Energy Monitoring And Benchmarking In Wastewater Treatment Plants Using The ENERWATER Approach

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INTRODUCTION

One of the higher costs of wastewater services is the energy consumption. The total electricity consumption in wastewater treatment plants (WWTPs) corresponds to about 1% of the total electricity consumption per year of a country (Cao et al., 2011). In order to compare WWTPs having different processes and scheme configurations, the most useful methodology is energy efficiency measurement using benchmarking procedures (Parena et al., 2002). However, the available audit methodologies do not support well the decisions of the water utilities in order to best target their actions to improve the energy efficiency. Traditionally, energy consumption of a WWTP has been simplistically reported using global KPIs such as kWh/m3 (Mizuta and Shimada, 2010) or kWh/PE (Krampe, 2013; Balmer, 2000). As WWTPs are composed by several stages, each one with a different function, the use of specific KPIs for each treatment stage or function is more appropriate (Longo et al., 2016). A standard methodology is required in order to carry out the energy audit in WWTPs (Tao et al., 2009). Horizon2020 ENERWATER project (www.enerwater.eu) deals, inter alia, with development of a standard methodology for continuously assessing, labelling and improving the overall performance of WWTPs. The objective of this study is to illustrate the application of the ENERWATER methodology to three real wastewater treatment plants (WWTPs).

The ENERWATER methodology considers two approaches for the determination of energy consumption in WWTPs, namely Rapid Audit and Decision Support. The Rapid Audit allows for a quick estimation of the water treatment energy index (WTEI) based on existing information such as historical data pertaining to energy use records along with influent and effluent quality values. The Decision Support requires intensive monitoring across a WWTP of energy usage and water quality parameters that provides an accurate and detailed calculation of WTEI for each stage as well as its overall value for the plant. For the sake of brevity only the results of the Rapid Audit methodology will be presented here.

ENERWATER METHODOLOGY

The ENERWATER Methodology aims at describing, in a systematic way, the various steps required to establish the WATER TREATMENT ENERGY INDEX (WTEI) of a particular wastewater treatment plant (WWTP). The objective of this method is to guide water experts and auditors on how to evaluate the energy performance of a WWTP reaching a final energy diagnosis and the calculation of the WTEI

Rapid Audit methodology

This method uses existing data including historical data on energy consumption as well as the wastewater influent and effluent quality that are necessary to calculate key performance indicators (KPIs). A trained auditor can calculate the WTEI and the obtained values can be compared against the ENERWATER database including data on 650 WWTPs around the world. The aim of the ENERWATER Rapid Audit methodology is to provide an WWTP energy benchmark, a rapid tool to identify energy efficiencies and inefficiencies so further actions can be planed, as well as evaluate the impact of WWTP retrofitting.

ENERWATER identifies key performance indicators (KPIs) which account for the energy consumption required to remove a specific masse of pollutants (TSS, COD, NH_4, TN, TP, pathogens, etc.), for example kWh/kg CODremoved. These are combined into a composite indicator to facilitate the communication of the energy efficiency results.

The total pollution equivalent (TPE) is calculated, according to Benedetti et al, 2008, as a weighted sum of COD, total nitrogen (TN) and total phosphorus (TP) as described in Equation 1.

Total Pollution Equivalent (TPE)= COD (kgCOD)+20 TN (kgTN)+100 TP (kgP) (Equation 1)

To obtain the WTEI based on the calculated KPIs for a given WWTP, several steps involving the statistical treatment of the KPIs need to be followed, namely normalization, weighting and aggregation. Normalization allows the comparison of the different KPIs and is done here by comparison with a distribution function, so that the percentiles for each KPI are normalised indicators of performance, here called energy performance indicators (EPI). Weighting emphasizes the contribution of a given KPI over others in terms of energy consumption. Finally, aggregation consists in the combination of the weighted KPIs at either the stage or the whole plant level so that the corresponding WTEI can be computed and results compared based on a ranking. The procedure for determining the WTEI in the Rapid Audit Calculation is summarised in Figure 1.

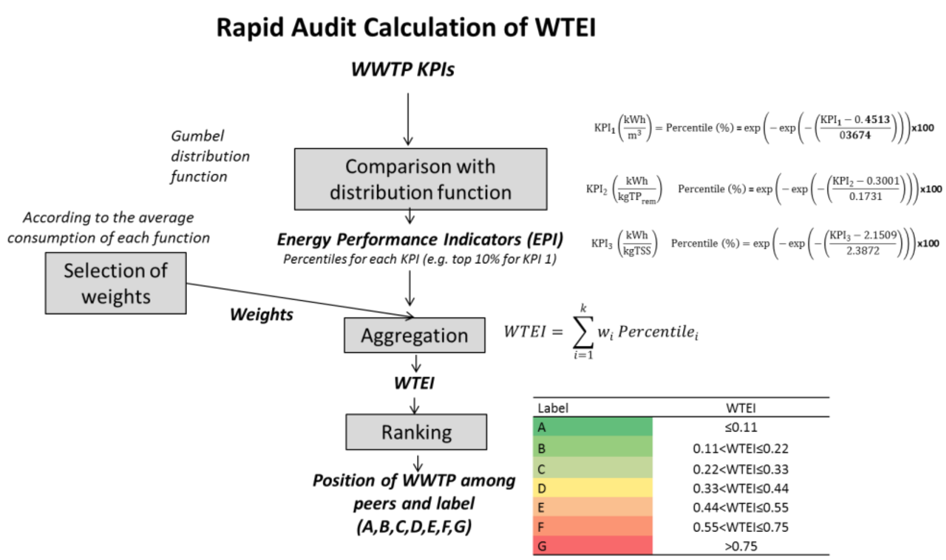

Figure 1. Workflow for the determination of the WTEI according to the Rapid Audit methodology.

CASE STUDY

The objective of these case studies is to illustrate the application of the ENERWATER methodology to three wastewater treatment plants (WWTPs) that deploy different treatment technologies and thus energy demands. Each case study comprises the following sections:

* WWTP key performance indicators
* Classification of WWTP according to WTEI

WWTP key performance indicators

Table 1 presents the quality parameters for both influent and final effluent at the WWTPs under analysis. For each parameter, average values were calculated from a 3-year historical database. Energy values were obtained from a meter that measures the overall energy consumption in the plant.

The following energy carriers are considered in the Rapid Audit ENERWATER methodology: electric energy, diesel, natural gas and biogas, and energy for chemicals. To obtain the WTEI for plants A, B and C, KPIs listed in Table 1 were combined following the statistical treatment described in the section 2.1 and in Figure 1. For flow and TPE, individual energy performance indicators (EPIs) were calculated with the corresponding Gumbel's cumulative distribution functions, whose parameters were estimated from the 470 WWTPs included in the ENERWATER benchmark database. Once the WTEI is calculated, the corresponding energy label was assigned according to boundaries. For the WWTP analysed, the energy label calculated is F, C, and F, respectively for WWTP A, B, and C.

Table 1. WWTPs characteristics and key performance indicators.

Parameter	WWTP A		WWTP B		WWTP C	
	Influent	Effluent	Influent	Effluent	Influent	Effluent
Flow [m^3]	1,730,329		1,791,271		5,760,845	
COD [mg/L]	255.00	50.00	305.53	10.40	308.00	22.00
TN [mg/L]	22.00	4.00	30.06	0.06	36.60	6.40
TP [mg/L]	7.20	2.60	4.63	0.46	4.63	0.57
Sludge [ton]	106		158		494	
Total energy [kWh]	759,534		541,054		3,659,745	
KPI_1 [kWh/m^3]	0.439		0.302		0.635	
KPI_2 [kWh/kg TPE]	0.428		0.230		0.490	
KPI_3 [kWh/kgTSS]	7.135		3.417		7.404	
WTEI	0.61		0.26		0.71	
Label	F		C		F	

CONCLUSIONS

The application of the ENERWATER Rapid Audit methodology to benchmark and audit the municipal WWTPs advanced the current state of the art and allowed: (1) the comparison among heterogeneous WWTPs based on the basic functions of a plant, namely i) pumping of wastewater, ii) removing of pollutants, and iii) sludge treatment and dewatering; (2) the disaggregation of the key performance indicators based on these functions (3) the definition of single WTEIs and energy labels (classes A to G) that can support the decisions of the water utilities to best target of energy saving actions to less performing WWTPs. The ENERWATER Rapid Audit methodology has proved to be a rapid tool to identify energy efficiencies and inefficiencies of a WWTP.

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