

The influence of the vitiated air from the treatment plants on the urban and rural development

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Abstract. In order to reduce the emissions produced by the operational flow of a wastewater treatment plant, regardless of whether they are located in urban or rural areas, the quality of air must be analyzed. For this reason, the Constanta Nord treatment plant was chosen as a study location. This is near the Mamaia resort and does not fall within the recommended sanitary protection norms, according to NP-032-1999 (at least 300 m from the last house). Therefore, it was necessary to take measures to reduce the repellent gases generated in the neighborhood of wastewater treatment plants. The solution is in attention of all wastewater treatment plants from the world because this depend on operational flux management and health of population. The research consists of: description of the technological flow of the treatment plant and in particular of the deodorizing installation of the contaminated air, choosing a work scenario for a day with 2 shifts per hour, respectively 6 shifts per hour, the air flow needed to treat the vitiated air (the deodorization plant components) and the efficiency of the regulation system from the point of view of energy consumption. Also, possible leakage of dangerous gases into the atmospheric air was monitored (H₂S, Cl₂, CO), taking into account the fact that in the immediate vicinity there is the Mamaia resort, the student housing and rural locations Palazu and Mamaia village.

1 Introduction

Europe's air quality has been improving in recent decades. However, many people continue to be negatively affected by air pollution, especially in cities. Given its complexity, tackling air pollution requires taking coordinated action at many levels [1]. The level of emissions of pollutants released into the atmosphere may be reduced significantly through the implementation of environmental policies and strategies such as:

- greater use of renewable energy sources (wind, solar, hydro, geothermal, biomass);
- replacement of conventional fuels with alternative fuels (biodiesel, ethanol);

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- the use of plants and equipment with high energy efficiency (low consumption, high yields).

“Policy makers and governments has focused their attention on air quality in the urban areas only. Air quality in rural areas remains a neglected issue so far” [2]. More than 100 substances in rural areas have been identified, like solids, vapors, gases. There are many natural sources of air pollution like: SO₂, Nox, carbonaceous particles, non-carbonaceous primary particles, ozone, volatile organic compounds (Voc; e.g. isoprene). The causes of air pollution in rural locations are natural (contaminants from animals, plants and land resources- spores, pollens, moulds, fur, feather, hair, dander, dust, grit, etc, forest fire, coal fires, dust storm, sand storm, meteorological factors, topography, air movements and climate) and anthropogenic (human activities) [3], [4], [5], [6], [7], [8].

Along with the existing causes in the rural environment adjacent to urban areas, the influences of urban pollution are added as a result of meteorological and anthropogenic factors. These caused are called trans-boundary pollution [2]. One of these sources is the pollution generated by uncontrolled emissions into the atmosphere from wastewater treatment plants. The SO₂ concentration in air would threaten physical health and even cause respiratory system diseases [4]. A study found that higher SO₂ and NO₂ particles would increase risks of suicide [5], [7].

For this reason, the Constanta Nord wastewater treatment plant (WWTP) was chosen as a study location (Figure 1). This is near the Mamaia resort and does not fall within the recommended sanitary protection norms, according to NP-032-1999 (at least 300 m from the last house). Therefore, it was necessary to take measures to reduce the repellent emissions generated in the neighbourhood of wastewater treatment plants.



Fig. 1. The sewage treatment plant in North Constanta –View after covering the objectives that gave repellent gases

The paper proposes a solution for optimizing the process of air deodorization and optimization of operating costs and energy for this solution. The solution is in attention of all wastewater treatment plants from the world because this depend on operational flux management.

There are three units of air deodorization stations in the sewage treatment plant North Constanta. These units purify the air resulting from the operation of bioreactors, secondary settler tank, distribution chambers and the connection pipes. We propose a study on the quality of the treated air, but at the same time, the study will focus on the consumption of

electricity. We will also try to identify the possibilities of reducing the electricity consumption that is absorbed from the grid using oxygen detectors on bioreactors.

2 Plant description

2.1 Operational flow

The operational technological flow in Constanta North Wastewater Treatment Plant (WWTP) (Figure 2) contents: primary stage, secondary stage and tertiary stage.

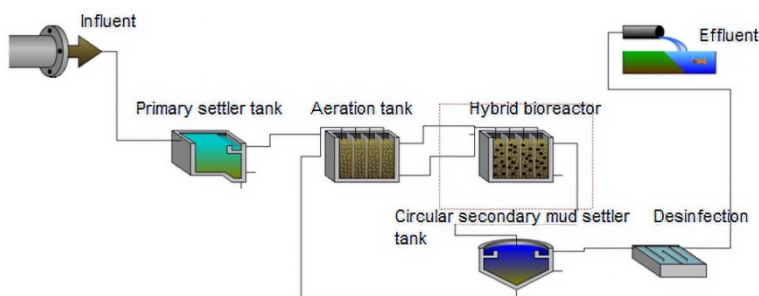


Fig. 2. Operational flow in WWTP Constanta-North.

Major processes of treatment includes [9], [10]: a) physical treatment-remove suspended large solids by settling or sedimentation and eliminate floating greases; b) biological treatment-degradation or consumption of the dissolved organic matter using the means of cultivated in activated sludge or the trickling filters; c) chemical treatment-remove other matters by the means of chemical addition or destroying pathogenic organisms through disinfection; d) advanced treatment- removing specific constituents using processes such as activated carbon, membrane separation, or ion exchange. Particular treatment processes are: a) sedimentation; b) coagulation and flocculation; c) activated sludge; d) sand filters; e) membrane separation; f) disinfection.

2.2 The deodorization plant

Three deodorization units were designed using H_2S concentrations to reflect the odor levels to be removed. To treat the waste air from these surfaces and processes, we selected several activated carbon treatment systems based on the volumes corresponding to the objectives, the number of air changes required, the anticipated levels of H_2S contaminant and the imposed emission limits. Although there are several odorous substances at a treatment plant, the deodorization units were designed using H_2S concentrations to reflect the odor levels that need to be removed [9], [10].

2.2.1 Second settling deodorization plant

The deodorization units that equip each of the secondary settler tanks extract the air from the free space between the surface of the water, the walls and the roof of the settler tank through a suction tube and lead it into the air treatment compartment composed of two parallel activated carbon blankets which they absorb H_2S as well as other odorous gases as well as suspended particles. This treated air is then discharged into the atmosphere through a chimney. The deodorization units of the secondary settler tanks are installed outdoors on concrete platforms specially designed for them. Each secondary settler tank has a deodorization unit. The deodorization units of the decanters are designed to make 2 shifts of the entire volume of air per hour (Figure 3) and 6 shifts of the whole volume of air per hour (Figure 4) when an operator wishes to enter the settler tank. The air flow requiring treatment is calculated based on the number ACH - the number of air exchanges per hour, from the capsule volume. For decanters, the volume of air between the surface of the water in the decanter and the roof is 8872 m^3 . The two projected situations take into account 2 ACH when the operators are not in this space and 6 ACH when they are the operators in this space.

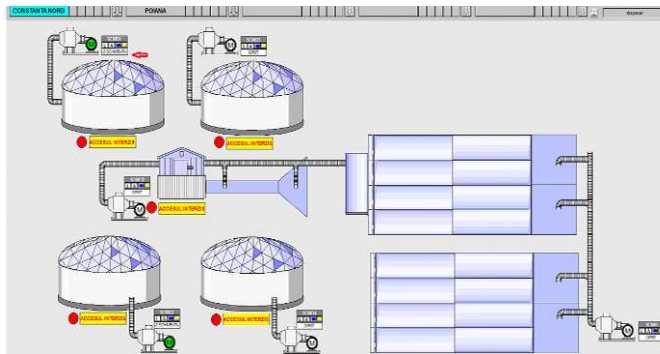


Fig. 3. Operational flow-2 shifts per hour

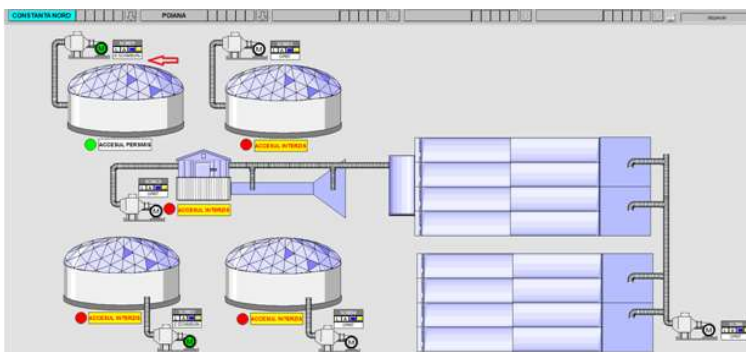


Fig. 4. Operational flow-6 shifts per hour

2.2.2 Bioreactors deodorization plant

Bioreactor deodorization unit extracts air from the free space between the water surface and roof from the four bioreactors and leads it to the air purification compartment composed of two parallel activated carbon blankets that absorb H_2S and other odorous gases as well as particles. in suspension. This treated air is then released into the atmosphere through a chimney.

The bioreactor deodorization unit is designed to operate a volume of $44,000 \text{ m}^3 / \text{h}$ which represents the aeration rate of the bioreactor plus 10% for compensation if there is air leakage through the roof (Figure 5). The roof of the bioreactor is not designed to allow personnel to enter. The operational staff will not be able to get under the roof because the air in it does not have enough oxygen to hold the breath. The bioreactor deodorization unit is installed outdoors, on a concrete platform.

The four bioreactors are provided with roofs that form eight separate air spaces (two cells per bioreactor). The operation on the two shifts (2 shifts per hour, respectively 6 shifts per hour) implies a monitoring of the odor treatment units at the secondary settler tanks.



Fig. 5. View of the bioreactor distribution chamber

2.2.3 Deodorization plant. Distribution rooms-connection pipes

The deodorization unit of the pipes and the distribution chambers extracts the air from the free space between the surface of the water, walls and roof, leads it to the treatment compartment composed of a series of three layers of activated carbon for the absorption of H_2S and other obnoxious gases plus suspended particles. This treated air is then released into the atmosphere through a chimney. The deodorization unit of the distribution rooms and the channel is installed outdoors, on a concrete platform (Figure 6).



Fig. 6. Deodorized air defective station mechanical cleaning stage

The deodorization unit of the distribution chambers and the connection pipes is designed to provide 2 shifts of the entire air volume per hour and 6 shifts of the entire air volume per hour when an operator wishes to enter the closed spaces. The air flow requiring treatment is calculated based on the number of ACH shifts, the number of air exchanges per hour, from the capsule volume. For the distribution room, the closed volume of air is 1070 m³.

3 Research and methods

3.1 Design scenarios

The design scenarios provide for 2 (ACH) shifts when the operators are not in the encapsulated space and 6 (ACH) shifts when they are operators in the encapsulated enclosure. The clean air comes through the ventilation slots left on the roof of the rooms. Being a very short section, the diameter of the manifold pipe is chosen: 1200 mm since, whenever it is possible and even necessary to stop and isolate one or maximum of two bioreactors, it has been provided that the system of collecting pipes of the vitiated air will be equipped with elements of adjustable closing of the extracted air flow. Thus, four dampers with a diameter of 600 mm were introduced into the installation, equipped with butterfly type lenses and devices for regulating the flow of extracted air. Keeping the constant velocity of 10.16 m / s of air flow through the piping system, from the central tube of 1200 mm diameter, two pipes, left / right, of 900 mm diameter, each of them ensuring the extraction of the vitiated air from two bioreactors. Further, each of these two pipes is branched into two pipes of 600 mm diameter, one for each bioreactor (table 1). Due to the production of reinforced concrete beams, four in number, in each bioreactor, with the role of creating supports for the new roofs in zone A of the bioreactors, each bioreactor can be considered to be composed of two distinct cells, cell 1 and cell 2, separated through the concrete beam to which we refer. For the extraction of the vitiated air from the two cells of each pipe of 600 mm diameter, equipped with a damper of the same diameter, another two pipes, one of 600 mm diameter each, for cell 1 and another 450 mm diameter for cell 2 are branched.

The dimensions of the pipes for extracting the foul air are calculated so that the air speed is kept below 10.16 m / s, which prevents excessive pressure losses in the pipe. For the distribution and channel chambers there are 4 types of supply pipes (Table 1).

Table 1. Pipeline distribution and construction elements.

Location	Flow [m ³ /h]	Velocity [m/s]	Dimensions [mm]
Total	7020	10.16	500
Settler tanks distribution chamber	2148	10.16	300
Settler tanks distribution chamber plus connection channel	1980	10.16	300
Bioreactors distribution chamber	4128	10.16	450
Pumps station	2310	10.16	300
Distribution chamber plus pumps station	582	10.16	200

3.2. Experimental research

The vitiated air in these enclosures passes through the deodorizing station in which there is a mixture of tree bark that retains and filters, so that at the exit of the deodorizing station a clean air is given to the atmosphere. As this deodorizer station is equipped with an extractor.

The values of parameters for the repellent gases at the inlet and outlet of the contaminated air enclosures were measured (Table 2). When the sensors detect exceedances of the repellent gases values, a red light signal illuminates which expresses the exceeding of the standard limit value.

Table 2. The inlet standard air parameters.

Gas	Threshold alarm	Danger threshold	Unit
CH ₄	20	40	% LIE
O ₂	19	23	% Vol.
Cl ₂	0,5	1	Ppm
H ₂ S	5	10	Ppm
CO	30	60	ppm

During our scenario, overruns were reported for H₂S, Cl₂ and CO. During the study, operational parameters (inlet/outlet) are monitored with SCADA program, air parameters with Dräger X-am 5000 gas analyzer and GasSens system (Table 3).

The values of repellent gases were recorded for the case study:

Table 3. The recorded values of repellent gases parameters.

Location	H ₂ S [% LIE]	Cl ₂ [ppm]	Oxygen [% vol.]
Rare Grills	6.5	0.7	21
Desander	7.1	0.75	18
Settler tanks distribution chamber	7.3	0.75	17
Bioreactors distribution chamber+ recirculation pumps	6.7	0.6	15

GasSens is an online monitoring system for detecting dangerous gases in atmospheric air. It is designed for gas leak detection from cylinders, pipelines or gas supply equipment and for alarms, in virtually any environment from industrial installations. There are systems for monitoring different gases:

- *Sensor / transmitter* -it consists of an electrochemical gas sensor, directly coupled to a NEMA 4X transmitter. This component measures the concentration of gas and converts the measurement result into a digital signal for transmission to a receiver module. It is installed in the area where a leak or accumulation of gas is possible, either on the wall or supported by the tube for electrical cables through which the interconnecting conductors pass. Sensors / transmitters can be optionally fitted with *Auto-Test*, an electrochemical gas generator that automatically tests the sensor response daily and warns of any sensor problems. For hazardous areas there are explosion-proof sensors / transmitters.

- *Receiver module* - receives digital data from the sensor / transmitter and ensures the LED display of the gas concentration, two regulated gas alarm values, three gas alarm relays, an isolated output of 4-20 mA, as well as an alarm and a relay for damage.

- *Power supply module* - provides 12 V DC power supply. for one or two receiver modules, as well as the power supply for a siren and for charging an external battery.

- *NEMA 4X enclosures* (for alarm modules only). Four standard enclosures are available for mounting the receiver and power supply modules. The polystyrene enclosures are suitable for outdoor environments, and the digital displays and alarm indicators are very visible through a transparent polycarbonate window at the front.

- *Explosion-proof enclosures* (for gas monitors / sensors only). There are two versions that allow the use of receiver and power supply modules in hazardous areas. One version is suitable for only one receiver module, and the second version is large enough to receive both a power source and a receiver.

- *Siren* - an alarm siren, piezoelectric, of 12 V c.c. can be fitted for all NEMA 4X enclosures. The siren is connected to the receiver module and emits intermittent sounds when it reaches the set value for warning, respectively continuous sounds when it reaches the set value for alarm. The siren can be switched off by pressing the A / R switch on the front panel of the receiver.

- *Strobe lamp*- provides light status alert.

- *Backup Battery* - provides a 12 V DC, 4 AH battery and control circuits for charging, in a separate NEMA 4X enclosure. The backup battery is connected directly to the power supply module to ensure the backup power supply of the detection system.

The concentrations of gas emissions recorded at the exit from the deodorization installation are less than the allowable limit, so the impact is insignificant.

3.3 Solutions for optimizing energy consumption and monitoring oxygen levels in bioreactors

Under anoxic conditions, the denitrification process takes place, and under aerobic conditions the nitrification process takes place in the four lines of the bioreactors [11].

Therefore, in the Constanta-Nord treatment plant, four blowers are installed in operation, 1 and 2 assistance and stand-by to cover the required oxygen in the bioreactors. The electricity consumption of the turbochargers has an important weight in the general energy consumption per each stage station (table 4)[12]. The difference in consumption is due to the fact that during operation, many equipments have interruptions due to various maintenance reasons, or some have a discontinuous operating flow. Thus, each of the four THOLANDER turbochargers has a rated power of 355kW, while the FLYGT C 3400 intake pumps have a rated power of 125kW each (five pumps), and FLOTTWEG centrifuges have a rated power of 55kW each (4 centrifuges).

Table 4. Distribution of equipment by processes in Constanta WWTP.

Stage/ Power [kW]/ Energy [kWh]	Share of equipment consumption[%] $P_{instal}/P_{instal.total}$	Share of equipment consumption [%] $E_{instal}/E_{instal.total}$
Mechanical stage: P=768.83 [kW] E=4132112.4 [kWh]	25.372	20.815
Biological stage: P=1924.68 [kW] E=13704521.4 [kWh]	63.516	69.035
Mud treatment stage: P=325.86 [kW] E=2012138 [kWh]	10.754	10.136
TOTAL: P=3019.37 [kW] E=19848771.8 [kWh]	99.642	9.986

For our case study the electricity consumption for a full day of operation with 2 shifts per hour is 136 kWh (19.02 2020), and for 24 hours of operation with 6 shifts per hour is 182 kWh (20.02.2020) (Table 5).

Table 5. Operating hours index and electricity consumption index secondary deodorization stations.

Operating time	Operating hours 2 shifts/ hour [hours]	Operating hours 6 shifts/hour [hours]	The hourly energy consumption index/shifts/hour [kWh]	Energy consumption index [kWh]
18.02. 2020	4466	7642	7/2 shifts 47/6 shifts	127/2 shifts 168/6 shifts
19.02. 2020	4491	7763	6/2 shifts 46/6 shifts	136/2 shifts 175/6 shifts
20.02. 2020	4515	7862	8/2 shifts 49/6 shifts	143/2 shifts 182/6 shifts

We observe the hourly energy consumption of 2 shifts which is about 6 kWh and in the case of 6 shifts per hour it is 46 kWh. Moreover, the air flow is $18000\text{m}^3 / \text{h}$, in case of operation with 2 shifts per hour, flow that does not ensure an acceptable quality for the air inside. The air flows in the two situations are $18000\text{m}^3 / \text{h}$, respectively $53232\text{m}^3 / \text{h}$.

We analyze the efficiency of the regulation system in terms of energy consumption (turbochargers have a significant share in station consumption (over 68%).

Description of the proposed solution:

□ Small bubble diaphragm diffusers absorb pressurized air. Bioreactor air supply lines are equipped with air control valves, each tank having an air control valve.

□ Two oxygen flow meters (a main probe and a reference probe) are installed at each bioreactor to adjust the volume of air intake in the bioreactor in question. The air flow at each separate bioreactor line is measured and recorded by four flow meters.

The control of the aeration systems mainly comprises a concentration of two separate control cycles.

The assessment of ambient air quality is regulated by Law 104/2011 on quality ambient air transposing Directive 2008/50 / EC of the European Parliament and of the Council on ambient air quality [13], [14]. In Constanta county, air quality is monitored by continuous measurements in 7 stations automated located in representative areas. Pollutants in the area of Constanta Nord treatment plant, Mamaia resort and Mamaia village, are monitored by CT-3 and CT-6 stations, respectively: sulfur dioxide (SO_2), nitrogen oxides ($\text{NO}_x / \text{NO} / \text{NO}_2$), carbon monoxide (CO), ozone (O_3), benzene, particulate matter (PM10) and weather parameters (wind direction and speed, pressure, temperature, solar radiation, humidity relative, precipitation). Also, possible leakage of dangerous gases into the atmospheric air was monitored (H_2S , Cl_2 , CO), taking into account the fact that in the immediate vicinity there is the Mamaia resort, the student housing and rural locations Palazu and Mamaia village (Table 2, Table 3).

In order to protect the population from the possible effects of pollution due to the processes in the treatment plant and taking into account the location conditions, the

hydrological and climatological conditions, it is recommended to reduce the impact of repellent gases:

-rehabilitation of the ecological balance in the area of WWTP by monitoring emissions and their impact on fauna, flora and population, as well as by planting dendrological material;

- removing sludge from the site;
- controlling the wastewater treatment and sludge treatment process and monitoring parameters of these processes;
- covered structures for sludge treatment and storage;
- avoiding crossing urban and rural areas;
- avoiding wrong operational maneuvers due to human errors;
- execution of works without causing discomfort to the inhabitants by generating noxious substances, dust, noise and vibration;
- operation at the optimal designed parameters of the technological equipment and means of transport to reduce nuisance and noise that could affect the human factor.

4 Conclusions

We have done a study on the quality of the treated air, but at the same time, the study will focus on the optimization of energy consumption and oxygen level in bioreactors. We will also try to identify the possibilities of reducing the electricity consumption that is absorbed from the grid using oxygen detectors on bioreactors.

We analyzed the reduction of energy consumption at large consumers in the station and mainly at the deodorization station by proposing work on 2 shifts, respectively 6 shifts / hour, as well as the regulation of air flow, respectively oxygen level.

The control system tests the oxygen concentration in the aerobic bioreactor and maintains its value of about 1.5%.

The quick control valve system is set to operate in the 15% -65% opening range. When the oxygen detector detects reaching the 1.5% threshold, the valves open and the air flow increases; at the same time, the power consumed by the turbocharger obviously increases.

In addition to H₂S, Cl₂ and CO are also monitored. The deodorization stations aim to purify the air from the enclosures so that the limits of the concentrations of H₂S, Cl₂ and CO are within the accepted limits. The control of gas emissions outside is done through the monitoring system of the deodorization station, and the impact of these repellent gases has proven, experimentally, to be insignificant.

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