VENTILATION AND DEODORIZATION SYSTEM OPTIMIZATION OF A WASTEWATER TREATMENT PLANT

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Abstract: *Quality of life is entirely linked to air quality around us, whether inside or outside a building. Therefore, it is not surprising that the owners and occupants of certain spaces pay attention to the air quality, especially when they work or are close to a wastewater treatment plant. The aims of this work are to diagnose the existing situation in ventilation and deodorization system of covered wastewater treatment plant and to suggest changes to improve indoor air quality and make the operation of this system more reliable and economical. The ventilation system, consisting of 10 air handling units, supply 230.000 m^3/h, where some ventilation lines have 250 m.*

The system's optimization solution, as well as the two new centrifugal fans implementation, with speed variation, allow a reduction in the total fans power to 60 kW and increase the energy efficiency in 60 %.

Keywords: air quality, deodorization, scrubber, ventilation, energy efficiency

1. INTRODUCTION

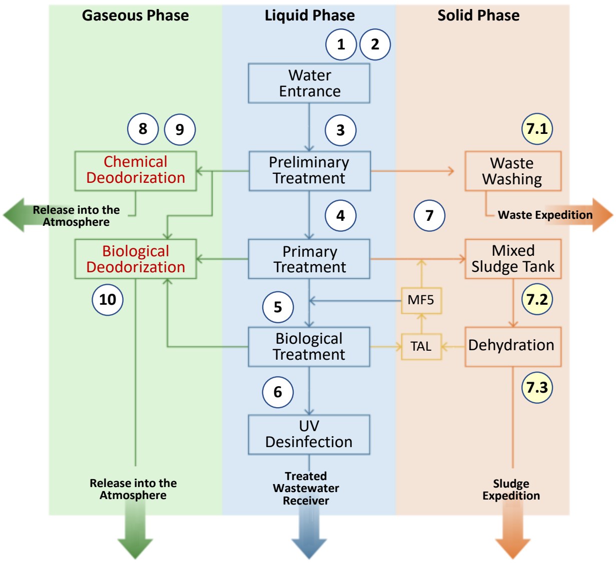
To ensure comfort conditions inside a building, there is a need to improve air quality by eliminating contaminants or pollutants and controlling temperature and humidity. However, care should be taken to assess and control whether the activity of that building, or industry can result in a safety issue, referring to human activity and polluting emissions to the ambient air, causing undesirable changes in these places [1]. One of the polluting groups, which is the main cause of people's complaints about atmospheric air quality, are odours emitted by wastewater treatment plants (WWTP).

Deodorization methods, applied in wastewater treatment plants to limit the emission of unpleasant odours, are often omitted [2]. Biofiltration is one of the methods used for air purification, being characterized by its high efficiency in removing volatile organic compounds from the air [3–6]. In addition to the environmental impact of wastewater treatment plants, energy consumption due to their operation is also one of the problems. In a recent work, González-Martin et al [7] analysed indoor air pollution control strategies and found that the implementation of biotechnologies would bring benefits in indoor air quality as well as reducing energy costs in buildings. In a WWTP, for this improvement in indoor air quality and energy efficiency to occur, there is a need to consider the best way to dilute and extract pollutants, never neglecting the improvement in energy efficiency. Through numerical simulation, using Computational Fluid

Dynamics, several configurations were carried out for the evacuation of pollutants, having been possible to define the optimal solution for the general ventilation of the place and for the improvement of the technological parameters and the working conditions [8].

2. GENERAL SPECIFICATIONS

To treat the polluted air resulting from the entire wastewater treatment process, the covered WWTP is equipped with a ventilation and deodorization system that treats polluted air in two different ways: one chemical and one biological, being the latter reserved for the entrance area. In figure 1 it can be visualized the WWTP treatment processes and the relationships between them.



WWTP Processes

1. Water Entrance North
2. Water Entrance South
3. Preliminar Treatment
4. Primary Treatment
5. Biological Treatment (Secondary)
6. UV Desinfection
7. Sludge Treatment
    7.1 Waste Washing
    7.2 Mixed Sludge Tank
    7.3 Dehydration
8. Reagents Building
9. Chemical Deodorization
10. Biological Deodorization

Figure 1. WWTP treatment processes and the relationships between them

The WWTP ventilation and deodorization system, whose scheme is shown in Figure 2, is highly complex, with spaces needing differentiated renovation, forced and natural insufflations and duct branches with lengths of up to 250 m. Air compensation is obtained directly from outdoor (ODA) or indirectly by recirculation (RCA and/or SEC) in the 10 existing air handling units (AHU). In the WWTP chemical deodorization system, the contaminated air is extracted through a network of ventilation ducts from the primary, biological and sludge treatment buildings, and flows into an "air plenum", from which it is aspirated by two centrifugal fans that feed two separate treatment lines, each one with 4 scrubbers, and then released into the atmosphere through the chimney.

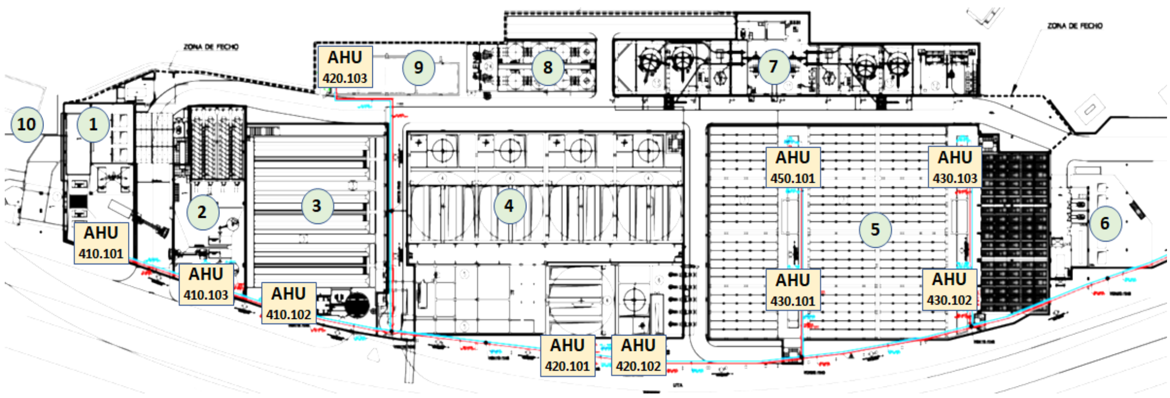


Figure 2. AHU of the WWTP ventilation and deodorization system

In order to make installation more flexible and allow chemical deodorization for occasional extracted air flow increases from areas that prove to be deficient, there are also two ducts, equipped with motorized registers and their own axial fans, which allow that extracted air (EHA) from biological treatment can be directly channelled to the chimney without being treated by chemical deodorization system. The use of these by-pass ducts will only be possible if the corresponding access valves to the plenum are closed and if it is verified that air resulting the junction of extracted air from the biological treatment and treated air, both driven to the chimney, presenting a pollutant load not exceeding 300 UO/m^3.

The biological deodorization system (1-3) is a chemical deodorization system reinforcement. In the entrance area, a centrifugal fan sucks in the air from entrance area, preliminary treatment and reagent buildings which is later humidified in a washing system consisting of a tank with water and a washing tower where the water is sprayed on the aspirated gases. This humidified air is treated in a biofilter using biomass fixed in heather. Table 1 show the relationship of existing flows in biological and chemical deodorization systems.

Table 1. Air flows in the biological and chemical deodorization systems

Biological Deodorization					**Chemical Deodorization**				
Site	**ODA (m^3/h)**	**SEC (m^3/h)**	**EHA (m^3/h)**	**AHU**	**Site**	**ODA (m^3/h)**	**SEC (m^3/h)**	**EHA (m^3/h)**	**AHU**
North Entrance	25 000	6 000	31 000	410.103	Primary Treat.	22 000	85 000	27 500	420.101 & 102
South Entrance	2 000	8 000	3 380	410.101	Sludge Treat.	24 310	45 689	69 999	450.101
Preliminar Treat.	9 000	19 000	17 000	410.102				(45 689 + 24 310)	
Reagents Build.	1 000	1 531	2 531	420.103	Biological Treat.	48 000	52 200	66 000	430.101, 102 & 103
								(33 000 + 33 000)	
Total	**37 000**	**34 531**	**53 911**		Total	**94 310**	**182 889**	**163 499**	

Actually, several AHU, and in particular the one that does the air treatment in the sludge treatment building, are practically inoperable due to the constant filters' clogging and to the lack of appropriate maintenance. This deficient air treatment capacity, aggravated by the insufficiently treated air recirculation in a closed WWTP, allow poor indoor air quality and the concentration of strong odours in certain areas.

3. IDENTIFICATION AND TECHNIQUES OF DEODORIZATION PROPOSED

3.1. Biological deodorization system

On north side of entrance area, it is proposed to introduce electrostatic filters sized for a flow of 25.000 m^3/h to improve air quality. On the south side, the elimination of air recirculation is recommended, since it does not bring any benefit to the quality of the interior environment, having instead a pernicious effect on the AHU filters performance, due to its rapid clogging. Considering this change, the outdoor air (ODA) flow becomes 2,800 m^3/h, recommending for this purpose the outdoor air intake grille alteration and an electrostatic filter introduction, both dimensioned for this flow value.

In preliminary treatment, an increase in extraction air (EHA) flow from 17,000 m^3/h to 30,000 m^3/h is considered to guarantee a 3.5 air changes per hour, considering a new extraction duct to be installed in the south end of the room with connection to the extraction duct for the biofilter. Additionally, the installation of grilles with manual regulation in the new extraction duct is considered, to be able to regulate the extraction flow in this duct in the event of replacing the covering screens of preliminary treatment tanks that are now inoperative. The elimination of the air recirculation is also recommended, including dismantling the recirculation duct. To improve air quality, an increase in outdoor air flow to 24,000 m^3/h, corresponding to 80% of the extraction flow, is foreseen. For this purpose, the outdoor air intake grille will have to be enlarged and an electrostatic filter must be introduced, both dimensioned for a flow of 24,000 m^3/h. On the other hand, in order to sweep the entire place longitudinally with outdoor air, the air duct existing at the north end must be extended. After carrying out the system operation and considering the recommended changes, the air flows to be deodorized by the biofilter will be those shown in table 2 and figure 3.

3.2. Chemical deodorization system

Table 2 and Figure 3 shows the air flows proposed in the biological and chemical deodorization system.

In primary treatment, main changes considered are air recirculation elimination and the AHU mixing boxes alteration. Additionally, it was considered to equip the air intakes with electrostatic filters sized for a flow of 11,000 m^3/h and make the smoke extraction circuit autonomous.

Table 2. Air flows in the biological and chemical deodorization system (proposal)

Biological Deodorization					**Chemical Deodorization**				
Site	**ODA (m^3/h)**	**SEC (m^3/h)**	**EHA (m^3/h)**	**AHU**	**Site**	**ODA (m^3/h)**	**SEC (m^3/h)**	**EHA (m^3/h)**	**AHU**
North Entrance	25 000	6 000	31 000	410.103	Primary Treat.	22 000	5 500	27 500	420.101 & 102
South Entrance	2 800	580	3 380	410.101	Sludge Treat.	40 600	29 399	69 999	450.101
Preliminar Treat.	24 000	6 000	30 000	410.102				(45 689 + 24 310)	
Reagents Build.	1 000	1 531	2 531	420.103	Biological Treat.	57 000	9 000	66 000	430.101, 102 & 103
								(33 000 + 33 000)	
Total	**52 800**	**14 111**	**66 911**		Total	**119 600**	**43 899**	**163 499**	

In sludge treatment building, it is necessary to replace clogged filters and disconnect the air recirculation circuit. In addition, outdoor air intake duct external grille will have to be resized and an electrostatic filter introduced, both for a flow rate of 40,600 m^3/h, which will correspond to 58% of extracted air flow. In this way, to facilitate the 29,600 m^3/h remaining air flow entry from the corridor, additional underpressure grilles must be installed in access doors, each one with a minimum area of 1 m^2.

For the biological treatment building, it is recommended air recirculation circuits elimination and outdoor air intake circuits alteration, that will be dimensioned for 19,000 m^3/h flow for each AHU. The outdoor air intake grilles of each AHU must be also resized for a 19,000 m^3/h flow and should also be considered the introduction of electrostatic filters sized for the same flow rate.

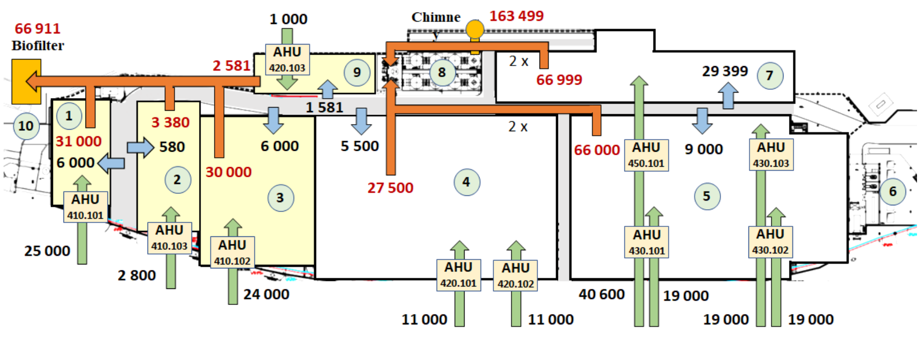


Figure 3. Air flow balance in the biological and chemical deodorization system (proposal)

4. SYSTEM OPTIMIZATION AND SIZING

4.1. Proposed deodorization systems

In biological deodorization system, the existing equipment allows expected air flow extraction, being necessary to carry out changes considered in point 3.1 and make operating conditions adjustment. The existing fan, equipped with a speed variator, has an extraction capacity for the 13,000 m^3/h additional flow considered for the preliminary treatment.

In chemical deodorization system, ventilation and deodorization system head loss is currently very high. This is essentially due to scrubbers clogging, high air flow speed in fans suction collectors and the deficient layout and configuration of connecting ducts to fans. In order to improve the system functioning, it is proposed to join the two suction collectors so that their section results in 7500 x 1000 mm^2, as shown in Figure 4, using guides inside to optimize air flow, as well as the replacement of fans for more efficient units and requiring less mounting space. The use of a single suction collector to fans, as proposed, reducing the air velocity from about 15 m/s to 6.2 m/s, and the geometry improvement in final connection to fans, allow a head loss reduction of about 150 Pa.

Additionally, scrubbers functioning improvement was also considered, through filling material replacement, to optimize polluted air flow and its contact with reagents, which result approximately in a head loss reduction of 100 Pa per scrubber comparing with current situation.

In order to obtain sizing parameters to the new fans, the extraction ducts that flow into the fans' air plenum head losses were calculated, as well as chemical treatment system head losses, from air plenum to chimney, where polluted air is expelled after being treated [9–11]. Of the extraction ducts that flow into the air plenum, the one with the highest head loss, with 887 Pa, corresponds to one of two extraction ducts coming from the biological treatment (north side).

Given the existence of the two bypass ducts mentioned above, if the 66,000 m^3/h extracted flow from the biological treatment will be routed directly to the chimney, there is the possibility of chemical deodorization system may treat the 30,000 m^3/h extracted flow from the preliminary treatment, taking advantage of scrubbers' available capacity. In this way, extraction ducts head loss since preliminary treatment to fans air plenum was also calculated. A total head loss value of 870 Pa was obtained, which is lower than the critical ducts head loss that flows into the air plenum, which amounts to 887 Pa.

In conclusion, by sending the air extracted from the biological treatment (66,000 m^3/h) to the chimney, the air extracted from the preliminary treatment (30,000 m^3/h) can be sent to air plenum (Figure 4). Since head loss is lower than the critical ducts head loss that flows into air plenum, this decision does not affect fans design parameters, which can be dimensioned considering the flow rates and head losses associated with the most severe air extraction situation (primary, biological and sludge treatment buildings).

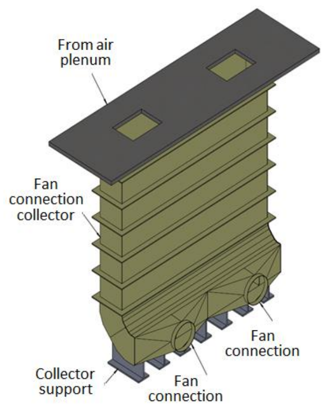


Figure 4. Fan connection collector schematic

4.2. Sizing of the ventilation system

In order to calculate the total head loss to be overcome by the chemical treatment fans, 4 chemical deodorization system operating scenarios were studied. It was considered the possibility of using 3 or 4 scrubbers in each chemical deodorization line and the possibility of treating the air extracted from the biological treatment or routing it directly to the chimney. The results obtained are shown in Table 3.

Table 3. Chemical deodorization system operating scenarios

Fan's Motor Power Sizing					
Fan Data		**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**
Air Flow	(m^3/h)	81 750		48 750	
	(m^3/s)	22,7		13,5	
Head Loss	(Pa)	2348	2088	2082	1837
Motor Efficiency		0,95		0,95	
Fan Efficiency		0,7		0,7	
Absorbed Power	(kW)	**80,2**		**42,4**	

Scenario 1 - Primary, Sludge and Biological Treatments + 2 x 4 Scrubbers

Scenario 2 - Primary, Sludge and Biological Treatments + 2 x 3 Scrubbers

Scenario 3 – Primary and Sludge Treatments + 2 x 4 Scrubbers

Scenario 4 – Primary and Sludge Treatments + 2 x 3 Scrubbers

Replacing current chemical deodorization fans with more efficient ones allows for a reduction in fans energy consumption, the design flow rates maintenance, the operational safety increase and system maintenance optimizing. The selected fans have three-phase asynchronous motors driven by frequency inverters, not requiring the use of belts, and are dimensioned to achieve a unit air flow of about 1.5 times the rated flow in the event of the other fan failure. The two recommended fans, equipped with 101 kW motors, have a total unit airflow of 81,750 m^3/h and head loss of 2,348 Pa. For similar operating points, the proposed fans allow a power reduction of about 30 kW for each fan, compared to those currently installed, with an efficiency superior by 60 %, resulting in significant savings in energy consumption.

CONCLUSIONS

The ventilation system, consisting of 10 AHU, supply 230 000 m^3/h in the WWTP complex, where some ventilation lines have 250 m. It is verified that the outside air is very polluted, requiring constant maintenance due the filters' clogging in air intakes. Additionally, the chemical deodorization system comprises two distinct lines with four scrubbers each, fed by two belt driven centrifugal fans, without frequency inverter, with individual power of 132 kW and poor efficiency. The installed fans capacity is deficient given the existing conditions, and they have a head loss to 3080 Pa, which leads to high energy costs. It is also proven that indoor air quality is not guaranteed, since the existence of odours in certain areas of the WWTP.

The system's optimization solution is mainly based on the introduction of electrostatic filters in outdoor air intakes, elimination AHU air recirculation and changes in the duct system, namely the connection between air plenum and chemical deodorization fans. This last change allows a reduction in air velocity and a head loss of 150 Pa at the entrance of fans. By also changing the scrubbers' filling, it is also possible to reduce the total head loss by roughly more than 500 Pa. These changes, as well as the two new centrifugal fans implementation, with speed variation, allow a reduction in the total fans power to 60 kW and increase the energy efficiency in 60 %.

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