Reducing Energy Consumption in a WWTP. Case study: Constanta Nord WWTP

Nicolae Ion¹, Andreea Ghiocel¹, Valeriu Panaitescu¹, Mariana Panaitescu²

¹Politehnica University of Bucharest, 313, Splaiul Independentei, Bucharest, Romania
²Constanta Maritime University, 104, Mircea cel Batran, Constanta, Romania

ghiocel.andreea@gmail.com

Abstract. The 21st century society is faced with a serious issue that is worsening day by day: water scarcity. The lack of fresh water resources that fail to meet the increasing demand of the population led to 844 million people living without access to safe water, 2.3 billion people living without access to improved sanitation and 1 million people killed by water, sanitation and hygiene-related disease each year. One of the possible solutions to tackle this problem, would be the construction of wastewater treatment plants. But looking more in-depth at the issues, we can definitely say that wastewater treatment is a very capital-intensive process, especially due to its high energy consumption. This paper presents two solutions to decrease the energy consumption in a wastewater treatment plant, following the case of the turbo blowers in Constanta Nord WWTP.

1. Introduction

As we know, the water scarcity issue that we are facing, is forcing us to design and implement new, sustainable ways for managing water resources. This is also a valid argument as we are discussing the issue of treating wastewater.

Wastewater treatment plants appeared as a water management solution, back in the days when people realized that the existing power of water sources to self-clean, was beginning to be overwhelmed.

During the treatment, the wastewater goes through a series of mechanical, chemical and biological processes. The mechanical aspect is the step where all the large bodies contained in the water, like cans, tree branches, sticks and plastics, are filtered through a bar screen. After this stage, the water is temporarily held in grit chambers, where all the solid particles settle to the bottom, while grease, oil and other lighter solids raise to the surface. The chemical and biological processes are the steps where the organic substances in the influent are neutralized [1].

The biological step is the most important in a treatment plant, as during this stage a series of highly important processes take place: the carbon and phosphorus elimination, the nitrification-denitrification process and also the oxygen consumption of the nitrogen compounds[2].

In order for these processes to run at normal parameters, we need a good aeration and mixing systems within the bioreactors. The aeration system consists of turbo blowers that provide the necessary air for the aeration process, the pipeline system connecting the turbo blowers and the diffusers mounted on the pipes inside the bioreactors to about 25 centimeters from the bottom of the bioreactors. The mixing system is made up of several mixers to ensure the continuous homogeneity of waste water with recirculated sludge. The turbo blowers are required to aerate the bioreactors, but in
addition to aerating some bioreactor areas, the air introduced into the bioreactors contributes to the sewage sludge homogenization.

In the case of the SEAU Constanța Nord the aeration system used is based on a system in which the air bubbles reach the bioreactor by means of the diffusers, which are actually plastic devices that allow the release of air through the rubber membranes provided with some holes, the system being completed by four turbo blowers. If in the past the holes in the rubber membranes were larger, the diffusers with which the aeration systems within the SEAU Constanța Nord are equipped, have smaller holes, the so-called fine bubble diffusers. It has been necessary to reduce these holes as it has been observed that the oxygen transfer has a much higher yield when the diffusers have smaller orifices. This is possible because the air bubbles coming out through these holes also have smaller dimensions, thus increasing the size of the oxygen transfer surface from the intrusion air into the bioreactors. This system is preceded by four turbo blowers.

One of the great downsides of using the turbo blowers is that they are the greatest energy consumer within the plant. Basically, they account for around 50% of the total energy consumption of the plant, as it can be seen in table 1.

Despite using an improved and newer version of the original turbo blowers installed, they are still far from being low-energy. The purpose of this paper is presenting two solutions to reduce the energy consumption due to the use of the turbo blowers.

2. Energy consumption within the Constanța Nord WWTP

One of the great downsides of using the turbo blowers is that they are the greatest energy consumer within the plant. Basically, they account for more than 50% of the total energy consumption of the plant, as it can be seen in table 1.

Despite using an improved and newer version of the original turbo blowers installed, they are still far from being low-energy. The purpose of this paper is presenting two solutions to reduce the energy consumption due to the use of the turbo blowers.

| Table 1. Monthly energy consumption distribution in a WWTP (kWh) |
|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|
| Week                        | MCC1 (Mechanical Step)      | MCC2 (Bioreactors)          | MCC3 (Decanters)            | MCC4 (Sludge dehydration)  |
|                             | Weekly Total                |                             |                             |                             |
| Week 1 (days 1-7)           | 16.618                      | 39.466                      | 8.449                      | 168                         | 64.701                      |
| Week 2 (days 8-14)          | 19.258                      | 44.875                      | 8.702                      | 3.240                       | 76.075                      |
| Week 3 (days 15-21)         | 18.937                      | 45.315                      | 7.827                      | 8.670                       | 80.749                      |
| Week 4 (days 22-28)         | 20.205                      | 42.536                      | 9.336                      | 7.205                       | 79.282                      |
| Week 5 (days 29-30)         | 5.653                       | 10.896                      | 2.635                      | 989                         | 20.173                      |
| Total                       | 80.671                      | 183.088                     | 36.949                     | 20.272                      | 320.980                     |

However, some of the wastewater treatment plants can be equipped with sludge treatment technologies, like methane tanks that make it possible to produce methane out of this primary by-product of the treatment process. If we use this methane is installations designed to produce electricity,
we can achieve a small reduction in the power consumption of the wastewater treatment plant, thus reducing the price per cubic meter of treated water.

3. Reducing energy consumption during the biological treatment
Reducing the energy consumption of Constanta Nord WWTP’s turbo blowers (Table 2 and Figure 1) is being constantly researched, operationally-wise.

| Characteristic            | Type                      |
|---------------------------|---------------------------|
| Model                     | KA120SC                   |
| Capacity                  | Min: 1013 mbar; Max 1723 mbar |
| Air temperature           | 20°C - 40°C               |
| Speed                     | 14.582 rpm                |
| Power                     | Min: 142 kW; Max 295.7 kW |
| Engine power              | 355 kW                    |
| Engine speed              | 2.980 rpm                 |

**Figure 1.** Turbo blower at Constanta Nord WWTP
Reducing energy consumption when operating the turbo blowers can happen by two methods: operating under lowest consumption protocols or by improving the technology used.

For a more economical operation of the turbo blowers, the parameters of the treatment plant and the changes applied on these parameters must be monitored in order to make it possible to reduce the electricity consumption. For an energy-sustainable operation of the turbo blowers we need to monitor if the changed settings are still within the working parameters. Figure 2 shows the first turbo blower’s parameters when operating: the electrical current absorbed through the network along with the pressure levels at a set time. The pressure level provided in the system is directly proportional to the intensity of the electric current absorbed.

![Figure 2. Pressure limit [2]](image)

Figure 3 shows the level at which the air system’s slide valve is open. Additionally, the bioreactor’s O₂ concentration value is displayed.

The plant’s command system is the one that decides how long the slide valves have to be open for, depending on the O₂ concentration. We notice that if we override the commands and manually input new parameters for the opening of the slide valves, the energy consumption can be significantly reduced. This happens due to the command’s system also handling the width of the slide valves’ openings. The level at which the ventilation system valve is opened is directly proportional to the turbo blowers power consumption, as a lower opening level implies less air in the bioreactor, so a lower power operation, which is a very convenient situation when we are looking at reducing the energy consumption. Nonetheless, this is a lengthy process, during which the turbo blower has a high energy consumption as the command system monitors all parameters from the plant and adjusts the valve’s opening step-by-step. This can be changed manually, saving energy from both air pressure reduction and the modification of the slide valve widening. The system can do this but it takes a long time, as you can see in figure 4. If the O₂ concentration is high and the slide valve is only slightly opened, the oxygen consumption can be reduced by lowering the air system’s pressure. This parameter cannot be modified by the command system. This is also the only option that does not require new technology acquisitions.
Turbo blower 1 was monitored for 24 hours, it can be seen that increasing or decreasing electricity consumption is very slow, as it can be seen in figure 4.

In order to reduce energy consumption at the turbo blower’s level by other means than manually, modifications when it comes to size, location and financial investment need to be made. One beneficial change can be installing two smaller (capacity) turbo blowers. This is due to the fact that at any point only one turbo blower can be operated, powering the second one only if needed. This would not require manual supervision.
A second change would be investing in frequency changers. These would be installed to feed into the turbo blowers, reducing the energy consumption by sustainably managing the turbo blower’s engine.

The last option would be completely replacing the existing system and introducing a newer and improved set of turbo blowers.

4. Conclusion

When we talk about wastewater treatment, we automatically refer to environmental protection. We can only achieve that by minimizing as much as we can the negative impact we have upon it. Producing and using energy is an intrinsic part of life, thus the need for sustainable energy use in society and industry.

While explicit calculations have not been shared in this paper, my estimate would be that with a proper and efficient operating mode, 100 kW/day of energy can be saved.

Specifically referring to the first two potential changes, smaller turbo blowers and introducing frequency changers, the reduction would be at least about 50 kW/h. The third option depends on what kind of technology would be used and in order for it to be cost effective, the most important characteristic that it needs to have – to show a 45% energy consumption reduction. Operating with lower capacity turbo blowers when the oxygen concentration is at optimal parameters requires a very low consumption in comparison to the energy consumption of the installed turbo blower, even at low power. In case of frequency converter operation, it is possible to operate the turbo blower at a power less than the minimum power when operating without a frequency converter, which implicitly leads to reduced electricity consumption.

References
[1] D.I. Robescu, S Lanyi, A. Verestoy, D. Robescu, Modelarea și simularea proceselor de epurare, Ed. Tehnică, București, 2004;
[2] Bosneagu, R., Scurtu, I.C., Popov, P., Mateescu, R.-D., Dumitruache, L., Mihailov, M.-E., Simulation on Marine currents at Midia Cape-Constanta area using computational fluid dynamics method, (2018) Thermal Science, 22, pp. 353-360. DOI: 10.2298/TSCI1705058247B
[3] Dobref, V., Popa, I., Popov, P., Scurtu, I.C., Unmanned Surface Vessel for Marine Data Acquisition, (2018) IOP Conference Series: Earth and Environmental Science, 172 (1), art. no. 012034, DOI 10.1088/1755-1315/172/1/012034
[4] Scurtu, I.C., Manufacturing and design of the offshore structure Froude scale model related to basin restrictions, (2015) IOP Conference Series: Materials Science and Engineering, 95 (1), art. no. 012068, DOI: 10.1088/1755-1315/95/1/012068
[5] Katona C, Panaitescu V., Scurtu I.C., Optimal parametric rudder shape based on numerical analysis using commercial software CFX, CIEM Conference, 7th International Conference on Energy and Environment, Iasi, Romania, ISSN 1223-7027.
[6] Scurtu I.C.- CFD Simulation Approach for Semisubmersible Response in Waves Based on Advanced Techniques, Applied Mechanics and Materials Vol 772 (2015) pp 108-113, © (2015) Trans Tech Publications, http://www.ttp.net/978-3-03835-502-1.html, Switzerland, doi:10.4028/www.scientific.net/ AMM.772.108.
[7] A. Nedelcu, C. Clinci, A Survey Of Autonomous Vehicles In Scientific Applications, “Mircea cel Batran” Naval Academy Scientific Bulletin, Volume XX – 2017 – Issue 2
[8] The captions were taken at the Constanta Nord WWTP, SCADA and ACRON programs.