CIRAIG™

International Reference Centre for the
Life Cycle of Products, Processes and Services

TENDER PROPOSAL

CALL FOR TENDERS FOR DEVELOPING AND PROVIDING ECOINVENT WITH A "MODELLING TOOL FOR CALCULATING AND GENERATING LCI FOR ACTIVITIES ON TREATMENT OF WASTEWATER OF VARIED COMPOSITION"

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Submitted to

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ecoinvent Centre

By a consortium composed of research teams coming from the following universities:

Polytechnique Montréal – Laval University – Universitat de Gerona and University of Cape Town

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1 Context

The ecoinvent association is the world's leading supplier of consistent and transparent Life Cycle Inventory (LCI) data of renowned quality. ecoinvent is a proud partner of the Sustainable Recycling Industries (SRI) programme, a programme funded by the Swiss State Secretariat for Economic Affairs (SECO) and jointly implemented by the Swiss Institute for Materials Science & Technology (Empa), the World Resources Forum (WRF) and ecoinvent, and is in charge of component A - Life Cycle Inventories: SRI gathers and provides local LCI data for the assessment of agricultural and industrial activities through the enhancement of local and regional LCA expertise with the aim to provide freely available regionalized LCI data for India, South Africa and Egypt.

With this call for tender, ecoinvent aims to subcontract the task of developing a Modelling Tool for calculating and generating LCI datasets for wastewater treatment activities, including some water resource recovery ones, a new paradigm in the field.

2 Project description

2.1 Modelling Tool

The tender shall develop and supply ecoinvent with a Modelling Tool for calculating and generating LCI for wastewater treatment activities. The Modelling Tool shall follow the functionality of the existing Modelling Tool in ecoinvent version 2 for wastewater-specific inventories, but updated and adapted to ecoinvent version 3, and extended with more applications and functionalities to cover a wider range of wastewater compositions and wastewater treatment technologies in geographies listed in Table 1. The developed Modelling Tool shall be flexible to accommodate for future additions and for updating of the underlying model.

The Modelling Tool consists essentially of two aspects:

- The model, which is a conceptual framework for calculating LCI data of wastewater treatment activities based on the composition of the wastewater, technology of wastewater treatment and the capacity of the WWT plant and
- The calculation tool, which is the software platform (for example an excel sheet) to enable and facilitate the exchange of information between the underlying model and the user, delivering results in the form of ecoSpol2 Unit Processes.

2.1.1 LCI Model

The tender shall generate and supply ecoinvent with an LCI modelling framework to be applicable to wastewater treatment activities in ecoinvent database version 3. The model shall allow for estimating the energy use, infrastructure and emissions associated with, and generating unit process datasets for wastewater treatment activities, according to the composition of wastewater input, common wastewater treatment practice(s) and technologies with respect to wastewater type and legislations, geographical considerations, and climatic conditions.

Wastewater composition: The model shall consider at minimum all relevant wastewater compositions already present in the ecoinvent database, including average wastewater and industrial processes. Additionally, the model shall be able to fit any wastewater composition into the calculation routine, provided the geographical scope and treatment technology are known.

Treatment practices: The model shall include relevant disposal practices and/or treatment technologies (including untreated wastewater dumping) for the following regions with focus on specific countries: Latin America (Colombia, Peru and Brazil), Southern Asia (India), and Sub-Saharan Africa (South Africa), as well for Switzerland, representing Europe, for comparative purposes. The underlying model shall be valid globally and for the wastewater treatment activities currently available in the ecoinvent database to ensure comparability of results.

Treatment technologies within the treatment plant: each wastewater treatment plant contains different types of technologies of wastewater treatment. These can be organized in different order. The tenderer is expected to consider a modular approach which would allow users of the tool certain flexibility when it comes to a selection of technologies included in the wastewater treatment plant. The user of the model should be able to combine the different technologies of wastewater treatment (within what can be still considered a reasonable combination) to build the requested wastewater treatment plant.

The model shall be consistent with and be prepared according to the ecoinvent Data Quality Guidelines v3. It shall be provided in a form so that changes to basic underlying assumptions can be made easily, to facilitate future maintenance and updating of the model.

Table 1 - Scope of requested services

Geography	*Global, with focus on Southern Asia (India), Sub-Saharan Africa (South Africa) and Latin America (Brazil, Colombia, Peru)*
Products/services	*An LCI Modelling Tool for wastewater treatment activities*
Sectors	*Wastewater treatment activities*

2.1.2 Calculation tool

The calculation tool shall be the users' interface to facilitate the transformation of input data (such as wastewater compositions) into LCI datasets, using the model explained above. The tool shall have a user interface to receive inputs - such as composition of the wastewater, type(s) of wastewater treatment technologies, geography - and generate LCI datasets in ecoSpold2 format.

The tool can be implemented in any common software platform, such as MS Excel, or be based on a standalone solution. Regardless of the type of platform, it should allow the users to trace the calculations performed by the model.

The tool shall imperatively be user-friendly to facilitate the generation of LCI datasets for inexperienced users. The Modelling Tool shall be provided with an easy-to-follow user-guide manual.

2.2 List of deliverables

A globally applicable LCI Modelling Tool, for calculating and generating LCI datasets for wastewater treatment activities, according to composition of the wastewater, treatment technology, as well as local conditions and regulations. The tool shall be based on a model that is updateable and well documented. The Modelling Tool shall have a user interface for entering the user inputs (such as wastewater composition, treatment technology, and geography), and it shall be supplemented with a user manual and information about the composition of average wastewater as well as for common industrial processes for the geographies listed in Table 1, Switzerland and Europe.

3 Tender specifics

Follows the detailed explanation on the LCI Modelling Tool to be developed:

3.1 Types and formats of inputs and outputs

I**nputs,** specified by the user directly into the Excel-based user interface:

- Geography:
    - Relevant climatic conditions (temperature, rainfall);
    - Treatment goals (based on relevant local legislation);
- Flowrate to the wastewater treatment plant (WWTP);
- Population equivalent in terms of BOD_5 loading
- Wastewater elementary composition using as basis the one implemented in the existing Modelling Tool in ecoinvent v2 (see Appendix 1);
    - Unit per capita domestic pollution loading (according to geography);
    - Unit pollution loading from industrial sources (including drinking water characteristics);
    - Water dilution from rainfall, snowmelt (according to geography);
- Treatment technologies implemented at WWTP and their characteristics (based on technologies accepted in the region and the local way of design/operation);

Outputs:

- Graphs presented in an Excel-based user interface (see http://ecam.hol.es/ for examples);
- Export: The output of the Modelling Tool is an ecoSpold2 Unit Process file presenting all the required fields to be integrated into the ecoinvent v3 database.

For each technology combination, the model will provide:

- Consumption of materials for the WWTP construction;
- Performance of pollutants removal (e.g. COD, BOD, TSS, TKN, TP);
- Sludge production and composition;
- Estimate of chemicals consumption;
- Energy consumption;
- Direct greenhouse gases emissions (N_2O and CH_4, emitted in the different stages of the process), and including the emissions from the river, from treated and untreated wastewater and from deposited biosolids;

- Other direct emissions (in relation to composition) to air and water (WWTP effluent) and from deposited biosolids;

3.2 Methodologies employed in the Model to calculate LCI

An influent tool (Excel-based) will be provided to generate a Wastewater elementary composition expressed in concentration units (c.f. Appendix A). The user will be able to enter each parameter value or to generate them from the per capita mass constituents discharge (provided as default by the Modelling Tool), which varies by region and country, to which could be added some specific tap water and industrial contributions.

A wastewater treatment plant (WWTP) modelling tool will be provided to generate the desired outputs. Factors considered will be:

- Plant flowrate (smaller or larger than 4000 m^3/d),
- Region (for treatment technology intensity; discharge regulations)
- Treatment objectives
  - by region (e.g. Europe, Africa, Asia, North-America)
  - by parameter (e.g. COD, BOD_5, TSS, TKN, NH_4, TP, pathogens)
- Liquid treatment line
  - to reach specific treatment objectives
  - defined by functions: pumping, preliminary, primary, secondary, tertiary, advanced (see Appendix 2)
- Solids treatment line
  - defined by functions: thickening, digestion, conditioning, dewatering, drying, incineration, composting (see Appendix 2)

Equations for design would be obtained from references including CapdetWorks, ATV, Metcalf &Eddy-Aecom (2014), GLUMRB (2004) and the scientific literature.

All flows (inputs or outputs) quantified by the Model will be accompanied with uncertainty defined using the probability distribution functions available in the ecoEditor software.

Examples would be provided for the Influent and a number of typical WWTP configurations for some regions such as Switzerland and South-Africa.

3.3 Software platform used to develop the Tool

The model will be built using the Python platform to allow for the use of more advanced nonlinear WWTP models and the user interface will be built using the Excel platform.

The equations used and intermediary calculations will be transparently displayed to the user via the Excel interface.

To illustrate the expected user experience, please find below a few screen shots to illustrate how transparency and traceability of the calculations was implemented in the ECAM tool developed through the WaCClim project, to which Luis Corominas participated.

Traceability of equations:

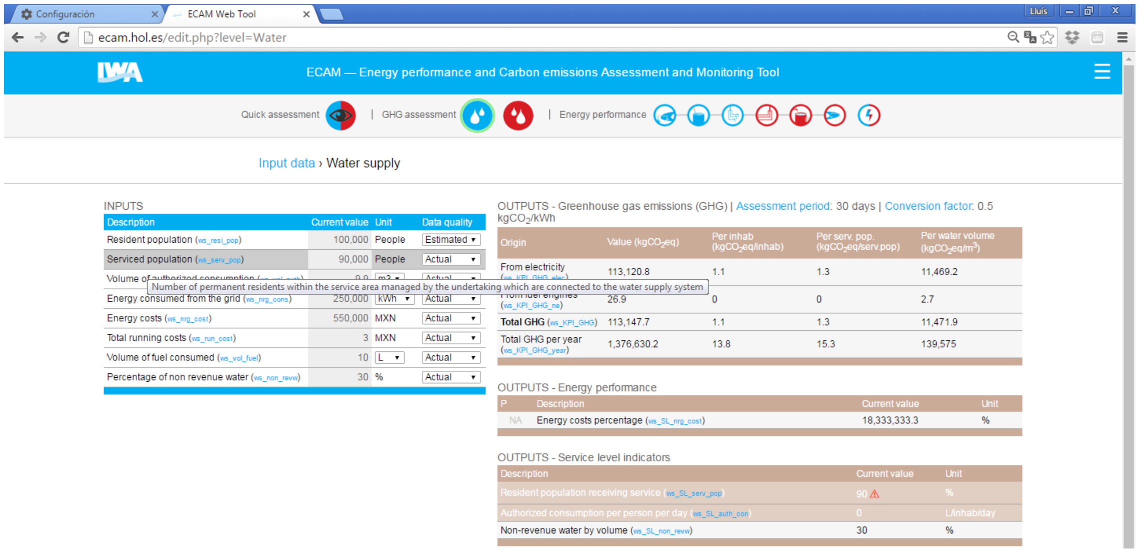
Stage	Go back to Wastewater: Treatment
Description	[translation not found, please report this error]
Type	Output Formula: wwt_nrg_cons/wwt_vol_trea
Inputs involved	wwt_vol_trea: 0 m3 wwt_nrg_cons: 0 kWh
Value	[Missing inputs] kWh/m3
Magnitude	Energy/Volume
Outputs that use this equation as input	None
Is benchmarked?	YES (info) > See formula

The user can identify which equations use a particular input by clicking on the variable name (in brackets just after the description). The value of the input can be modified and the outputs are automatically updated.

Resident population (ws_resi_pop)

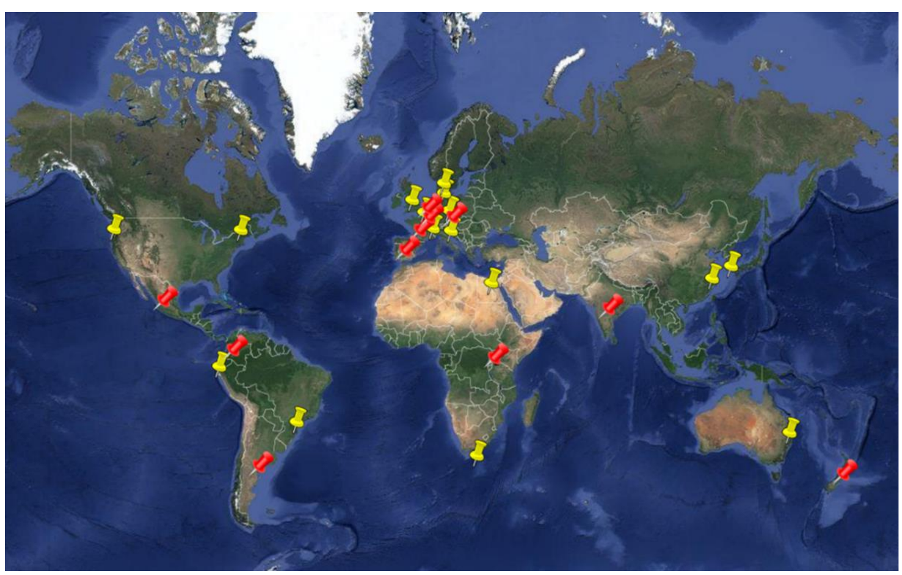
Stage	Water Supply
Explanation	Number of permanent residents within the water utility area of service
Type	Input
Value	100.000
Magnitude	People
Unit	People
Is used to calculate	ws_SL_serv_pop = 90 %

Relationships between inputs and outputs. When the mouse button is hovering over an input, the long description appears, and in the key performance indicators table, a green shadow appears for the indicators related to that input.



3.4 Integrated Background data

Integrated background data and equations will be provided in Excel spreadsheets for easy reference and modification. The work conducted over the last five years by Peter Vanrolleghem and an international panel of experts regarding the diversity of WWTP regulations implemented throughout the world (world map shows covered regions) will be put to use by incorporating it into the background data provided by the tool. The design equations that are currently in use throughout the world for designing WWTPs will form the basis for the calculations of the treatment plant outputs. Descriptions of the used models will be integrated in the tool as background information for the user.



3.5 Special features (if any)

Luis Corominas participated in a study where construction inventories for four WWTP of varying size located in Spain were created. Linear regressions were carried out to relate material usage to plant capacity. The material use inventories were then compared to those from the ecoinvent database and showed lower consumption of materials. The differences increased with plant capacity ranging from factors of 7 (for plastics) to 145 (for other materials). It would then be possible during this project to update the WWTP construction inventories in ecoinvent, that is 20 years old and based on Switzerland data, and take into account the location of the WWTP.

If some of the chemical input or by-products output flows generated by the Modelling Tool are not already present in the ecoinvent v3 database, we will submit the necessary datasets.

3.6 Schedule and budget

The total amount for this project is **44 987 CHF**. Tasks and budget are detailed in Table 2, including an estimate of the effort required for each step of the project. The project could start in April 2017. A kick-off meeting will be held during the first days of the project by teleconference or using an online communication tool such as GoToMeeting.

Note: In order to keep indirect research fees as presented in Table 2, a multi-partite contract will be required.

Table 2 - Tasks description and schedule and proposed budget

Tasks/Delivrables	CIRAIG - Polytechnique Montreal		Yves Comeau - Polytechnique Montreal		Peter Vanrolleghem - Laval University		Luis Corominas - Universitat de Girona		George Ekama - University of Cape Town		Total		Proposed schedule
	Days of professional services	Daily rate for professional services (CHF)	Days of professional services	Daily rate for professional services (CHF)	Days of professional services	Daily rate for professional services (CHF)	Days of professional services	Daily rate for professional services (CHF)	Days of professional services	Daily rate for professional services (CHF)	Days of professional services	Cost of professonal services (CHF)	
0 – Project management	***4,25***		***1***		***1***		***2***		***0,1***		***8,35***	***5436***	
Proposal development	1,5	651	1	651	1	651	1	651	0,1	651		2995	March 2017
Project management	2,75	651					1	651				2441	Summer 2017
1 – Construction of Model	***0***		***4***		***4***		***67***		***4***		***79***	***23016***	
Construction of model code							60	200				12000	
Contribution of experts													
Yves Comeau			4	651								2604	
Peter Vanrolleghem					4	651						2604	Summer 2017
Luis Corominas							4	651				2604	
George Ekama									4	651		2604	
Writing of user guide manual							3	200				600	
2 – Construction of Calculation Tool	***10***		***0***		***0***		***0***		***0***		***10***	***6510***	
Specification of user interface fields	2	651										1302	
Construction of ecoSPold2 file generation module	7	651										4557	Summer 2017
Writing of user guide manual	1	651										651	
Sub-total		**9277**		**3255**		**3255**		**16506**		**2669**		**34962**	
Indirect research fees		**40%**		**40%**		**50%**		**20%**		**0%**			
Total days and cost (including all applicable taxes and fees)	**14,25**	**12988**	**5**	**4557**	**5**	**4883**	**69**	**19807**	**4,1**	**2669**	**97**	**44987**	

3.7 Project team and expertise

The project team will bring together experts from the wastewater treatment modeling sector and from the LCA sector. Prof. Peter Vanrolleghem, Prof. Yves Comeau and Prof. George Ekama are leading experts in the field of wastewater treatment modeling. They have wide experience in the development of models for different wastewater treatment technologies. Dr. Dr. Lluís Corominas is the Chair of the International water association working group on Life cycle assessment, covering expertise on both fields (wastewater modeling and LCA). All four have a long-standing collaboration with respect to standardization of modelling methodologies, e.g. the common nomenclature that was adopted under their impetus (Corominas et al., 2010). Dr. Pascal Lesage (CIRAIG) is an expert on LCI development and was the project leader for the Quebec LCI database (as an ecoinvent NDI).

Both Peter Vanrolleghem and Lluís Corominas have been actively involved in the IWA Task Group on greenhouse gases emissions from wastewater treatment, and hence are up-to-date with emission factors from fugitive emissions (N_2O and CH_4). The project team also has expertise in the development of software tools; e.g. Prof. Peter Vanrolleghem has actively participated in the development of the commercial modeling software WEST, and Lluís Corominas has actively participated in the development of the ECAM tool from the International Water Association to monitor greenhouse gases emissions. Prof. Yves Comeau has experience in state-of-the art modeling software tools, such as BioWin and CapdetWorks.

3.7.1 Prof. Peter Vanrolleghem, Université Laval, Québec City, Québec

Peter Vanrolleghem holds the Canada Research Chair in water quality modelling since 2006. He is full professor at Université Laval's Civil and Water Engineering Department and his research team, model*EAU*, focuses on urban wastewater systems and tackles challenges such as nutrient removal and recovery, micropollutants (incl. heavy metals) and greenhouse gases, by developing and using mathematical models in different ways. He is a reknown expert in mathematical modelling of wastewater treatment plants, uncertainty analysis and greenhouse gas emissions from whole plant studies.

He has worked in collaboration with Lluis Corominas on Life Cycle Assessment of nutrient removal plants (Corominas et al., 2013) and with CIRAIG for the LCA of aerated lagoons for WWT (Godin et al., 2012).

He will be responsible, in close collaboration with the other experts of the team, for specifying the treatment models, focusing on greenhouse gas emissions and sludge treatment, and on the international regulations.

3.7.2 Prof. Yves Comeau, Polytechnique Montréal, Montréal, Québec

Yves Comeau conducts research on wastewater treatment and resource recovery, particularly for nutrients (phosphorus and nitrogen both biologically and chemically), the minimization of sludge production, mathematical modeling and wastewater treatment plant optimization. Yves has been involved on the scientific committee of a number of international conferences including the IWA World Water Congress of 2008 in Vienna and of 2010 in Montreal, and is Co-chair of the Water Resource Recovery Modelling (WRRmod) 2018 symposium to be held in Quebec in 2018. The role of Yves Comeau in this project will be on the construction and validation of the LCI modelling tool.

He will be responsible, in collaboration with other experts of the team, for specifying the design criteria for each selected unit processes of the liquid and solids line of WWTPs.

3.7.3 Prof. George Ekama, University of Cape Town, Cape Town, South Africa

George A Ekama, PhD, has 35 years research experience into activated sludge systems at the University of Cape Town, South-Africa, where some of the original biological N and P removal kinetic simulation modelling research was done in the 1980s. This work found its way into Activated Sludge Models No. 1 and 2. Over the years he has been at the forefront of developments in BNR activated sludge systems modelling, filamentous bulking, secondary settling tank design and modelling. He and his research group have been co-authors of 4 of the International Water Association (IWA) Scientific and Technical Reports (STR) on activated sludge modelling, community analysis and secondary settling tanks. He has been visiting Professor at Virginia Tech, University of Padua and the UNESCO-IHE in Delft. He regularly teaches courses for local authorities and industry, both nationally and internationally, such as for the Hong Kong Government in 1999, 2003 and 2008, and Beijing Water Corporation in 2006. He is one of a few environmental engineering professors listed on Thomson's ISI Highly Cited website

He will be responsible, in close collaboration with the other experts of the team, in providing modelling expertise, information on regionals technological preferences for both South-Africa, India and South-East Asia where he has performed extensive studies.

3.7.4 Lluis Corominas, PhD., Universitat de Girona, Girona, Spain

Lluís Corominas is leading a research group at ICRA on Integrated Management of Urban Water Systems and Sustainability Assessment. It involves the development of new monitoring tools, models for water quality prediction and methods for incorporating sustainability into decision-making. He has experience in leading national and international projects that involve fundamental and applied research. Lluís chairs the IWA Working Group on Life Cycle Assessment of Water and Wastewater Treatment. Lluís has been cooperating within the WaCCliM project from IWA to develop a web-based software platform (called ECAM; http://ecam.hol.es/) to monitor greenhouse gases emissions from the urban water cycle. The role of Lluís Corominas was on the coding of the platform and the integration of knowledge from different experts.

He will be responsible, in collaboration with other experts of the team, for specifying the design criteria for each selected unit processes of the liquid and solids line of WWTPs and for supervising the construction of the model on the Python platform by one of his students who has worked on the ECAM project.

3.7.5 Pascal Lesage, PhD., CIRAIG – Polytechnique Montréal, Montréal, Québec

Pascal Lesage has over 15 years of experience in the field of LCA. He has been involved in multiple projects associated with LCI development, notably with the US LCI database (data generation, data submission, data scrubbing and creation of a linked version of the database) and, more recently, as project leader for the Quebec LCI database (as an ecoinvent NDI). In the latter, Pascal was responsible for the team of data developers. He produced and reviewed hundreds of datasets via the ecoEditor. He has attended ecoinvent Expert Working Group meetings, has had direct communications with the ecoinvent team on multiple methodological aspects of ecoinvent data modelling, and regularly teaches a seminar on the workings and the use of ecoinvent v3.

Coming from the field of Civil engineering, Pascal also has a good understanding of wastewater treatment, although he has not worked in the field per se.

He will be responsible for the creation of the user interface and the ecoSPold2 file generation from the user specified inputs and the LCI model results.

3.7.6 Valérie Patreau, M.Sc.A., CIRAIG – Polytechnique Montréal, Montréal, Québec

Valérie Patreau is a senior project manager. She has participated in various development and deployment projects in different industrial contexts. She follows the Project Management Institute approach.

She will be responsible for the project management aspects.

4 References

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Appendix 1: Wastewater elementary composition

Total Chemical Oxygen Demand t**COD** as O_2	[kg/m^3]
Soluble Chemical Oxygen Demand sCOD as O_2	[kg/m^3]
Biological Oxygen Demand **BOD$_5$** as O_2	[kg/m^3]
Dissolved organic carbon **DOC** as C	[kg/m^3]
Total organic carbon **TOC** as C	[kg/m^3]
Sulfate **SO$_4$** as S	[kg/m^3]
Sulfide HS as S	[kg/m^3]
Particulate **S part** as S	[kg/m^3]
Total **S tot.** as S	[kg/m^3]
Ammonia **NH$_4$** as N	[kg/m^3]
Nitrate **NO$_3$** as N	[kg/m^3]
Nitrite **NO$_2$** as N	[kg/m^3]
Particulate **N part.** as N	[kg/m^3]
Organic soluble **N org. sol.** as N	[kg/m^3]
Soluble Kjeldahl **SKN** as N	[kg/m^3]
Total Kjeldahl **TKN** as N	[kg/m^3]
Total Nitrogen **N-tot.** as N	[kg/m^3]
Phosphate **PO$_4$** as P	[kg/m^3]
Particulate **P-part.** as P	[kg/m^3]
Total **P-tot.** as P	[kg/m^3]
Boron **B**	[kg/m^3]
Chlorine **Cl**	[kg/m^3]
Bromium **Br**	[kg/m^3]
Fluorine **F**	[kg/m^3]
Iodine **I**	[kg/m^3]
Silver **Ag**	[kg/m^3]
Arsenic **As**	[kg/m^3]
Barium **Ba**	[kg/m^3]
Cadmium **Cd**	[kg/m^3]
Cobalt **Co**	[kg/m^3]
Chromium **Cr**	[kg/m^3]
Copper **Cu**	[kg/m^3]
Mercury **Hg**	[kg/m^3]
Manganese **Mn**	[kg/m^3]
Molybdenum **Mo**	[kg/m^3]
Nickel **Ni**	[kg/m^3]
Lead **Pb**	[kg/m^3]
Antimony **Sb**	[kg/m^3]
Selenium **Se**	[kg/m^3]
Tin **Sn**	[kg/m^3]
Vanadium **V**	[kg/m^3]
Zinc **Zn**	[kg/m^3]
Beryllium **Be**	[kg/m^3]
Scandium **Sc**	[kg/m^3]
Strontium **Sr**	[kg/m^3]
Titanium **Ti**	[kg/m^3]
Thallium **Tl**	[kg/m^3]
Tungsten **W**	[kg/m^3]

Silicon **Si**	[kg/m^3]
Iron **Fe**	[kg/m^3]
Calcium **Ca**	[kg/m^3]
Aluminium **Al**	[kg/m^3]
Potassium **K**	[kg/m^3]
Magnesium **Mg**	[kg/m^3]
Sodium **Na**	[kg/m^3]

Appendix 2: Wastewater treatment technologies/unit operations integrated into model

The wastewater treatment plant (WWTP) will be designed by choosing unit processes for the liquid and solids lines indicated below. Each unit process (or group of unit processes achieving similar functions) would have specific design criteria for small and large WWTPs (e.g. differentiated by their flowrate, 4000 m^3/d). A set of modifiable default data for different geographic locations would be provided.

Only some of the unit processes would be integrated in the project deliverable. They include those underlined in the list below. Other unit processes could eventually be added.

Liquid treatment line unit processes

- pumping
- preliminary: to remove trash and grit
- screening, degritting, neutralization, equalization
- primary: to remove settleable matter
    - primary clarification, chemical addition
- secondary: to remove organic matter (BOD_5, TSS)
    - activated sludge, lagoon (anaerobic, facultative, aerobic), constructed wetlands
- tertiary: to remove ammonia, total nitrogen, total phosphorus, metals
    - multistage activated sludge, multistage biofilm processes, chemical addition
- advanced: to reach low levels of TSS, BOD_5, total nitrogen, total phosphorus, pathogens
    - filtration, ultrafiltration, disinfection (e.g. Cl_2, UV, O_3), activated carbon

Solids treatment line unit processes

- thickening: to increase the solids content
    - gravity thickening
- digestion: to stabilize organic matter
    - anaerobic digestion
    - aerobic digestion
- conditioning: to improve dewatering
    - coagulant and polymer addition
- dewatering: to increase the solids content
    - centrifugation, filter pressing, vacuuming
- nutrient treatment and recovery
    - (struvite formation, anammox)
- drying: to increase the solids content
    - sludge beds, heat drying
- sludge or biosolids disposal
    - composting, land application, landfilling, incineration