Supplementary Material of the article "ENERWATER - A standard method for assessing and improving the energy efficiency of wastewater treatment plants"

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Section 1. WWTP boundaries and definition of stages

The following definitions are applied in this document:

- **Stage 1: Preliminary treatment** includes all pumping required to discharge the wastewater to the WWTP (i.e.: pumping stations that can be found within the boundaries of the WWTP), the equipment involved in screening, grit removal, oil separation and flow equalisation. Storage of wastewater in storm tanks and respective pumps, as well as effluent pumping (e.g. treated wastewater) is also included in Stage 1.

- **Stage 2: Primary treatment** includes all the equipment involved on primary sedimentation/clarification, as well as the elements required for desludging the primary sedimentation and dose of chemicals (e.g. iron dosing for phosphorus removal or coagulant dosing for enhanced solids removal) that takes place before or during primary sedimentation/clarification. Specific control and instrumentation tools that are required to operate Stage 2 should also be considered here.
- **Stage 3: Secondary treatment** includes all processes and their auxiliary equipment required for biological wastewater treatment after primary sedimentation (if present). Common processes used in secondary treatment include biofilm processes (e.g. trickling filters) and flocculent processes (e.g.: activated sludge and biological nutrient removal) and their respective humus tank or secondary clarifier. Equipment required to operate the biological wastewater treatment pumping (recirculation), aeration and secondary clarification, should also be considered in Stage 3. Equipment required for desludging the secondary clarifier and dose of chemicals (e.g. iron dosing for phosphorus removal that takes place before or during secondary clarification), should also be considered in Stage 3. Specific control and instrumentation tools that are required to operate Stage 3 should also be considered.
- **Stage 4: Tertiary and advanced treatment** can be completed by a wide variety of processes including: chemical (e.g. chlorination or ozonation), physical (e.g. sand filters, UV disinfection) and biological (e.g.: reed-beds; submerged aerated filters, tertiary nitrification) processes. For simplicity the ENERWATER methodology defines as Stage 4 any process that takes place between secondary treatment and effluent discharge and their respective equipment. Pumping required for effluent discharge should be included as part of Stage 4. Specific control and instrumentation tools that are required to operate Stage 4 should also be considered.
- **Stage 5: Sludge treatment** consists in any processes that handle concentrated streams derived from primary, secondary and physical-chemical treatment, that are traditionally above 0.5% total solids and their respective equipment. Stage 5 can be divided into two sub-stages based on

the different functions carried out in this section of the plant, that is a) concentration of sludge and b) reduction of sludge. **Stage 5a** often includes two range of steps such as i) thickening (e.g.: gravity thickeners), and dewatering (e.g. centrifuges, belt presses etc.). **Stage 5b** includes sludge stabilisation technologies that range from alkalinity dosing, anaerobic digestion to thermal processes such as incineration, gasification and pyrolysis. If the WWTP receives import sludge this should be also accounted as in the energy monitoring exercise. Nevertheless if the WWTP receives other waste to complete co-digestion then processing of these wastes should be excluded from the exercise. Also of high relevance is the fact that many sludge stabilisation technologies are energy producers, not consumers. Energy production on site should be considered either by accounting for the biogas production on site, or if possible measuring the kWh produced by these processes. Specific control and instrumentation tools that are required to operate Stage 5 should also be considered.

- **Stage 6: Return liquors** treatment can include processes for treatment of return liquors (reject water) that are usually focused on nitrogen removal and phosphorus removal through processes such as Anammox or struvite precipitation, respectively, just give some examples. Specific control and instrumentation tools that are required to operate Stage 6 should also be considered.
- **Stage 7: Odour treatment** often includes recovering of extraction the air of air extracted from sludge processing technologies (Stage 5) or even pumping stations. Odour treatment technologies can be classified into physical/chemical (chemical scrubbers, incinerators, adsorption systems, and so forth) and biological (bio-filters, bio-trickling filters, bio-scrubbers, and activated sludge diffusion reactors).
- **Auxiliaries.** Many WWTPs will have exterior lighting, offices and labs. Other possible auxiliaries include pumping of water for garden irrigation, servers for data storage and transfer etc. The energy consumption from these auxiliary facilities should be measured and considered for calculating the energy index.

Section 2. Chemical energy consumption

Table S1. Chemical energy consumption (cec) of chemicals commonly used in WWTPs as commercial products. Cec are obtained from Ecoinvent database **[1]**.

Chemical	Chemical energy consumption (kWh/kg)
Acetic acid 80% sol.	10.3
Aluminium sulphate 50% sol.	1.04
Iron(III) chloride 40% sol.	3.40
Iron(III) sulphate 12.5% sol.	1.90
Iron(II) sulphate 100%	0.90
Methanol 100%	9.21
NaOH 50% sol.	4.17
Peracetic acid 15% sol.	6.90
Polyaluminium chloride (PAC) 25% sol.	1.94
Polyelectrolyte (polymer 5%)	1.40

Section 3. Parameters of Gumbel's cumulative distribution functions

Table S2. Parameters of Gumbel's cumulative distribution functions

	Rapid Audit		Decision Support	
	μ	σ	μ	σ
Stage 1	0.327	0.242	0.032	0.0319
Stage 2	-	-	0.018	0.0179
Stage 3	0.324	0.189	0.2	0.201
Stage 4	0.057	0.037	0.0166	0.0172
Stage 5	1.997	1.334	0.1773	0.1819

Section 4. Description of the WWTP under analysis

After a storm water tank, the wastewater is pumped into the plant and it is mechanically treated with a screen and grit chamber. After suspended solids are removed in a primary settlement tank, the wastewater is sent to the biological treatment where an upstream process for denitrification and nitrification is present. P is removed by chemical P precipitation by dosing aluminium sulphate. Activated mixed liquors are then sent to two secondary sedimentation tanks for clarification and discharge of treated wastewater. Waste secondary sludge (WAS) generated by the biological treatment is recycled to the primary sedimentation and mixed with primary sludge. Mixed sludge from the primary sedimentation tank is pumped to a pre thickening tank. Process water is extracted here, which after being stored in a process water tank is dosed back to the plant right before the primary sedimentation. Excess sludge from the secondary sedimentation is fed to the pre thickener. Sludge from the pre thickener is anaerobically stabilized in a digester, after which it goes to a post thickener with process water extraction. The stabilized sludge is then stored in a sludge storage tank from which it is dosed to a mobile sludge press. The press water is fed to the process water tank. In the digestion process biogas is produced which is used to power a CHP unit and a normal heating unit for backup.

References

[1] H. J. Althaus *et al*, "Life Cycle Inventories of Chemicals. Final report ecoinvent data v2. 0 No. 8. EMPA Dübendorf, Swiss Centre for Life Cycle Inventories, Dübendorf, CH," *Online-Version Under: Www.Ecoinvent.Ch,* 2007.