Energy efficiency of Gherla wastewater treatment plant

Marius D. Roman

Technical University of Cluj-Napoca, Building Services Engineering Department, Cluj-Napoca, Romania. Corresponding author: M. D. Roman, Marius.ROMAN@insta.utcluj.ro

Abstract. Energy consumption in the treatment plants represents a significant operating cost, about 15 to 30% for large capacity treatment plants and between 30 to 40% for small plants. Energy costs used for the operation of these goals are constantly growing due to the increasing fuel costs and the stringent discharge requirements for treated water into the environment, leading to the use of a process with a high energy consumption. Regarding the electricity consumption can vary between 0.2 and 1.2 kWh/m^3 of treated water discharged due to the treatment technology chosen and the degree of treatment required.
Key Words: process optimization, efficiency, energy consumption, blowers.

Aims and background. In March 2007, the EU's leaders endorsed an integrated approach to climate and energy policy that aims to combat climate change and increase the EU's energy security while strengthening its competitiveness. The EU Heads of State and Government set a series of climate and energy targets to be met by 2020. These are a reduction in EU greenhouse gas greenhouse of at least 20% below 1990 levels, 20% of EU consumption energy to come from renewable sources, a 20% reducing in primary energy use compared with projected levels, to be achieved by improving energy efficiency (European Commission Communication 2011). In wastewater treatment plants, energy consumption is often correlated with the magnitude and type of pollutant load, which can influence the treatment methods and technologies used in a plant. Wastewater treatment plants that have more influent biological oxygen demand (BOD) use more energy. The aeration in biological treatment it is the main consumer of electricity (erc.uic.edu) (Figure 1). Regarding optimization of energy needed in the wastewater treatment process, optimization can be considered as major consumers, such as blowers, aerators is a standard measure. They are often complemented with significant energy savings by automatically controlling the aeration by integrating appropriate sensors, variable speed blowers and proper planning so as to meet the demand for oxygen to periodic variations in system requirements (Larsson 2011).

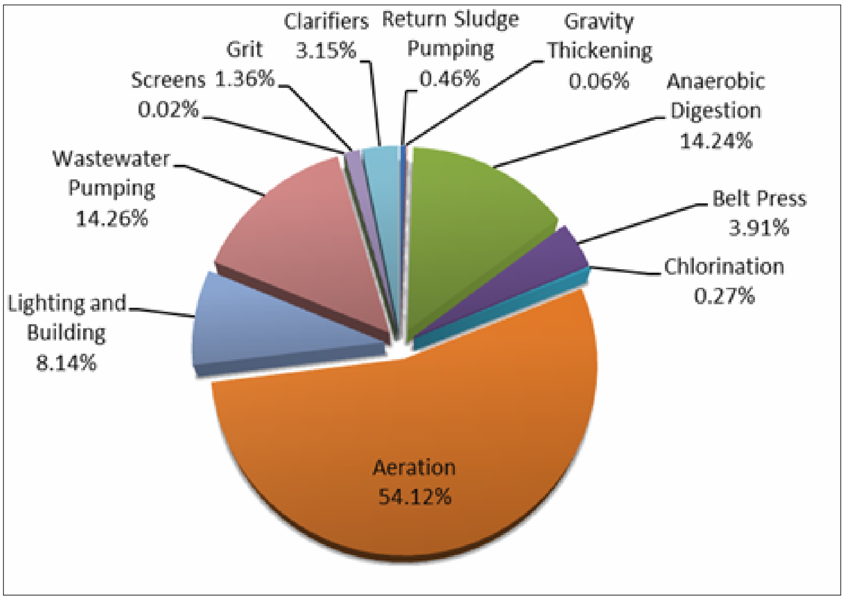

Figure 1. Total energy consumption use for a wastewater treatment plant (erc.uic.edu).

Wastewater treatment plants consume large amounts of energy. They also have the capability to produce a fuel, biogas (a combination of methane and carbon dioxide), through anaerobic digestion of sewage sludge. A secondary treatment plant may use as much as 1500 to 1700 kilowatt hours (kWh) of electricity to treat one million gallons of sewage and manage the resulting sludge and residuals (Svardal & Kroiss 2011). Natural gas, fuel oil, and biogas are usually burned in boilers to provide heat energy for some sludge management practices and plant heating and cooling (Pakenas 1995).

In the activated sludge process, surface aerators or submerged air diffusers continuously disperse air into the aeration tanks to support the living biomass population and to maintain proper mixing (Roman & Muresan 2015). Due to oversized equipment, inefficient operation, or lack of controls, the amount of air delivered to the aeration basins is usually much more than required for mixing and biological activity. This excess air represents wasted energy, and highly aerated sewage may lead to sludge settling problems and solids carryover into the plant effluent.

To relate the energy use to the volume of water only tells part of the truth. It is important to relate the energy consumption both to the amount of organic components, nitrogen and phosphorus removed. Usually it is difficult to find reliable data for energy consumption related to the wastewater load. There is a significant difference between the energy requirements for different wastewater treatment plants. The differences are due to plant size, the type of load (for example industrial or mainly domestic) and the type of operation. For example, in Sweden the energy requirement for wastewater operations varies from 1.5 to 40 kWh per kg BOD (organic carbon removal), with a median value of 4.5 kWh (Gustaf 2004). Energy requirement for wastewater collection and treatment in California is 0.3-1.2 kWh/m^3 (DOE 2006) and in the UK the average requirement is 0.63 kWh/m^3 (Environmental KTN 2008).

According to the Global Water Research Coalition (GWRC) it is quite feasible to obtain an energy consumption reduction by 20% by optimisation and innovation (Kenway et al 2011). The existing systems in the water and wastewater industry haven't reached the limits of improvement of its energy efficiency yet. GWRC also argues that a further reduction of the energy consumption with another 80% should be possible, but this requires a paradigm shift. The current water infrastructures have been designed and constructed on the basis of views, requirements, conditions and technologies of decades ago. It is recognised that in the present systems wastewater treatment, water treatment and distribution are very energy intensive. New concepts could include topics like alternative sanitation approaches (separation at the source), from waste towards resource (P and N recovery, wastewater as nutrient for algal based biofuel), microbial fuels cells, tailored water quality, and use of alternative resources etc. The water and wastewater sector could benefit from technology developments and breakthrough in related areas like energy production, sensor development, and nanotechnology (Gustaf 2004).

Experimental. The data used in this study was obtained from the wastewater treatment plant from Gherla's city for the years 2013 and 2014, designed for 20 000 population equivalents, were the specific energy consumption varies between 1.33 and 2.72 kWh per kg BOD_5 treated and between 0.28 and 0.35 kWh/m^3 treated water discharged. In general, energy consumption can vary between 1.0 and 3.8 kWh per kg BOD_5 treated (Roman & Muresan 2014). In this context, all this two years that were taken in study and the data collected were achieved as graphics and it has become an important data set related to the energy consumption.

Results and Discussion. In systems employing diffused aeration suspended growth activated sludge or aerobic digestion the power for aeration is consumed by the blowers supplying air to the diffuser system. Any attempt to optimize energy usage must necessarily include an analysis of the blower power requirements.

Blower power requirements as a function air flow for any blower may be calculated from inlet and discharge conditions and air flow. The generalized formula is:

$$h_p = 0.01542 \cdot \frac{Q \cdot p_i \cdot X}{\eta} \quad (1)$$

where:
hp = brake horsepower at blower shaft;
Q = blower inlet volumetric flow rate;
pi = blower inlet pressure, psia;
η = blower efficiency, decimal;
X = blower adiabatic factor.

The generalized formula for adiabatic factor is:

$$X = \left(\frac{p_d}{p_i}\right)^{0.283} - 1 \quad (2)$$

where:
pd = discharge pressure, psia;
pi = inlet pressure, psia

The two most significant parameters affecting the power requirement of any blower system are air flow rate and discharge pressure. In Table 1 energy consumption for equipments and blowers with a consumption of 22 kW per blower at the wastewater treatment plant from Gherla are presented.

Table 1

Energy consumption for year 2013

Month	*Energy consumption equipments kwh/month*	*Energy consumption blowers kwh/month*
1	45490	28235
2	47248	26543
3	43505	27064
4	47522	26476
5	42915	38436
6	44018	29042
7	41037	26419
8	42361	30613
9	39936	29954
10	41370	26220
11	37402	18153
12	40850	26429

Energy consumption for blowers represent approximately 54% of total energy consumption throughout the treatment plant, the rest consumption are given by submersible pumps, recirculation sludge pumps, excess sludge pumps, submersible mixers, screens, thickeners and others.

The biggest energy savings can be achieved by optimizing aeration but not only, also pumping, recirculation and other equipments. From the graphic shown in Figure 2 can be approximated that the treatment plant use for aeration 330584 kWh per year. It also notes that the ranges of consumption monthly is quite high, it is between a minimum of 25153 and a maximum of 30613 kWh. This describes the treatment plant in terms of electricity consumption a consumer is unpretentious, but with possibilities of optimization, with a duration curve annual electricity consumption not so flattened.

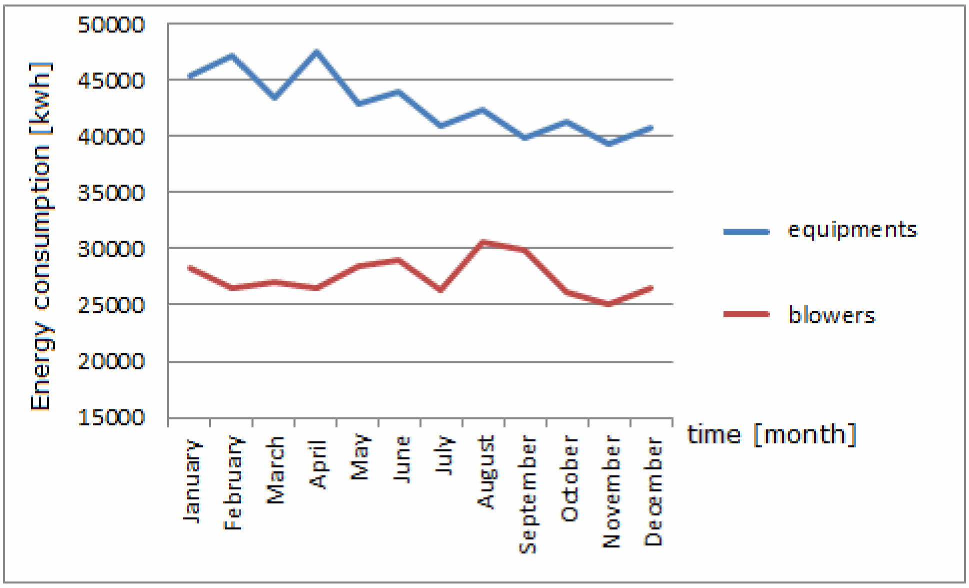

Figure 2. Energy consumption for year 2013.

In Table 2 the energy consumption for equipments and blowers at the wastewater treatment plant from Gherla for year 2014 is presented.

Table 2

Energy consumption for year 2014

Month	*Energy consumption equipments* *kwh/month*	*Energy consumption blowers* *kwh/month*
1	41716	28673
2	38792	28167
3	40529	32679
4	41506	32563
5	43726	34150
6	44018	35090
7	43653	33949
8	41940	30714
9	41564	32311
10	45107	34381
11	38485	29385
12	42601	30157

From the graphic shown in Figure 3 can be approximated that the treatment plant use for aeration 304062 kWh per year. It also notes that the ranges of consumption monthly is quite small, it is between a minimum of 25673 and a maximum of 29385 kWh. This describes the treatment plant in terms of electricity consumption a consumer is unpretentious, with a duration curve annual electricity consumption rather flattened.

As can be seen consumption from 2014 followed approximately the same trend, in comparison with the consumption from 2013.

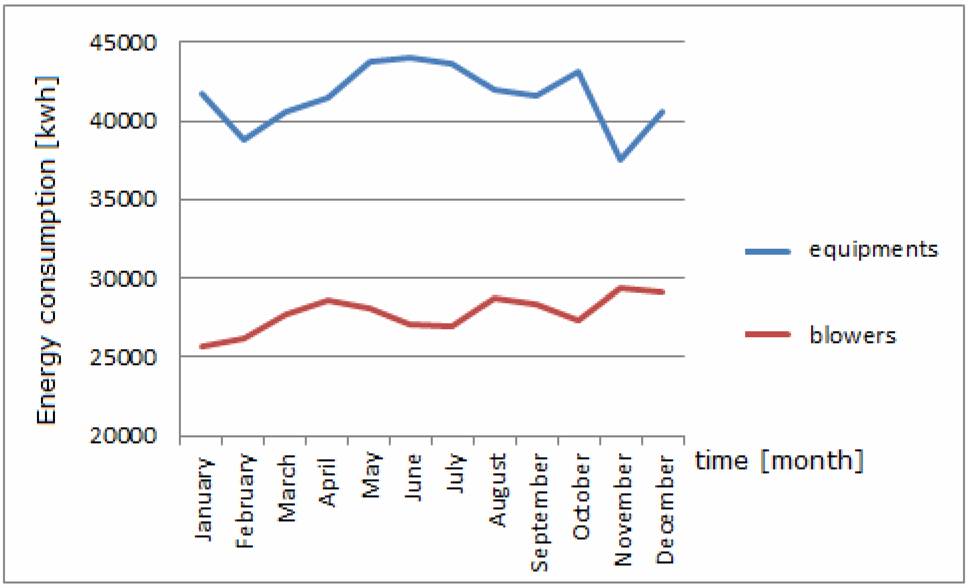

Figure 3. Energy consumption for year 2014.

In terms of equipment, we have identified a number of innovative technologies, more agreeable than standard submersible mixers such as hyperbolic mixers and mixing systems by generating large sequential bubbles (Holba et al 2012).

Conclusions. In conclusion to optimize energy consumption in the aeration process it's needed time in order to achieve significant energy reduction on aeration.

From analyzing data for the months corresponding to years 2013 and 2014 may also notice an improvement in water quality treated discharged into the environment, but also guaranteed consumption costs and parameters designed for the wastewater treatment plant.

The increase in energy savings performed from years 2013 and 2014 is a result of a better aeration and control system. The savings come from the new technologies of blowers operated with frequency converter, which set new standards of performance and energy savings in wastewater treatment plants. In view of fact that the frequency converter adjusts the level performance of the blowers, as a rule between 40 to 100% according to the required concentration of disolved oxygen in the aeration tanks, the results obtained without any other mechanical control systems.

Another advantage of these frequency converters is that they prevents the blower to fall below the minimum level set, this results having unwanted pressure oscillations through continuous monitoring of the flow.

References

DOE, 2006 Energy demands on water resources: report to Congress on the interdependencies of energy and water. Available at: http://www.circleofblue.org/waternews/wp-content/uploads/2010/09/121-RptToCongress-EWwEIAcomments-FINAL2.pdf. Accessed: October, 2011.

Environmental KTN, 2008 Energy efficient water and wastewater treatment. University of Oxford, Department of Earth Sciences, Environmental KTN. Available at: www.environmental-ktn.com. Accessed: February, 2010.

European Commission Communication, 2011 Committee on Environment, Public Health and Food Safety, Climate Change, pp. 1-2.

Gustaf O., 2004 Water and energy: threats and opportunities. IWA Publishing, London, UK, pp. 229-231.

Holba M., Bartonik A., Skorvan O., Horak P., Pocinkova M., Ploteny K., 2012 Wastewater energy potential. International Conference Water Supply and the New Energy Challenges, Palace of Parliament, 10-12 June, Bucharest, Romania, Rora Publishing, pp. 141.

Kenway S. J., Lant P. A., Priestley A., Daniels P., 2011 The connection between water and energy in cities, a review. Water Science and Technology 63(9):1983–1990.

Pakenas L. J., 1995 Energy efficiency in municipal wastewater treatment plants. Tehnology Assessment. New York State, Energy Research and Development Authority, 24 pp.

Roman M. D., Mureşan M. V., 2014 Analysis of oxygen requirements and transfer efficiency in a wastewater treatment plant. International Journal of Latest Research in Science and Technology 3(2):30-33.

Roman M. D., Muresan M. V., 2015 Process optimization of aeration in the biological treatment using fine bubble diffusers. 6th International Conference on Modern Power Systems MPS 2015, 18-21 May, Cluj-Napoca, Romania, pp. 315-318.

Svardal K., Kroiss H., 2011 Energy requirements for waste water treatment. Water Science and Technology 64(6):1355-1361.

Larsson V., 2011 Energy savings with a new aeration and control system in a mid-size Swedish wastewater treatment plant. Uppsala University, 78 pp.

http://www.erc.uic.edu.

Received: 28 December 2015. Accepted: 20 March 2016. Published online: 31 March 2016.
Author:
Marius-Daniel Roman, Technical University of Cluj-Napoca, Building Services Engineering Department, Blvd. December 21, no. 128-130, 400604 Cluj-Napoca, Romania, e-mail: Marius.ROMAN@insta.utcluj.ro

How to cite this article:
Roman M. D., 2016 Energy efficiency of Gherla wastewater treatment plant. Ecoterra 13(1):1-6.