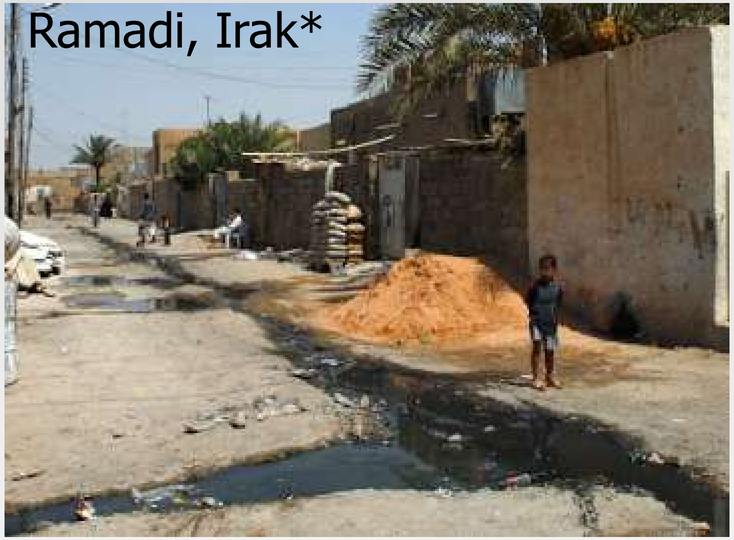
Coverage of wastewater components

Wastewater component	WW LCI v2	WW LCI v3	Examples
Organics	✓	✓	Surfactants, pesticides, solvents…
Inorganics (non-metals)	✓	✓	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?

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Doorn MRJ et al. (2006) Wastewater treatment and discharge. In: Eggleston HS et al. (eds) IPCC guidelines for national greenhouse gas inventories, vol 5. IGES, Chapter 6

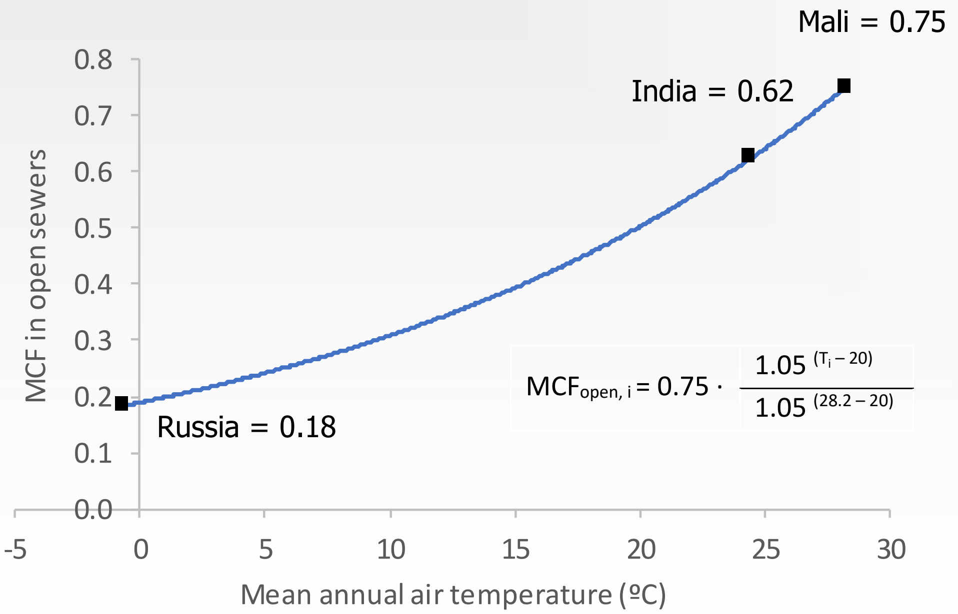
Geographical-technological coverage:

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*:

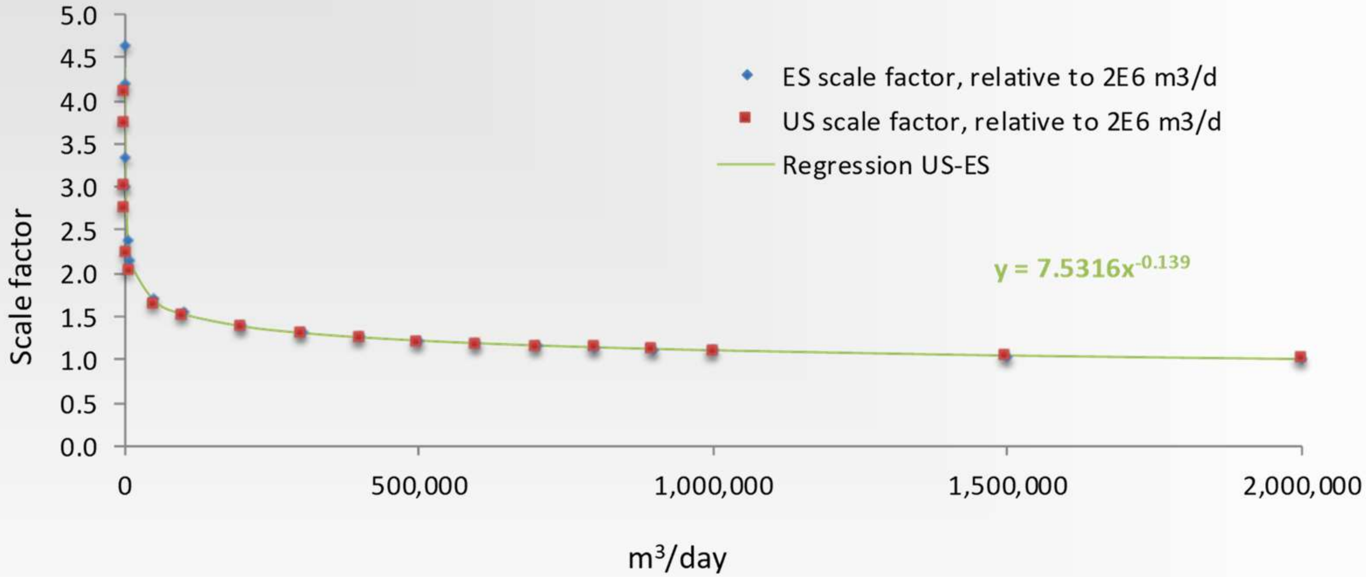


$$MCF_{open,\,i} = 0.75 \cdot \frac{1.05^{(T_i - 20)}}{1.05^{(28.2 - 20)}}$$

*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^3/d = 0.27 kWh/m^3
WWTP 2E+04 m^3/d = 0.27 × **1.9** = 0.51 kWh/m^3

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

Example: WWTPs in Thailand and Russia

Month	WWTP in Russia			WWTP in Thailand		
	Mean T (ºC)	Without CHP	With CHP	Mean T (ºC)	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

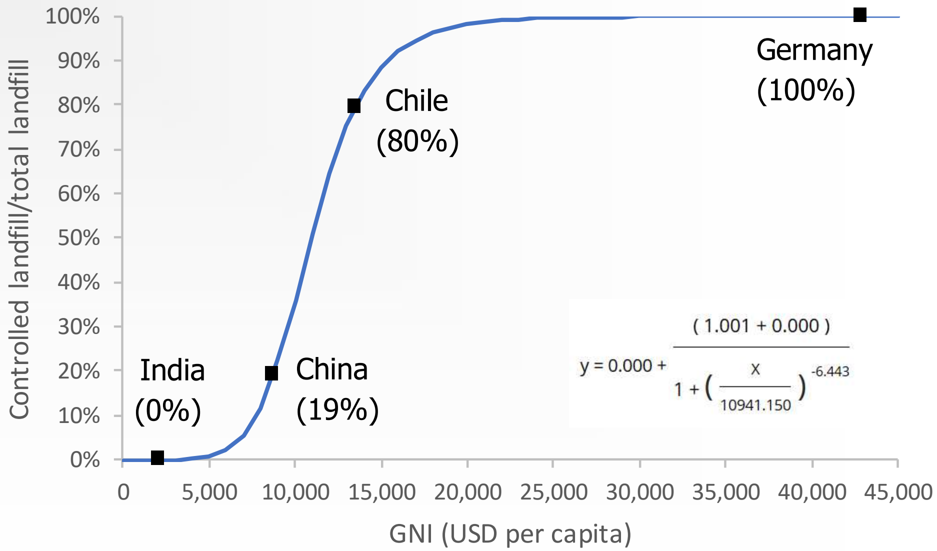
CHP: cogeneration of heat and power

Geographical-technological coverage:
Uncontrolled landfill and landfill mix

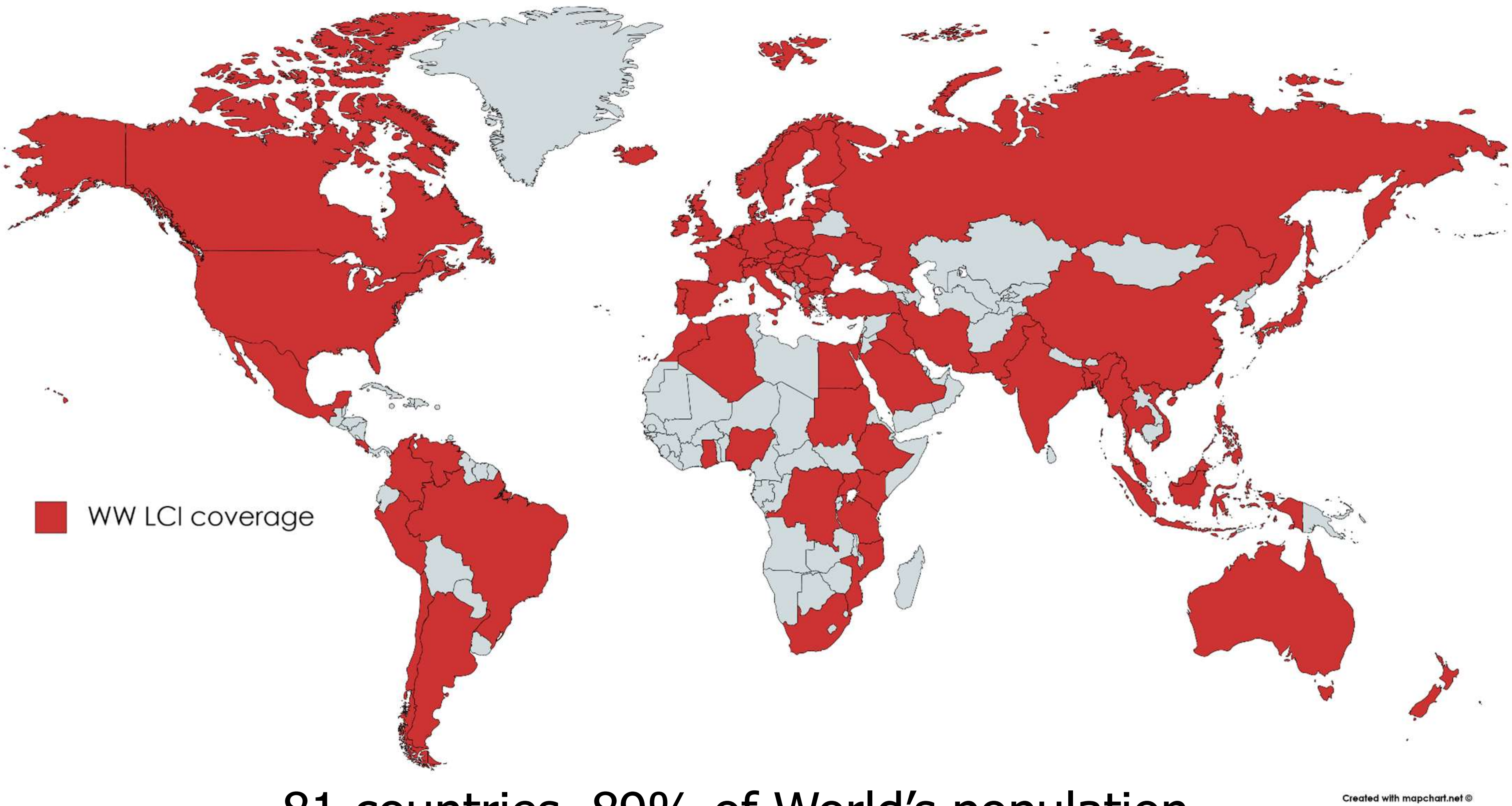
- Two landfill options in WW LCI v3:

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 → 100% controlled
  - GNI<2,500 → 0% controlled



Geographical-technological coverage:
WW LCI database country coverage



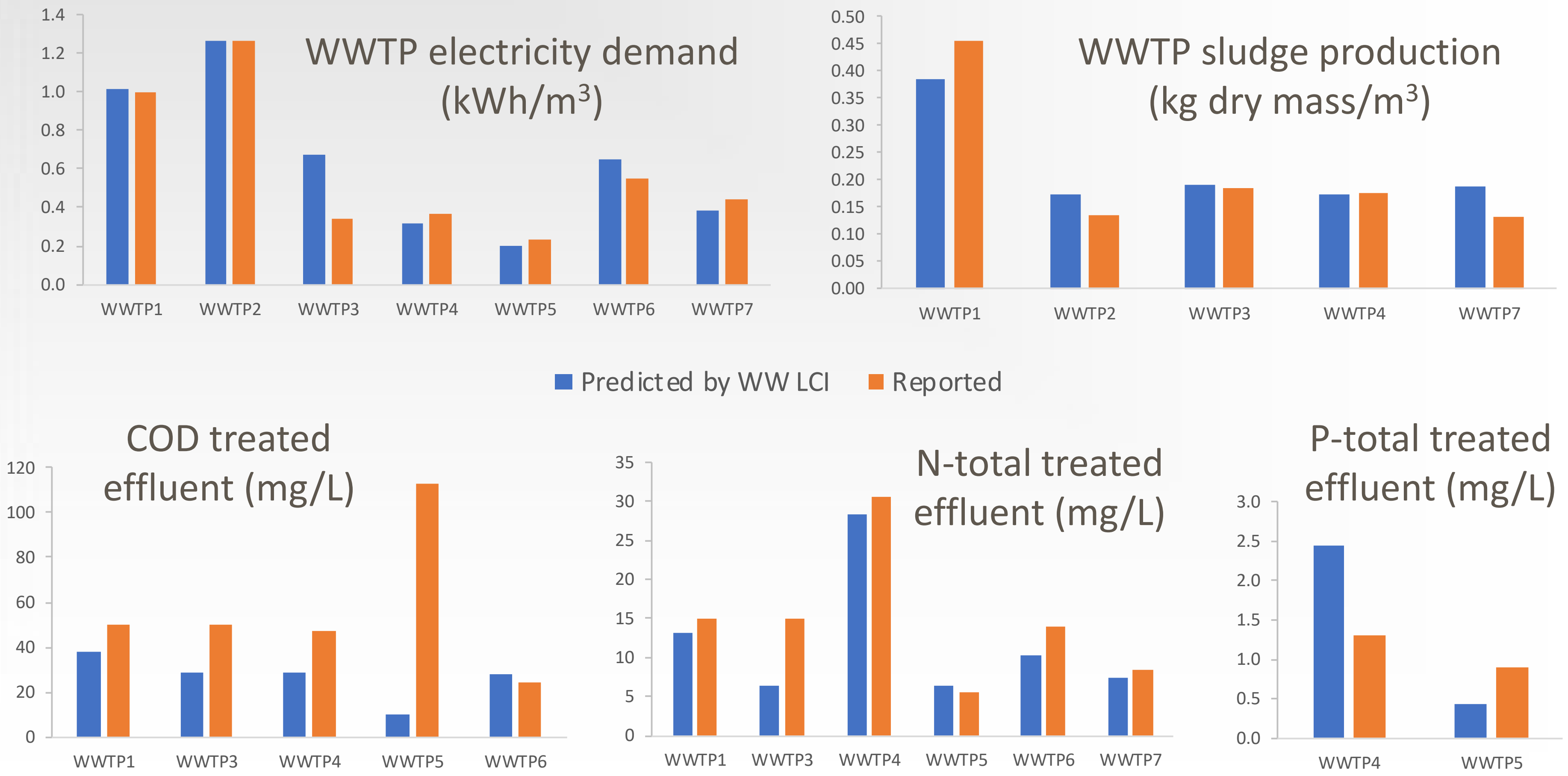
81 countries, 89% of World's population

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



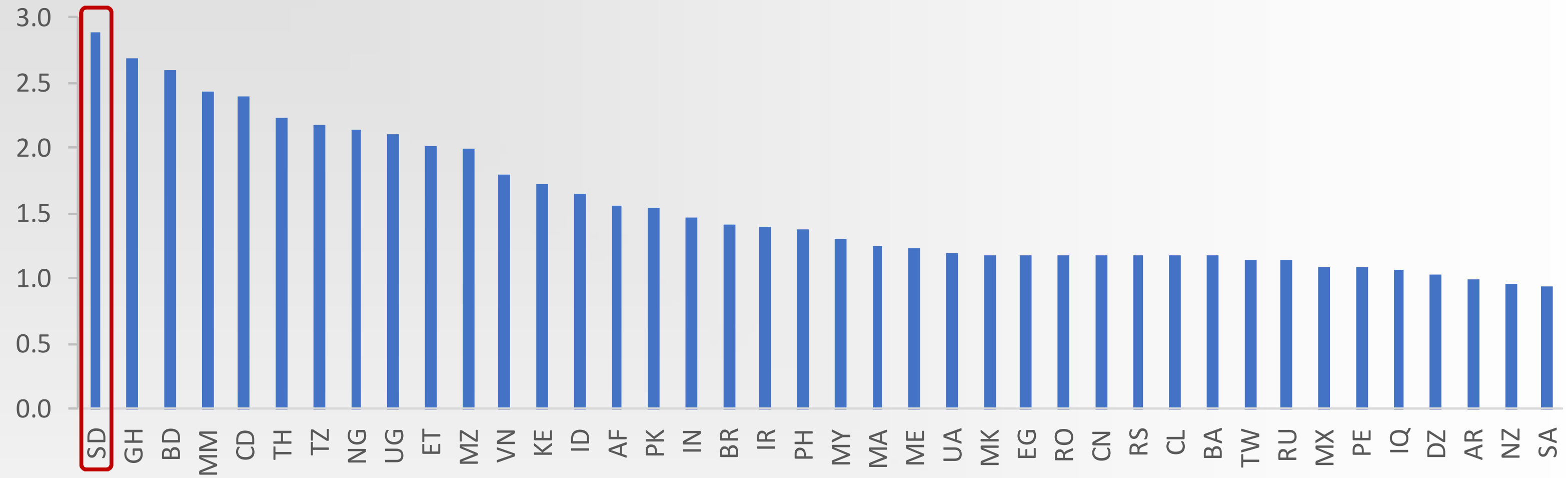
Example results for all countries
Hypothetical wastewater

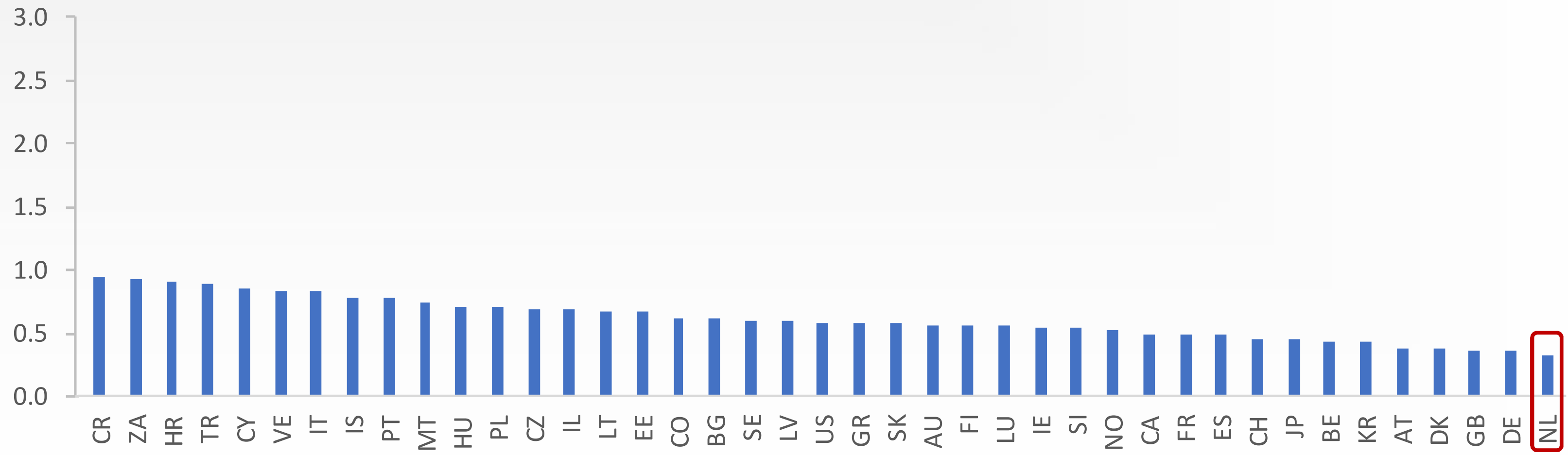
Wastewater component	mg/L
Chemical oxygen demand (COD)	500
Total suspended solids (TSS)	250
Total nitrogen	30
Total phosphorus	6
Dodecylbenzenesulfonic acid	5
Ibuprofen	0.012
Zinc	0.1
Diclofenac	6.5E-04
Copper	0.03
Silver	0.003
Lead	0.025

- 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

GHG emissions, kg CO_2-eq/m^3





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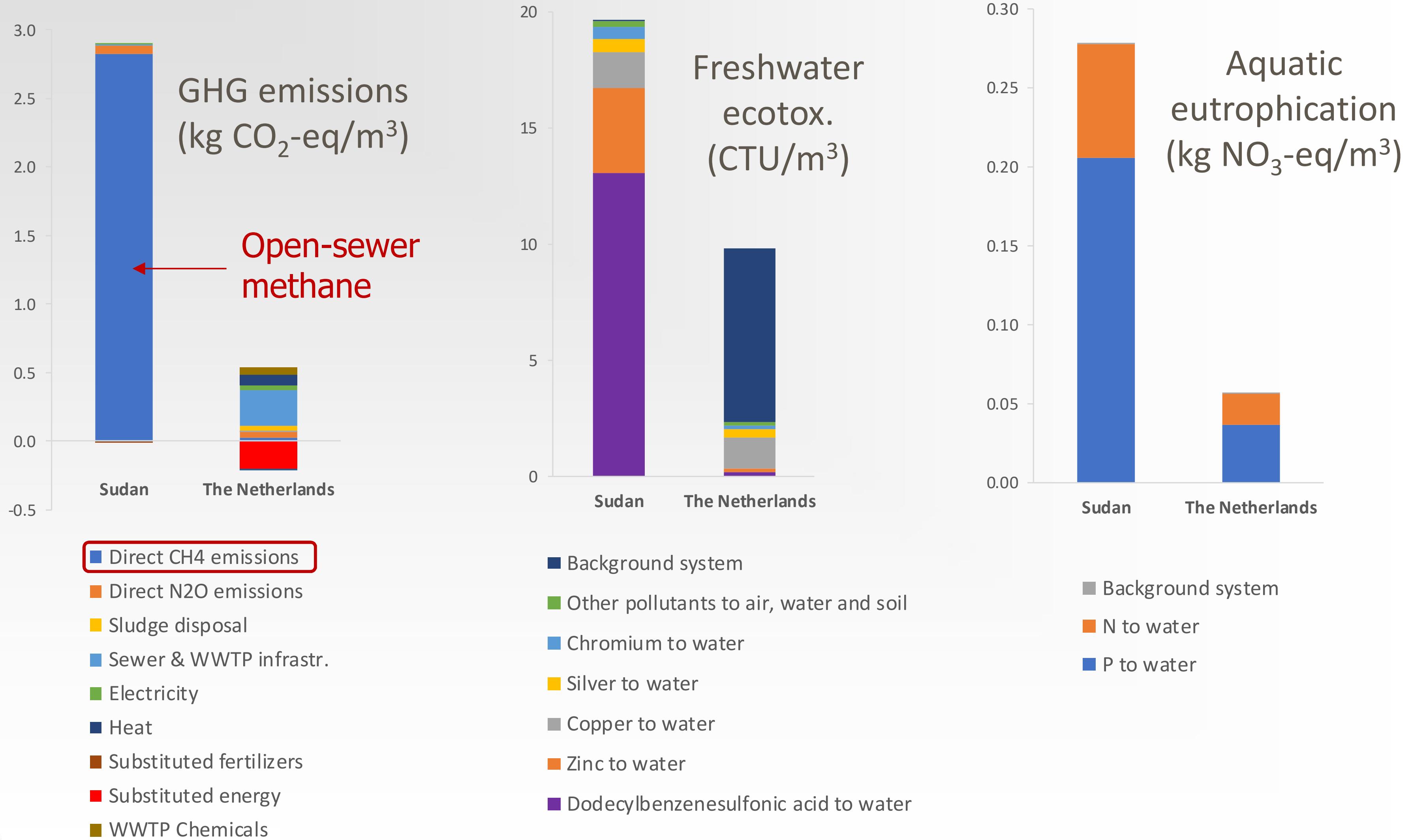
Example results for all countries

Contribution analysis SD and NL



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Thank you!

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

References:

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

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