The wastewater life cycle inventory tool by 2.-0 LCA consultants

The article by Ivan Muñoz was first presented by the IWA water Wiki :
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Introduction

Very often the fate of chemicals after use is to be sent to municipal wastewater treatment plants (WWTPs), where they are subject to degradation. In many life cycle assessment (LCA) studies we need to account for the environmental impacts caused by the disposal of chemical substances down the drain, however existing LCA models for wastewater treatment typically reflect the average performance of WWTPs, rather than the specific fate of particular chemicals. Obviously, different chemicals behave differently in WWTPs, depending on their physical-chemical properties and biodegradability. An accurate modelling of the life cycle impacts of chemicals requires taking into account this specific behaviour, namely whether a chemical will be either degraded, volatilized, partitioned to sludge, discharged unchanged, or a combination of these.

At 2.-0 LCA consultants we started a project with three major industrial companies in order to develop a tool to generate life cycle inventories (LCIs) associated with disposing of chemicals down the drain or directly into the aquatic environment. As a result of this partnership, the 'WW LCI tool' was released in October 2015. In this article we provide a short overview of this tool.

Scope and methodological summary

Figure 1 shows an overview of the tool's concept. A chemical substance's properties are used to predict its fate in a WWTP, as well as in the environment. Based on the predicted fate factors to effluent, sludge, degradation, etc., the tool calculates an LCI including the operation of the WWTP (use of energy, chemicals, etc.) and sludge disposal processes (landfilling, incineration, agricultural reuse), as well as emissions from degradation in the environment of any fraction of the chemical directly released to the environment.

The tool covers the treatment of organic as well as inorganic chemicals. The functional unit is 1 kg of chemical discharged down the drain. In case a chemical mixture is assessed, the functional unit is 1 kg of mixture, with the composition defined by the user. Wastewater treatment and sludge disposal provide more functions than just waste treatment, for example providing an organic fertilizer (sludge) that can displace mineral fertilizers in the market. The tool takes into account these additional functions by means of substitution, whereby any energy or fertilizer by-product displaces an alternative product in the market, potentially resulting in an environmental benefit.

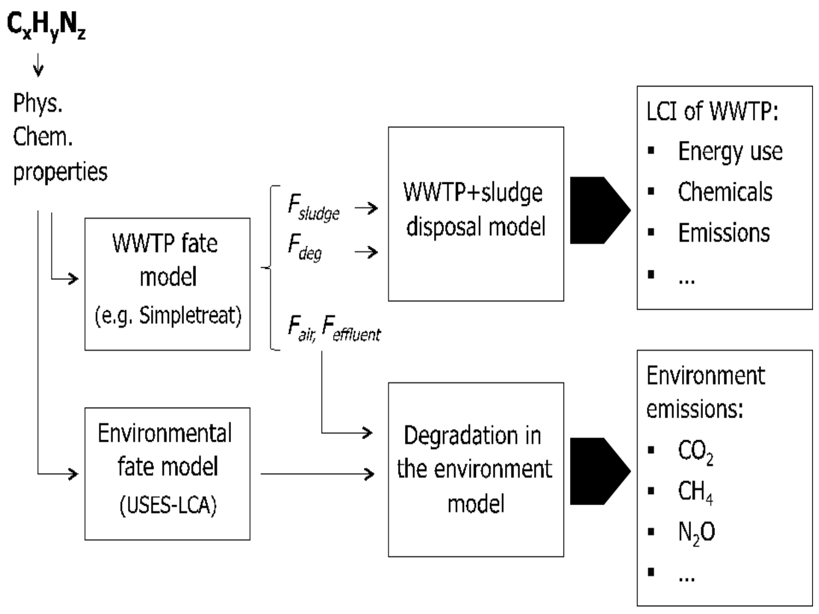


Figure 1. Conceptual diagram of the WW LCI tool. Note: Simpletreat is not incorporated in the tool.

The tool is based on three main modules or parts, namely:

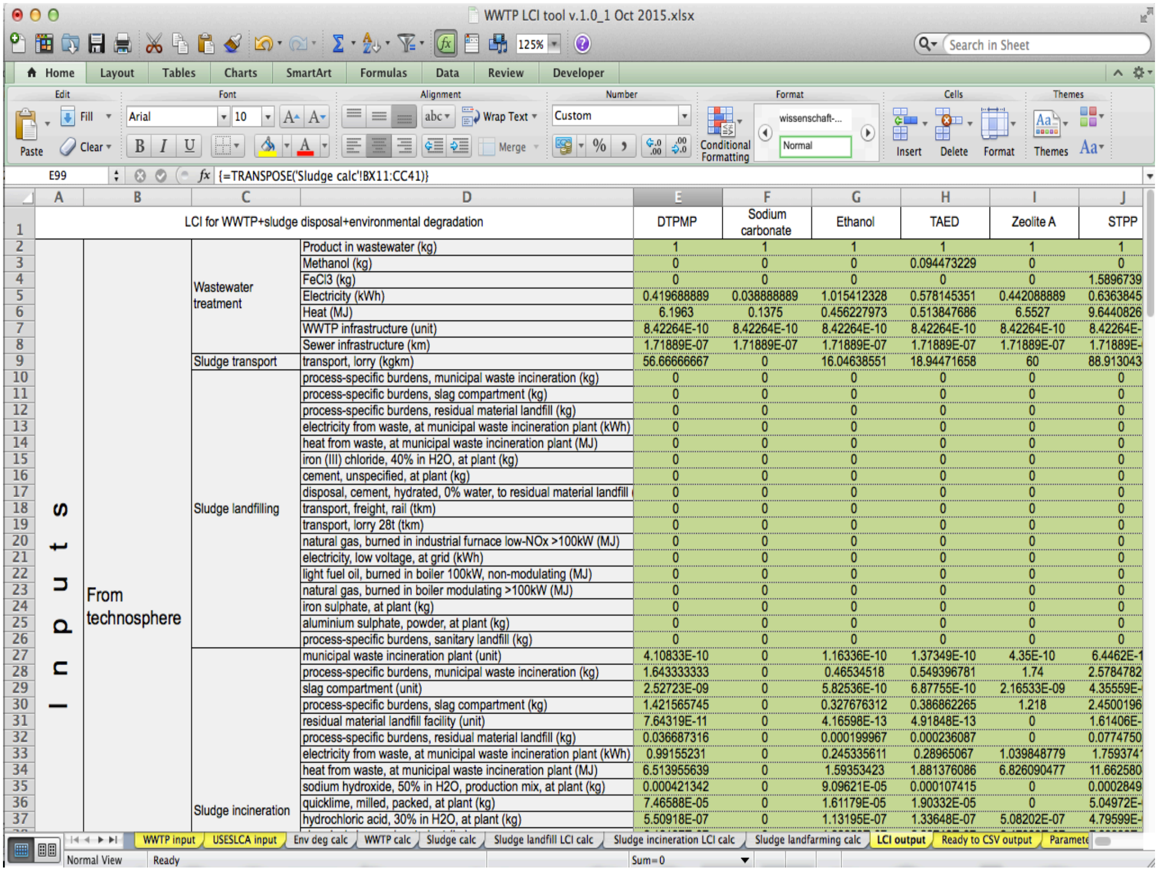
- The WWTP: considers a modern activated sludge plant with nutrient removal and anaerobic digestion of sludge. The calculations are based on a complete mass balance of the chemical and its components through different treatment stages: biological degradation, nutrient removal, anaerobic digestion of sludge and production of biogas from sludge. The LCI quantifies inputs from technosphere (capital equipment, electricity, fuels, chemicals, etc.) and emissions to air and water.
- Sludge disposal: includes three options, namely landfilling, incineration and application in agriculture. The two first options are based on the ecoinvent database (www.ecoinvent.org), whereas the agricultural option is based mainly on emission factors from the IPCC national guidelines for greenhouse-gas inventories (IPCC 2006).
- Degradation in the environment: in case a chemical is directly discharged in the aquatic environment or it is simply not removed by the WWTP, the model accounts for its eventual fate in the environment, where emissions of CO_2, methane, nitrous oxide and nutrients (N and P) are estimated based on the model developed by Muñoz et al. (2013).

Input data

The tool requires a number of input variables to be defined, falling into two categories: chemical-specific variables and scenario variables. The chemical-specific variables include physical-chemical properties, elementary composition, fate factors in the WWTP (from models like Simpletreat (Franco et al. 2013) or from monitoring studies) and fate factors in the environment (half-lives in water, soil, etc.). The scenario variables include the percentage of population connected to WWTPs, level of nutrient removal, and sludge disposal scenario. In practice, the model has additional variables, for which default values are provided. All values can be modified by the user if required.

The WW LCI tool

This tool is programmed in an Excel spreadsheet (Figure 2), which contains all the elements in Figure 1, with the exception of Simpletreat. The current implementation in Excel accommodates simultaneous calculations for 30 chemicals, which can be assessed individually or in a mixture. The LCIs can easily be imported into LCA software such as SimaPro. Impact assessment calculations are then easy to perform for different impact categories, such as carbon footprints (Figure 3), eutrophication and freshwater ecotoxicity, among others.



	A	B	C	D	E	F	G	H	I	J
1				LCI for WWTP+sludge disposal+environmental degradation	DTPMP	Sodium carbonate	Ethanol	TAED	Zeolite A	STPP
2	Inputs	From technosphere	Wastewater treatment	Product in wastewater (kg)	1	1	1	1	1	1
3				Methanol (kg)	0	0	0	0.094473229	0	0
4				FeCl3 (kg)	0	0	0	0	0	1.5896739
5				Electricity (kWh)	0.419688889	0.038888889	1.015412328	0.578145351	0.442088889	0.6363845
6				Heat (MJ)	6.1963	0.1375	0.456227973	0.513847686	6.5527	9.6440826
7				WWTP infrastructure (unit)	8.42264E-10	8.42264E-10	8.42264E-10	8.42264E-10	8.42264E-10	8.42264E-
8				Sewer infrastructure (km)	1.71889E-07	1.71889E-07	1.71889E-07	1.71889E-07	1.71889E-07	1.71889E-
9			Sludge transport	transport, lorry (kgkm)	56.66666667	0	16.04638551	18.94471658	60	88.913043
10			Sludge landfilling	process-specific burdens, municipal waste incineration (kg)	0	0	0	0	0	0
11				process-specific burdens, slag compartment (kg)	0	0	0	0	0	0
12				process-specific burdens, residual material landfill (kg)	0	0	0	0	0	0
13				electricity from waste, at municipal waste incineration plant (kWh)	0	0	0	0	0	0
14				heat from waste, at municipal waste incineration plant (MJ)	0	0	0	0	0	0
15				iron (III) chloride, 40% in H2O, at plant (kg)	0	0	0	0	0	0
16				cement, unspecified, at plant (kg)	0	0	0	0	0	0
17				disposal, cement, hydrated, 0% water, to residual material landfill (	0	0	0	0	0	0
18				transport, freight, rail (tkm)	0	0	0	0	0	0
19				transport, lorry 28t (tkm)	0	0	0	0	0	0
20				natural gas, burned in industrial furnace low-NOx >100kW (MJ)	0	0	0	0	0	0
21				electricity, low voltage, at grid (kWh)	0	0	0	0	0	0
22				light fuel oil, burned in boiler 100kW, non-modulating (MJ)	0	0	0	0	0	0
23				natural gas, burned in boiler modulating >100kW (MJ)	0	0	0	0	0	0
24				iron sulphate, at plant (kg)	0	0	0	0	0	0
25				aluminium sulphate, powder, at plant (kg)	0	0	0	0	0	0
26				process-specific burdens, sanitary landfill (kg)	0	0	0	0	0	0
27			Sludge incineration	municipal waste incineration plant (unit)	4.10833E-10	0	1.16336E-10	1.37349E-10	4.35E-10	6.4462E-1
28				process-specific burdens, municipal waste incineration (kg)	1.643333333	0	0.46534518	0.549396781	1.74	2.5784782
29				slag compartment (unit)	2.52723E-09	0	5.82536E-10	6.87755E-10	2.16533E-09	4.35559E-
30				process-specific burdens, slag compartment (kg)	1.421565745	0	0.327676312	0.386862265	1.218	2.4500196
31				residual material landfill facility (unit)	7.64319E-11	0	4.16598E-13	4.91848E-13	0	1.61406E-
32				process-specific burdens, residual material landfill (kg)	0.036687316	0	0.000199967	0.000236087	0	0.0774750
33				electricity from waste, at municipal waste incineration plant (kWh)	0.99155231	0	0.245335611	0.28965067	1.039848779	1.759374
34				heat from waste, at municipal waste incineration plant (MJ)	6.513955639	0	1.59353423	1.881376086	6.826090477	11.662580
35				sodium hydroxide, 50% in H2O, production mix, at plant (kg)	0.000421342	0	9.09621E-05	0.000107415	0	0.0002849
36				quicklime, milled, packed, at plant (kg)	7.46588E-05	0	1.61179E-05	1.90332E-05	0	5.04972E-
37				hydrochloric acid, 30% in H2O, at plant (kg)	5.50918E-07	0	1.13195E-07	1.33648E-07	5.08202E-07	4.79599E-

Figure 2. Screenshot of the WW LCI tool showing part of the LCI output tab.

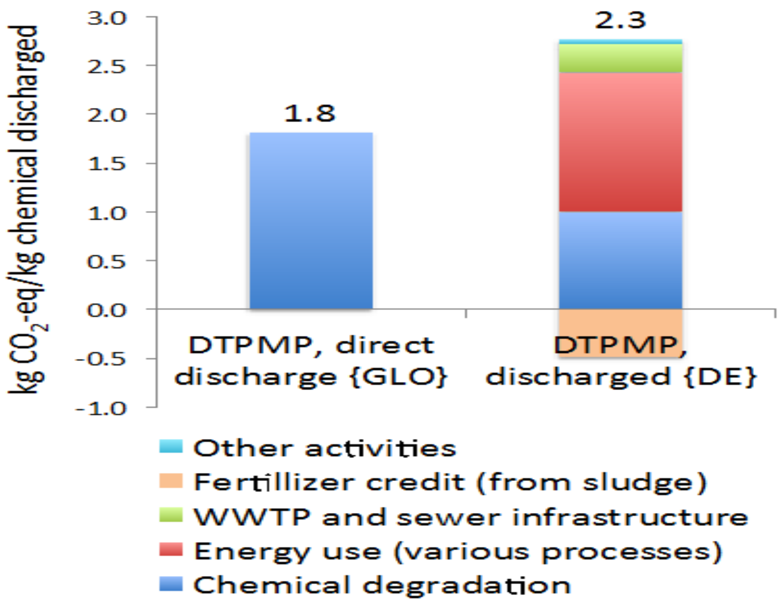


Figure 3. Greenhouse-gas emissions per kg Diethylenetriamine penta(methylene phosphonic acid), DTPMP) discharged down the drain in two scenarios: direct discharge (0% connection to WWTP) and Germany (100% connection to WWTP). Impact assessment calculations performed in the software SimaPro 8.0.4 with global warming potential (GWP) for a time horizon of 100 years.

A beta version of the tool was released in June 2015 and it was subject to a three-month testing by the industrial partners taking part in the project. A first official version was released in October 2015, together with a peer-reviewed article currently under review (Muñoz et al. 2016).

This tool is the first one to address a chemical-specific and comprehensive LCI of chemicals discharged down the drain, including not only treatment in the WWTP but also sludge disposal and degradation of chemicals in the environment when there is no connection to a WWTP. This is particularly important since emissions from direct discharges can be important (Muñoz et al. 2013), for example in developing countries, due to lack of sanitation infrastructure. This tool constitutes an advance over previous WWTP models using generic descriptors like BOD, COD, etc. and despite its limitations and room for improvement, it constitutes an advance in how the end-of-life stage of chemicals is addressed in LCA.

More information

Would you like to know more about the WW LCI tool? Visit the 2.-0 LCA consultants website (http://lca-net.com/projects/show/wastewater-lci-initiative/) or contact us at info@lca-net.com.

References

Franco A, Struijs J, Gouin T, Price O R (2013), Evolution of the Sewage Treatment Plant Model SimpleTreat: Applicability Domain and Data Requirements. Integrated Environmental Assessment and Management, Volume 9999, Number 9999, 1–9.

IPCC (2006) 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4 - Agriculture, Forestry and Other Land Use. Prepared by the National Greenhouse Gas Inventories Programme. IGES, Japan.

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