Analysis and Optimization of Energy Consumption in Relation to GHG Management: The Case Study of Medio Sarno Wastewater Treatment Plant

A. Falcone[1(✉)], L. Pucci[1], S. Guadagnuolo[1], R. De Rosa[1], A. Giuliani[1], B.M. d'Antoni[2], G. Lofrano[3], G. Libralato[4], F. Fatone[5], and M. Carotenuto[3]

[1] Consorzio Nocera Ambiente, Via S. Maria delle Grazie 562, 84015 Nocera Superiore, SA, Italy
[2] Department of Biotechnology, University of Verona, Strada Le Grazie 15, 37134 Verona, Italy
[3] Department of Chemistry and Biology, Salerno University, via Giovanni Paolo II, 132, 84084 Fisciano, SA, Italy
[4] Department of Biology, University of Naples Federico II, via Cinthia ed. 7, 80126 Naples, Italy
[5] Department of Materials and Environmental Science and Urban Planning, Università Politecnica delle Marche, Ancona, Italy

Abstract. A multistep methodology for the evaluation of the energetic behaviour of a wastewater treatment plant has been carried out, in according to Horizon2020 Enerwater methodology. The study took into account each phase of the process scheme, in order to obtain specific electricity consumption values for all the electro-mechanic devices. Data from both tele-control system and direct measurements in field have been acquired in order to perform a critical analysis for improving energy efficiency.

Keywords: Energy efficiency · Greenhouse gases · Wastewater treatment · Benchmarking

1 Introduction

Most direct emissions resulting from wastewater treatment plants (WWTPs) based on biological processes are greenhouse gases (GHG) such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), while other indirect emissions are released by on site energy generation from biogas combustion (De Haas and Foley 2009; Campos et al. 2016). The CO_2 emitted in relation to energy demand can be directly reduced enhancing the energy efficiency of WWTPs (Libralato et al. 2012). In this way, both the reduction of environmental impacts and the decrease of treatment costs, increasing energy savings, can be accomplished simultaneously. In terms of costs, the main efficient way to reduce GHG emissions is to modify the operational conditions of WWTP units even if this is could not be always possible due to the operational limitations of the installed units (Panepinto et al. 2016).

G. Mannina (ed.), *Frontiers in Wastewater Treatment and Modelling*,
Lecture Notes in Civil Engineering 4, DOI 10.1007/978-3-319-58421-8_68

In this study, we monitored for one year the energy consumption in all treatment units (pre-treatment and pumping stations; primary treatment rainwater and aerated storage; secondary treatment; tertiary treatment; sludge treatment; return liquor treatment; and odour treatment) of Medio Sarno WWTP (Nocera Superiore, Campania, Southern Italy) (300.000 p.e.) managed by Consorzio Nocera Ambiente. Moreover, GHG emissions were evaluated in order to support their minimization.

2 Materials and Methods

To estimate the overall electric energy consumption of Medio Sarno WWTP, the calculated power values (P) were multiplied for the operating time of each device. During the survey of the devices operating in the WTTP, the electro-mechanic equipment was later grouped and classified in homogeneous categories according to ENERWATER methodology.

3 Results and Discussion

Results were summarised in Table 1 and showed that the phase requiring the highest amount of electricity was the biological oxidation (> 50%) followed by pre-treatment and pumping stations.

Table 1. Electric energy consumption for each stage according to ENERWATER methodology

Stage description	**kWh/d**	%
Stage 1: Pre-treatment and pumping stations	3,430	25
Stage 2: Primary treatment rainwater and aerated storage	1,007	7
Stage 3: Secondary treatment	409	46
Stage 4: Tertiary treatment	802	6
Stage 5: Sludge treatment	700	5
Stage 6: Return liquor treatment		0
Stage 7: Odour treatment	1,497	11
Total	**13,844**	

The values of key performance indicators (KPIs) on the base of the estimated energy consumption were reported in Table 2. The comparison of KPIs of Medio Sarno WWTP with other WWTPs outlined a general equivalency in their values. The main deviations involved the indexes related to total nitrogen removal, while the values of the index connected to wastewater volume and COD removal were more similar (Panepinto et al. 2016).

Table 2. Critical evaluation of electric energy demand of Medio Sarno WWTP; EEC = electric energy consumption

SPECIFIC ENERGY PERFORMANCE INDICATORS (daily values average)		
EEC/volume of treated wastewater	kWh/m^3	0.38
EEC/BOD_5 load removed	kWh/kg BOD_5	2.50
EEC/COD removed	kWh/kg COD	1.00
EEC/TSS removed	kWh/kg TSS	3.18
EEC/TN removed	kWh/kg N	46.50
EEC/NH_4 removed	kWh/kg NH_4	38.40
EEC/P removed	kWh/kg P	209.06

In order to estimate GHG emissions, we referred to the "Methodology Guide for Evaluating Greenhouse gas emissions by water and sanitation services" (2013) prepared by ASTEE and based on IPCC Guidelines for National Greenhouse Gas Inventories (2006) and the GHG Protocol prepared by WBSCD and WRI. WWTP operational data were summarized in Table 3.

Table 3. Operational data for GHG emissions calculations

Scope	Operational data	Units	Value
1	TKN removed	ton/yr	118
1	COD removed	ton/yr	5,476
1	TKN discharged	kg/yr	69,275
1	Ton of COD discharged	ton/yr	455
2	Electricity consumption	MWh/yr	5,021
3	Peracetic acid consumption	l/yr	59,205
3	Poly consumption	kg/yr	16,863
3	Sludge landfilled	ton TSS/yr	3,049
3	Screenings landfilled	ton TSS/yr	45
3	Grit landfilled	ton TSS/yr	215
3	Annual transport for biosolids	t*km/year	1,798,245
3	Annual transport for grit	t*km/year	167,850
3	Annual transport for screen	t*km/year	35,157

GHG emissions (Table 4), as required by the GHG Protocol, were quantified in the following order: Scope (1) direct emissions from the sewage process and discharge into surface water; Scope (2) indirect emissions associated with the consumption of electricity, steam or gas; Scope (3) other indirect emissions related to production and transport of chemicals, transport and treatment of sludge and by-products.

As shown in Fig. 1, energy consumption provided the greatest contribution to carbon footprint (39%) followed by sewage process (31%), biosolids, screening and grits (24%), effluent (5%) and others (1%).

Table 4. GHG estimates (ton CO_2-eq/yr), with breakdown according to scope (IPCC, 2007)

Scope	Description of emission	Total (tCO_2eq/yr)
1	Emissions linked to the sewage process	2599.7
1	Discharges into surface water	447.5
	Direct emissions (SCOPE 1) Subtotal	**3047.2**
2	Indirect emissions linked to energy consumption	3263.9
	Indirect emissions associated with energy (SCOPE 2) Subtotal	**3263.9**
3	Indirect emissions (reagents and consumables)	93
3	Indirect emissions (biosolids, screenings&grit)	1997.3
	Other indirect emissions (SCOPE 3) Subtotal	**2090.3**
	Operational Carbon Footprint	**8401.5**

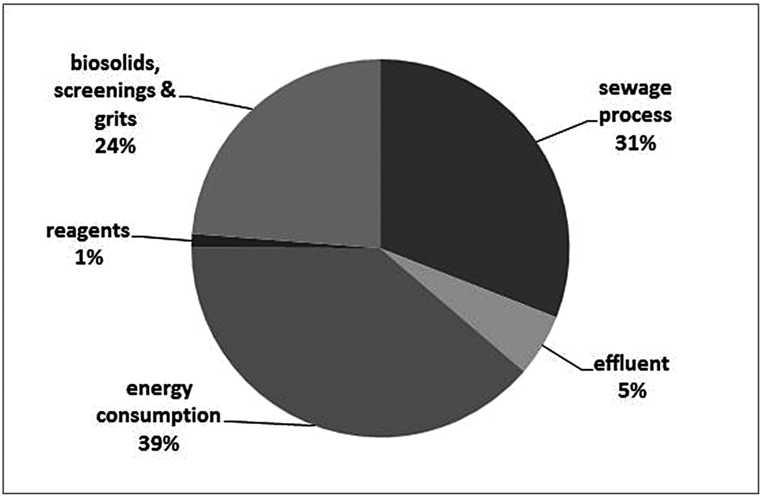

Fig. 1. Carbon Footprint (%) breakdown at Medio Sarno WWTP

4 Conclusions

This study evidenced that:

- The phase requiring the highest fraction of the electricity consumption is the biological oxidation (> 50%) followed by pre-treatment and pumping stations;
- The energy consumption associated to the oxidation tank and pumping stations can be greatly reduced thought optimization;
- Energy consumption provided the greatest contribution to the carbon footprint (39%) followed by sewage process (31%), biosolids, screening and grits (24%), effluent (5%) and others (1%).

Our next goal will be to set the best operational condition to keep the WWTP efficient as well as to minimize its carbon footprint.

References

Campos JL, Valenzuela-Heredia D, Pedrouso A, Val del Río A, Belmonte M, Mosquera-Corral A (2016) Greenhouse gases emissions from wastewater treatment plants: minimization, treatment, and prevention. J Chem 2016:1–12

De Haas D, Foley J (2009) Energy and green house footprints of wastewater treatment plants in South east Queensland. AWA Ozwater Conference, 16–19 March 2009, Melbourne Australia

Libralato G, Ghirardini AV, Avezzù F (2012) To centralise or to decentralise: an overview of the most recent trends in wastewater treatment management. J Environ Manage 94(1):61–68

Panepinto D, Fiore S, Zappone M, Genon G, Meucci L (2016) Evaluation of the energy efficiency of a large wastewater treatment plant in Italy. Appl Energy 161:404–411