TECHNICAL STUDY FOR UPGRADING THE AERATION REGIMES WITH AUTOMATION AT EGYPTIAN WWTP'S

ZENEIN WASTEWATER TREATMENT PLANT
GIZA GOVERNORATE

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List of Abbreviations

Abbreviation	Full Form
AC	Alternating Current
BOD	Biological Oxygen Demand
CB	Circuit Breaker
CO_2-eq.	Carbon Dioxide Equivalent
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
GPM	Gallons Per Minute
GPS-X	Wastewater Treatment Process Modeling Software
HCWW	Holding Company for Water and Wastewater
HV	High Voltage
KVA	Kilovolt-Ampere
KW	Kilowatt
LCA	Life-Cycle Analysis
LV	Low Voltage
MCB	Miniature Circuit Breaker
MCCB	Molded Case Circuit Breaker
MHUUC	Ministry of Housing, Utilities, and Urban Communities
OTE	Oxygen Transfer Efficiency
PLC	Programmable Logic Controller
RAS	Return Activated Sludge
RPM	Revolutions Per Minute
RVO	Netherlands Enterprise Agency
TANW	Towards future perspectives on wastewater treatment and sustainable sludge management
TDS	Total Dissolved Solids
TOR	Terms of Reference
TSS	Total Suspended Solids
WAS	Waste Activated Sludge
WWTP	Wastewater Treatment Plant

GENERAL INFORMATION CARD

Name of the WWTP	ZENEIN WWTP
Location/Address	Zenein, EL-GIZA, Egypt
GPS Coordinates	30.034852, 31.179795 (*Location*)
Location Area	307,585 square meters
Owner/End User of the WWTP	Cairo Company for Water and Wastewater
Design Nominal Hydraulic Capacity (m^3/day)	Average Design Capacity: 330,000 m^3/day Peak Design Capacity: 450,000 m^3/day
Level of Treatment (Primary, Secondary, Disinfection)	The Zenein WWTP's employs **Secondary Treatment Process**, that includes key units such as: - Preliminary Treatment: Head Works (Inlet chamber, Screens, Grit removal). - Primary Treatment: Primary Sedimentation, Pre-Aeration. - Secondary Treatment: Conventional Activated Sludge including Roughing filters, Final Clarification. - Sludge Handling and Treatment: Return and Waste Sludge Pumping Station. - Disinfection: Chlorine Contact Tank. - Ancillary Units: Transformers, Diesel Generators, Administration and Laboratory buildings, Workshop, Store, and a perimeter fence. Together, these components optimize wastewater treatment processes in the plant to meet the standards set by Law 48/82.
Final Disposal Point	Nahya Drain

1-INTRODUCTION

1-1 Overview

Egypt's infrastructure, particularly in the water and sanitation sectors, is under significant strain due to the country's rapidly growing population, which has been increasing by nearly 2 million people annually since 2018. This population boom, primarily concentrated in the narrow Nile Valley, has intensified the demand for Egypt's already limited water resources. The situation is further aggravated by inadequate solid waste management systems, posing serious challenges in both urban and rural areas. In response to these critical issues, the Ministry of Housing, Utilities, and Urban Communities (MHUUC) and the Holding Company for Water and Wastewater (HCWW) are chiefly responsible for overseeing the country's water supply and wastewater management. Their efforts help for relaxing infrastructure pressures and promoting sustainable resource utilization.

Historically, decisions in wastewater treatment projects in Egypt have focused on adhering to national design standards and minimizing initial capital and operational expenditures. However, this approach often neglects long-term financial sustainability and environmental impacts. As a result, many wastewater treatment plants (WWTPs) struggle with high operational expenses and limited cost recovery through user fees, leading to ongoing financial burdens.

Acknowledging these challenges, the HCWW, Egypt's main authority for the operation and maintenance of WWTPs, has emphasized the need to enhance existing facilities to lower operational costs and mitigate environmental harm. In line with this strategy, three WWTPs (Sakha, Zenein, and Qaha) located in different governorates, have been prioritized for upgrades (Figure 1). Each of these plants currently provides biological treatment processes, and their optimization is important for improving overall system performance and sustainability. These WWTPs are:

1. **Zenein WWTP**: situated in Cairo Governorate, the WWTP is the largest of the three, with a peak flow capacity of 450,000 m^3/day.
2. **Sakha WWTP**: located in Kafr El-Sheikh Governorate, it has a treatment capacity of 95,000 m^3/day. A distinctive feature of this WWTP is its co-digestion bioreactor, which processes a blend of municipal sludge from the plant itself combined with cow and chicken manure, enhancing energy recovery and waste reduction.
3. **Qaha WWTP**: situated in Qalyubiya Governorate, the WWTP is the smallest among the three, handling a capacity of 6,000 m^3/day.

Despite their differing treatment capacities, these WWTPs work together to deliver efficient wastewater processing by utilizing a range of proven treatment technologies in their service areas.

Figure 1. Location map showing the three WWTPs in Egypt

1-2 Conducted Life-Cycle Analysis (LCA) Observations

An in-depth Life-Cycle Analysis (LCA), carried out by the Netherlands Enterprise Agency (RVO) in collaboration with Partners for Water Consulting, assessed the environmental performance of the selected WWTPs (Annex 1). The analysis identified wastewater treatment operations as the main source of environmental degradation across all three facilities, surpassing the impact of sludge management. This is largely due to the substantial energy demand of secondary-treatment aeration, which consumes the most electricity within the plants. Since Egypt's national grid is entirely reliant on fossil fuels (grey electricity), this dependency significantly increases the plants' carbon footprint. Moreover, the use of chlorine gas for disinfection and the release of nitrous oxide (N_2O) further contribute to environmental harm.

In the case of sludge management, the process of transporting wet sludge to drying beds was highlighted as the most environmentally burdensome step, due to its reliance on fossil-fuel-based electricity as well.

The LCA study underscored the potential of modernizing aeration systems as a cost-efficient and environmentally friendly solution. Implementing automated aeration technologies was recommended to reduce both operational expenses and greenhouse gas emissions, offering a sustainable path forward for these WWTPs.

The LCA study has investigated four improvement scenarios as follows:

1. To replace 20 % of total electricity demand with green electricity
2. To automize aeration to decrease electricity use during aeration by 1/3th
3. To decrease sludge drying duration by implementation of solar thermal collector panels
4. To send all sludge at Sakha WWTP to co-digestion reactor

The main findings outlined by the LCA study were:

Environmental Impact and Plant Size

- Smaller WWTPs, such as Qaha, exhibit higher environmental impacts per m^3 of treated water compared to larger plants like Zenin and Sakha.
- Combining smaller WWTPs into larger facilities or avoiding the construction of small plants where feasible could enhance efficiency.

Potential Improvements

- Automating aeration can significantly reduce emissions, saving approximately 1,500,000 kg CO_2-equivalents per year at a low cost of 0.05 EP per kg CO_2-equivalents
- Shifting 20% of electricity demand to solar panels could cut CO_2 emissions by 18% and save about 500,000 EP annually, offering a positive payback period of 16.5–18.5 years, despite the low cost of grey energy in Egypt

Sludge Co-Digestion

- Co-digestion at Sakha WWTP reduces the environmental impact of sludge treatment by converting sludge to electricity. Scaling up co-digestion for the full sludge volume is more advantageous than relying on drying beds. However, impacts and costs associated with external parties managing the digester and liquid digestate distribution were not considered

Limitations of Solar Thermal Panels

- Solar thermal collector panels are not viable due to the high heat demand required for evaporation, necessitating significant land and equipment that offset the benefits of reduced sludge drying beds.

Enhancing the environmental performance of WWTPs in Egypt requires a comprehensive strategy that considers the specific conditions of each facility. A key component of this approach is transitioning from fossil-based electricity to renewable energy sources, which can significantly reduce greenhouse gas emissions and lessen the environmental footprint of treatment operations. Additionally, automating energy-intensive processes such as aeration can optimize energy consumption, lower operational costs, and minimize carbon emissions.

Encouraging sludge co-digestion by integrating organic waste materials, such as agricultural or animal waste, with municipal sludge can further improve energy recovery and waste management efficiency. This process not only reduces the volume of waste requiring disposal but also generates biogas, offering an alternative energy source for plant operations.

Moreover, optimizing the size and capacity of WWTPs to match the demands of their respective service areas can enhance overall efficiency and sustainability. Properly scaled plants reduce resource wastage and ensure effective treatment performance.

By implementing these integrated solutions, Egypt's WWTPs can achieve more sustainable and cost-effective operations, effectively addressing both environmental challenges and the growing demand for wastewater management.

1-3 Report Objectives

In response to these insights, the HCWW, in partnership with the RVO, has launched an extensive study to identify the most effective improvements for the aeration systems at the three targeted wastewater treatment plants.

The scope of work for this report is divided into two key modules:

Data Collection and Baseline Assessment

A thorough identification and documentation of all relevant hardware and operational protocols related to aeration systems in Sakha WWTP

Multidisciplinary Scenario Analysis

An evaluation of financially, operationally, and environmentally optimal technical upgrade pathways, focusing on equipment selection and the impact of upgrades on costs, emissions, and wastewater treatment quality

This study adopts a multidisciplinary approach by integrating technical, financial, and environmental factors to develop a sustainable solution for upgrading the aeration system at the Zenein WWTP. The work team works closely with representatives from the HCWW to collect essential data, conduct site inspections, and maintain steady progress.

1-4 List of Resources and Applicable Guidelines

All the documents and information used to produce this report are:

1. Terms of Reference - Technical study for the understanding and environment-friendly upgrading of the aeration regimes with automation at Egyptian WWTP's (Annex 2).
2. Towards future perspectives on wastewater treatment and sustainable sludge management based on Life Cycle Assessment (LCA) methodology, TANW, 2023 (Annex 1)
3. Egyptian Code or Practice for Wastewater Treatment Plant, 2017
4. Law No. 48 of 1982 concerning the Protection of the Nile River and Watercourses from Pollution, along with its Executive Regulations issued by Ministerial Decree No. 92 of 2013 (Annex 3)

2-ZENEIN WASTEWATER TREATMENT PLANT

2-1 General Description of the WWTP

The Zenein WWTP is a complex facility designed to manage large-scale wastewater treatment efficiently. The plant features a double-lift screw pumping station with Archimedean screw pumps, screen chambers for solid waste removal, grit removal systems, and both primary and secondary treatment processes. Key components include pre-aeration and primary settlement tanks, aeration tanks with coarse bubble diffusers, and secondary settlement tanks, all working together to ensure effective wastewater processing. Additionally, the plant features sludge handling system, compressed air system, and chlorination processes.

Figure 2. Aerial view of Zenien WWTP in GIZA governorate

The Zenein WWTP received the sewage by multiple force mains coming from various locations across Cairo, which are:

1. Force mains from **Main Giza lift station**
2. One Force main from **New lift station of EL-Omrania**
3. One Force main from **Ard AL-Lewaa lifting station**
4. Two force mains from **EL-Haram main lift station**
5. Two force mains from **Studio lift station**
6. One force main from **Al-Sadaqa Al-Yabaniya lift station**

2-1-1 Influent and Effluent Characteristics

The design and operation of WWTPs in Egypt must strictly adhere to Law No. 48 of 1982, which focuses on protecting the Nile River and other watercourses from pollution. This law serves as the primary legal framework ensuring that all activities related to water bodies comply with environmental safety standards. To enforce and expand on this legislation, the Executive Regulations were issued under Ministerial Decree No. 92 of 2013 (Annex 3), (Table 1). These regulations provide detailed guidelines for the design, construction, and operation of WWTPs, covering aspects such as effluent quality standards, treatment processes, sludge management, and the safe discharge of treated wastewater.

Additionally, several relevant ministerial decrees complement this legal framework by addressing specific operational and environmental considerations. These decrees establish permissible pollutant discharge limits, safety measures for chemical handling, and procedures for monitoring and reporting environmental compliance. Collectively, these regulations ensure that WWTPs operate sustainably, minimize environmental impact, and safeguard Egypt's vital water resources, particularly the Nile River.

Table 1. Law 48/82 details to be followed regarding the WWTP's effluents quality

Parameter (mg/l)	Law 48/82: Discharge into			
	Underground Reservoir	Nile	Drains	
	Nile Branches/Canals	(Mainstream)	Municipal	Industrial
BOD (5 days, 20 °C)	20	30	**60**	60
COD (Dichromate)	30	40	**80**	100
pH (units)	6-9	6-9	**6-9**	6-9
Oil & Grease	5	5	**10**	10
Temperature (deg.)	35	35	**35**	35
Total Suspended Solids	30	30	**50**	60
Total Dissolved Solids	800	1,200	**2,000**	2,000
Probable counting for the colon group in 100 cm^3	2,500	2,500	**5,000**	5,000

As depicted in Table 2, the Zenein WWTP demonstrates effective performance, with effluent quality meeting or surpassing the standards set by Law No. 48/1982. Parameters such as Total Suspended Solids (TSS), Biochemical Oxygen Demand (BOD), and Chemical Oxygen Demand (COD) are well within permissible limits, indicating efficient pollutant removal. The effluent pH and temperature also comply with regulatory standards. Additionally, dissolved oxygen (DO) and residual free chlorine levels meet required thresholds, ensuring proper disinfection. Notably, oil and grease concentrations have been reduced significantly. Overall, the plant operates efficiently, maintaining environmental safety and regulatory compliance.

Table 2. Average influent and effluent characteristics for Zenein WWTP (Annex 3)

Item	Average Influent	Average Effluent	Law48/82	Unit
Temperature	24.5	24.2	35	°C
pH	7.60	7.46	6-9	--
TDS	387	402	2,000	mg/L
TSS	126	20	50	mg/L
BOD	131	20	60	mg/L
COD	243	34.8	80	mg/L
DO	--	4.1	4	mg/L
Oil & Grease	12	3.25	10	mg/L
Residual free chlorine	--	0.5	0.5	mg/L

2-1-2 Site Layout and Components

The Zenein WWTP is a well-structured complex, comprising various specialized units organized in three treatment modules as shown in Figure 3, that collectively ensure efficient and effective wastewater treatment and overall operational management.

The process begins at the inlet chamber (1), where wastewater first enters the system. It then passes through the screening units (2) and grit chamber (3) for the removal of large debris and grit, followed by the sand settling basin (4) for finer particle removal. Excess flows are managed by the overflow basin (5).

The facility incorporates pre-aeration tanks for the 1st, 2nd, and 3rd modules (6) to stabilize the wastewater before moving into the primary sedimentation tanks (7) and the aeration tanks (8) for biological treatment. These are followed by clarification in the final sedimentation tanks (9). The screw pumps (10) handle return activated sludge within the treatment system. Treated effluent disinfection is managed at the chlorination building (27).

Maintenance and operational efficiency are supported by the numerous workshops in terms of general, welding, and for garage (11). Power supply is managed through the transformer building and electrical panel (12), and the generator building (13), with backup fuel provided by the diesel tank (14). Air supply is facilitated by the compressor building (15).

For staff needs, the WWTP includes a changing room (16), multiple guard rooms (17) for security, a mosque (18), and residential blocks (19) for accommodation. Operational support extends to the laboratory (20) for quality control, parking facilities (21), administration building (22), and storage areas (23), with recreational space provided by the playground (28). Additional infrastructure includes the cooling building (24), training center (25), and the General Department of Technical Services (26). A rapid repair unit (29) ensures timely maintenance and operational reliability.

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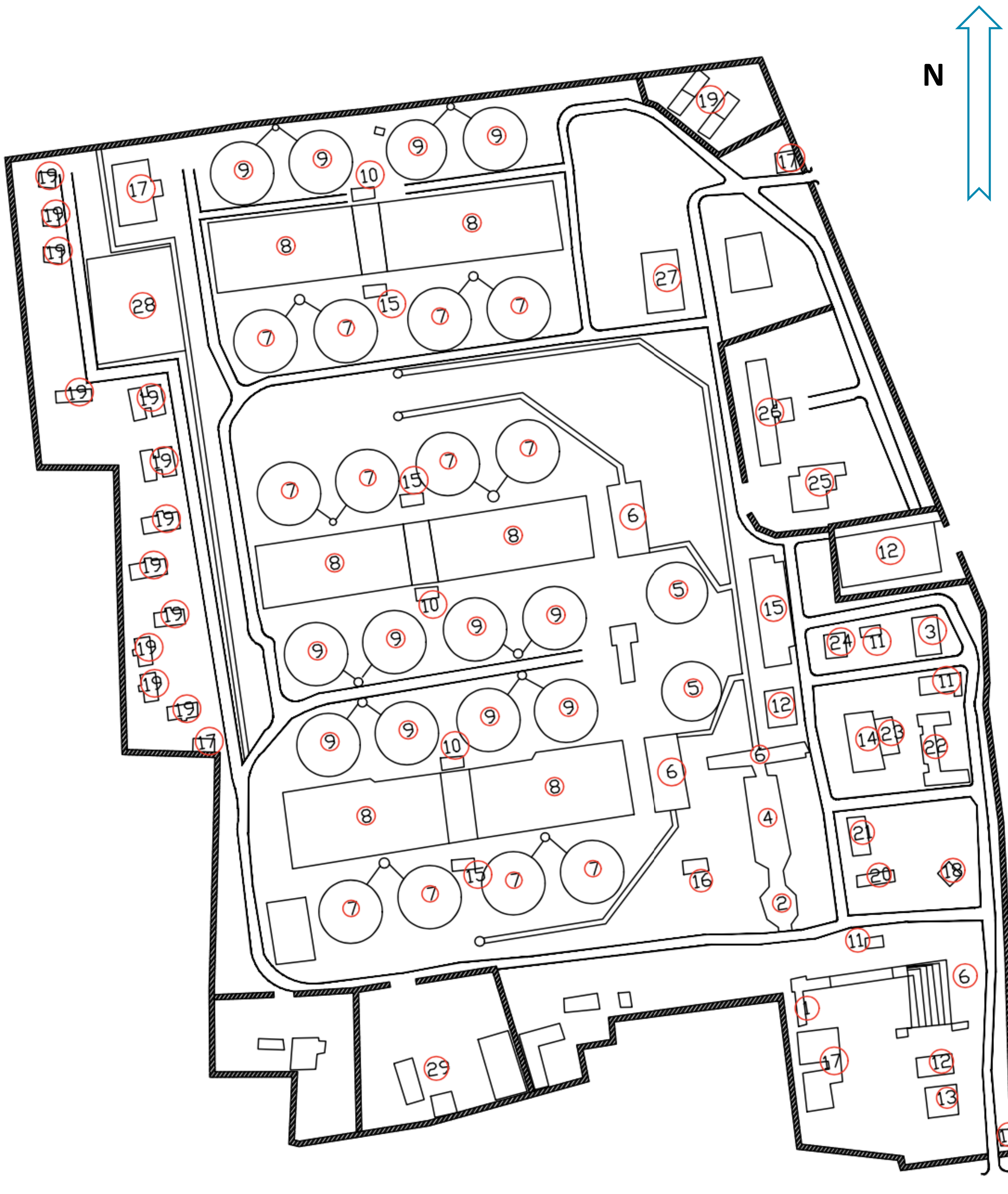


Figure 3. Site layout of Zenein WWTP

2-2 Mechanical Assessment and Recommended Rehabilitation

2-2-1 Headworks

2-2-1-1 Zenein Pumping Station Complex

The Zenein Pumping Station Complex consists of a double-lift screw pumping station, a transformer building, and a standby generator building (Figure 4). The pumping station houses four Archimedean screw pumps per lift with the following characteristics:

- 2 duty + 2 standby
- 6 PASSAVANT + 2 SPAANS BABCOCK
- Diameter: 2.6 m
- Average Flow: 330,000 m^3/day
- Peak Flow: 450,000 m^3/day
- Flow/pump: 131,000 m^3/day
- Head/stage: 8.5 m
- RPM: 26/900

Figure 4. Zenein Pumping Station Complex

The general condition of pumps are in good overall status, with no significant operational failures currently affecting their performance. However, the continuous exposure of lower bearing issues to water and solids accelerates wear and corrosion

Recommended Rehabilitation Works

- Replacement of the existing lower bearings with sealed bearings designed to withstand harsh conditions, reducing wear and extending their lifespan.

- Installing a protective shielding system around the lower bearing to minimize exposure to solids and debris.
- Implementation of a regular lubrication and inspection schedule to monitor bearing performance and address issues proactively.

2-2-1-2 Screens

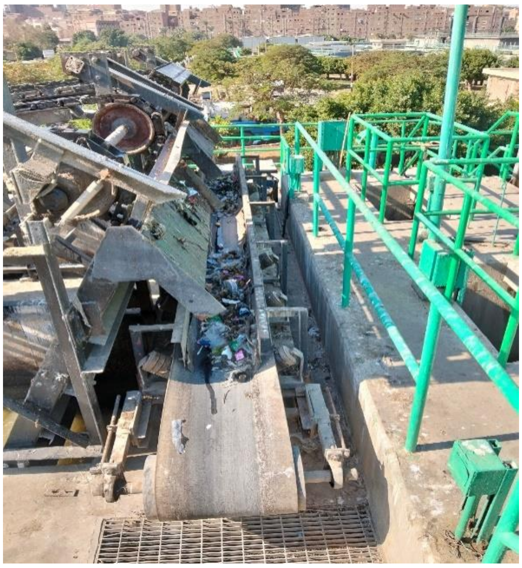
Coarse screenings are collected in a channel to be manually transferred to a ground-level concrete bin. The medium screens are provided with conveyors to transfer the screenings to one of two similar concrete bins. Each of the bins is provided with drainage to remove screening water. The mechanical screen mechanisms are provided with manual/automatic controls; the automatic mode operates on a combination of time interval and upstream water level controls. The screens system includes:

- 4 No. duty screens: 1,9 m wide with 65 mm clear spacing between bars
- 1 No. standby screen: 1,9 m wide with 50 mm clear spacing between bars
- 4 No. catenary raked medium screens with 25 mm clear spacing between bars and generate 10 m^3/day waste
- 2 No. adjustable overflow weirs with flow measurement. The weir length: 5 m/each with max. discharge: 178,000 m^3/day.

Mechanical Screens

Mechanical Screen

Manual Screen



Belt Conveyor

Figure 5. Mechanical and Manual Screens

The overall condition of the screens is rated as average, with operational effectiveness maintained through regular inspections and the availability of spare parts. The bar screens and associated equipment are fully operational, demonstrating effective maintenance practices. The manual screens generate approximately 5 m^3/day of waste, while the mechanical screens produce around 10 m^3/day. The belt conveyors, essential for transporting debris, are in average condition, with a speed of 0.5 m/min and a width of 600 mm. Notably, the screens lack a washing system, which could lead to increased manual cleaning efforts and higher maintenance costs over time. The screens are inspected weekly and monthly, reflecting a proactive maintenance schedule.

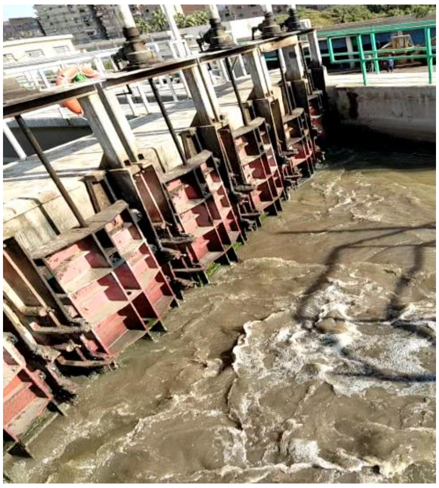
Recommended Rehabilitation Works

- Addition of a washing system for the screens that could enhance efficiency by reducing manual cleaning requirements and improving hygiene standards.

2-2-2 Grit Removal System

Grit removal is managed through periodic drain-downs of the grit channels, with flushing gates used to direct grit into collection channels leading to the Grit Separation Tanks. A standby channel ensures continuous full-capacity treatment during cleaning. The flushed grit is settled in the tanks, from which supernatant is drawn off through adjustable weirs and underfloor drains equipped with a backwash system. Dewatered grit and screenings are removed by loaders and trucked off-site. Grit supernatant and drainage water return by gravity to the Zenein Pumping Station inlet. Flow measurement is provided by venturi flumes equipped with sonic depth meters and indicators, while overflow weirs discharge to dedicated overflow settling tanks


Return Activated Sludge the Headworks


Penstocks at the Grit chambers inlet


Grit Removal channels (No. 6 duty + 1 degritted)


Grit Separation Tanks

Figure 6. Grit removal system

The grit removal system Includes:

- Constant velocity parabolic grit channels

- 7 Channels
- Length: 56 mm
- Width: 2,4 mm
- Flow velocity: 0.3 m/s
- 21 No. electrically actuated valves (grit removal)

- Grit separation Tanks

- 3 Channels
- Length: 24,6 m
- Width (each channel): 6,6 m
- Depth: 1,3 m

- Total volume: 366 m³

Recommended Rehabilitation Works

1. Upgrade of the grit removal system to a fully automated process, including the installation of modern grit scrapers and hydraulic flushing systems to minimize manual intervention and improve operational efficiency Equipment Maintenance and Upgrades.
2. To enhance the grit handling, a functional sand silo system and automated grit conveyors should be installed for efficient grit storage and off-site disposal, reducing reliance on manual handling and wheeled loaders.

2-2-2 Primary Treatment

2-2-2-1 Pre-Aeration Tanks

The Pre-Aeration Tanks (one/treatment module) provide grease/scum removal and fresh air to reduce any adverse effects of septic sewage on the subsequent biofilters at the head of the secondary treatment. It includes a grease/scum collection channel, tank drains, coarse bubble air diffusers, and screening of channels. Grease/scum is decanted to the collection channel using adjustable weir gates and discharges by gravity to the waste sludge pump station for pumping off-site. The average flow per module is 110,000 m³/d. Further specifications for the treatment modules are as follows:

- Modules 1 & 2

- No. of aeration channels per tank: 4
- Length (each channel): 41 m
- Width (each channel): 4,47 m
- Max. water depth: 3,8 m
- Total liquid volume: 2,945 m³
- Detention time at peak flow: 30 min

- Air required: 4200 m³/hr/module

- Module 3

- No. of aeration channels per tank: 2
- Tank length (each length): 37.8 m
- Tank width (each channel): 4.2 m
- Max. water depth: 3.3 m
- Total liquid volume: 1,000 m³
- Detention time at peak flow: 10 min
- Air required: 2,000 to 3,000 m³/hr

Although their status is good, some operations could be improved:

1. Installing sensors for real-time monitoring of grease/scum levels and air supply to improve operational oversight and efficiency.
2. Considering upgrading the aeration system to high-efficiency coarse bubble air diffusers to improve oxygen transfer while minimizing energy use.

Figure 7. preliminary aeration tank

2-2-2-2 Primary Sedimentation Tanks

The primary sedimentation tanks at the Zenein WWTP are employed to effectively separate settleable solids as well as organic matter. Each module includes four sedimentation tanks (total No. of tanks 12/WWTP) each with a diameter of 36 meters. The flow distribution among the tanks is balanced, with no signs of short-circuiting or overloading (Figure 8). However, despite their fair functionality, several operational and maintenance challenges require attention to ensure optimal performance. The sludge drawing-off are carried out by two methods: (1) Manually operated telescopic bell mouths, (2) Central timer-controlled plug valves for coordinated sludge draw-off among 4 settlement tanks.

Some issues were observed such as maintenance requirements for telescopic and emergency valves. The scrapers used in the tanks are made from materials that are unsuitable for the application, resulting in continuous erosion and frequent replacement. This increases maintenance costs and disrupts operations.

The effluent weirs, while kept clean and at a constant level, lack the ability for level adjustment, which limits operational flexibility. Despite this, the effluent baffle system functions properly, contributing to effective flow distribution and sedimentation. Additionally, the scraper bridge tires are in good condition, ensuring stable operation of the scraper bridges.

One notable gap in maintenance is the absence of an automated cleaning or brushing system for the tanks. Manual cleaning is labor-intensive and time-consuming, further straining resources.

Figure 8. Primary Sedimentation Tanks

Recommended Rehabilitation Works

1. Upgrade of the scraper blades and associated components to more durable, corrosion-resistant materials (e.g., stainless steel or specialty composites). This will reduce erosion, minimize frequent part replacements, and lower maintenance costs.
2. Introduction of adjustable effluent weirs or insert plates to allow fine-tuning of flow distribution and tank hydraulics. This flexibility enables operators to respond to changing flow and load conditions, improving the settling process and effluent clarity.

3. Incorporation of automated or semi-automated tank cleaning systems, such as brushing mechanisms or flushing jets, to maintain the walls, floor, and sludge collection areas. Reduced reliance on manual cleaning enhances maintenance efficiency and tank hygiene.

2-2-3 Secondary Treatment

2-2-3-1 Aeration Tanks

The aeration tanks at the Zenein WWTP are the core treatment units that facilitate oxygen transfer and mixing necessary for biological treatment in order to support the activated sludge process. As shown in Figure 9, the facility consists of a coupled process of Roughing filters (Biofilters) and aeration tanks, Roughing filters (biofilters) are often used as a pre-treatment step to remove larger particles and organic matter before the water enters the aeration tanks. This reduces the load on the aeration tanks, reducing aeration tanks volume, improving efficiency and lowering operational costs by allowing the tanks to focus on breaking down dissolved organic matter.

Each module has two roughing filters, each filter containing six channels and associated equipment. Additionally, each module has 2 aeration tanks with 15 channel per tank: 11 channels in operation and 4 on standby. The aeration mechanism is provided by coarse bubble diffusers.

Currently, the roughing filters do not operate, rather the influent water directly flows into the aeration tanks. This results in increase of air demand and retention time leading to a rise in operational cost.

Despite these challenges, the hydraulic and flow conditions in the aeration tanks are acceptable, with influent flow evenly distributed between the two tanks, preventing hydraulic imbalances.

Figure 9. Aeration Tanks

The Aeration Tanks are equipped by valved equalization pipes that provided between the corresponding inlets and outlets to balance water levels and flow. The Aeration Tanks employ coarse bubble diffusers, a froth control system, and tank drains.

- No. of tanks, per module: 2
- Total: 6 Tanks
- No. of channels (each tank): 15
  - Duty: 11 No.
  - Standby: 4 No.
- Liquid Volume (each channel): 537 m^3
  - 11 No. channels: 5,907 m^3
  - 15 No. channels: 8,055 m^3
- Retention Time at Average Flow:
  - 11 No. channels: 2.6 hours
  - 15 No. channels: 3.5 hours
- Air Required:
  - 11 No. aeration channels: 13,500 m^3/hr
  - 15 No. aeration channels: 18,400 m^3/hr

Recommended Rehabilitation Works

1. Considering of replacing coarse bubble diffusers with fine or medium bubble diffusers, which significantly improves oxygen transfer efficiency and reducing the required air volume and energy consumption.
2. Installation of DO probes, flow meters, and automated control systems to adjust aeration rates based on real-time process conditions. Using variable frequency drives (VFDs) on blowers can dynamically match airflow to actual treatment needs, thereby optimizing energy use.
3. Development of a structured preventive maintenance plan for diffusers, pipes, and controls to prevent fouling, leaks, and mechanical failures. Routine inspections and timely cleaning will sustain equipment efficiency and prolong service life.

2-2-3-2 Final Sedimentation Tanks

The final sedimentation tanks at the Zenein WWTP are needed for the clarification process, effectively separating treated effluent from activated sludge. The facility consists of four tanks per module (Figure 10), each with a diameter of 36 meters and a depth of 2.9 meters. The flow distribution system ensures balanced loading, contributing to efficient sedimentation.

The Secondary sedimentation Tanks including weir plates, sludge/scum collector, provision of tank drains, etc. In addition, a rapid sludge removal system comprising two submersible pumps and a suction header suspended from the scraper bridge, discharging to the central sludge well via a concrete channel constructed around the center inlet well. Sludge draw-off chambers are provided, one for each pair of tanks. Sludge draw-offs are continuous through telescopic bell mouths. Waste Activated Sludge (WAS) regulation is performed by sluice gate flow diversion. The system specifications are as follows:

- No. of tanks, per module: 4
- Average flow (each tank): 27,500 m^3/d
- Average flow with 0.5 average RAS flow (each tank): 41,250 m^3/d
- Peak flow (each tank): 35,750 m^3/d
- Peak flow with 0.5 average RAS flow (each tank): 49,500 m^3/d
- Diameter: 36 m
- Side wall depth: 2.9 m
- Bottom slope: 6°
- Surface loading at peak flow: 35.5 $m^3/m^2/d$
- Retention time at peak flow with 0.5 RAS flow: 1.7 hrs
- Solids loading at average flow with 0.5 RAS flow: 61 kg $TSS/m^2/d$
- Skimmer
- Lower Scraper

Figure 10. Final Sedimentation Tanks

Recommended Rehabilitation Works

1. Installing adjustable weirs or inserts to provide greater operational flexibility. This will allow operators to fine-tune overflow rates and improve effluent quality during fluctuating flow conditions
2. While the tanks are in good condition, using more durable, corrosion-resistant materials for scraper blades and related components can reduce wear, minimize downtime, and decrease long-term maintenance costs.
3. Addition of automated or semi-automated cleaning systems, such as brushing mechanisms or spray nozzles, to maintain tank surfaces and reduce manual cleaning efforts.
4. Regularly monitor sludge collection efficiency and make necessary adjustments to the baffle and scraper systems to optimize sedimentation performance.

2-2-3-3 RAS Pumping Station

- No. of pumping stations, per module: 1
- No. of pumps per station: 5
    - Duty: 4 No. (2 No. per Aeration Tank)
    - Standby: 1 No.

- Type of Pumps: Archimedean screw
- Diameter: 1830 mm
- Inclination: 37.14°
- No. of flights: 3
- Fill point elevation: 16.64 m
- Discharge point elevation: 20.70 m
- Capacity, (each): 725 L/s
- Power required (each): 45 kW
- Operation hours: 24/day

Figure 11. RAS/WAS pump station

2-2-6 Chlorination System

Chlorine solution is injected into the combined final effluent flows of the three modules at the inlet to the Contact Tank. The tank provides a retention time of 10 minutes at a flow of 330,000 m^3/d, while the effluent channel downstream provides a further 10-20 minutes retention before discharge to the Nahya Drain.

An air blower and diffuser system is provided at the Contact Tank to mix the chlorine solution, reduce short-circuiting, maintain any residual solids in suspension, and improve the dissolved oxygen content of the effluent.

- Chlorine dosage: 6-8 mg/L
- Duty cylinder connections: 44

- Reserve cylinder spaces: 44
- Chlorine feeder type: Solution feed, vacuum operated, variable orifice type.
- 2 booster pumps
- Number of chlorinators: 3
    - Duty: 2 No.
    - Standby: 1 No.
    - Capacity (each): 120 kg/hr


Figure 12. Chlorine Contact Tank

2-2-7 Sludge Pumping Station

The sludge pumping station uses two parallel off-site pumping systems, each capable of full flow, with pairs of vertical spindle pumps operating in series. Each pair discharges into a 500 mm DI force main to Abu Rawash WWTP, ensuring redundancy for maintenance or flushing. The pumps handle primary sludge, scum, and potentially WAS at 1–3% solids, operating about 16 hours daily.

The activated sludge/Tank Drainage system, with multiple submersible pumps, returns the activated sludge to the headworks (Figure 6) or directs it off-site. Site wastewater pumps drain to the same system. Sludge Storage Pumps can deliver sludge to overflow/thickening tanks if the off-site system fails.

Two tanks serve as overflow settlement, sludge storage, or thickening units. The operator selects the duty: storing sludge with air agitation, settling overflow at up to 178,000 m^3/d, or thickening WAS/scum by gravity. Primary sludge/scum ejectors and a dedicated Module 3 secondary sludge/scum pumping station complete the handling system.

Figure 13. RAS Pumps

2-2-8 Compressed Process Air Supply and Distribution

Under normal conditions, three blowers supply process air (one per module), with additional units available if needed. Suctions pass through stilling chambers and reusable air filters with differential pressure alarms for cleaning. Discharges connect to a common manifold with sectionalizing valves, allowing either combined or separate module feeds. Pressure losses vary, especially in Module 3, requiring flow balancing if feeds aren't sectionalized. Airflows are monitored via venturi tubes in the blowers House, with local indicators for Pre-Aeration Tank measurements.

<u>The specifications are:</u>

- No. of machines: 7 No.
- Inlet volume: 35,000 m³/h
- Inlet/Outlet pressure: 100.0 kPa / 145.0 kPa
- Drive speed: 3000 rpm, direct coupled
- Motor type: Squirrel cage, auto-transformer start
- Motor rating: 3.15 kV/ 2980 rpm / 670 kW
- Cooling type: Air

Figure 14. Air Blowers

2-2-9 Cranes

<u>Cranes are provided as follows:</u>

- Compressor Building
  - Type: Double girder bridge crane, all three motions powered
  - Capacity: 10 tones
- Generator Building
  - Type: Double girder bridge crane, all three motions powered
  - Capacity: 10 tones
- Sludge Pumping Station
  - Type: Double girder bridge crane, all three motions powered
  - Capacity: 8 tones
- Filter Inlet Pumps
  - Type: Gantry A frame with monorail crane and interchangeable hoist

  - Capacity: 4 tones

- RAS Pumping Stations
  - Type: Monorail crane, manual, in each station
  - Capacity: 1 ton

- Ejector Stations
  - Type: Monorail crane, manual, with interchangeable hoist
  - No. of trolleys: 2 (per station)
  - Capacity: 3 tones

- Chlorination Building
  - Type: Single girder bridge crane, all three motions powered
  - Capacity: 2 tones

- Workshop
  - Type: Manual double girder crane
  - Capacity: (not specified) tones

- Water Processing Building
  - Type: Manual jib hoist
  - Capacity: 1/2 tons

- Garage
  - Type: Portable hand hoist
  - Capacity: 2 tones

2-3 Electrical Works Description and Rehabilitation

2-3-1 Electric Source Station

- Load break switch (10.5 KV) for medium voltage source from general network.
- Two transformers for screw pump (one duty + one standby)
  - Power : 2500 KVA
  - Input voltage : 10.5 KV.
  - Output voltage : 3.15 KV.
- Two generator (For emergency)
  - Power : 1063 KW.
  - Output voltage : 3.5 KV.
- Two transformers for services (one duty + one standby)
  - Power : 300 KVA.
  - Input voltage : 10.5 KV.

- Output voltage : 0.4 KV.

2-3-1-2 Electric source station for sewage treatment plant

- (2) Load break switch (10.5 KV) for medium voltage source from general network.
- Two transformers for Blower station (one duty + one standby)
  - Power : 7500 KVA.
  - Input voltage : 10.5 KV.
  - Output voltage : 3.15 KV.
- (3) Generator (For emergency)
  - Power : 1362 KW.
  - Output voltage: 3.15 KV.
- (2) Transformer for Services (one duty + one standby)
  - Power : 1500 KVA
  - Input voltage : 10.5 KV.
  - Output voltage : 0.4 KV.

2-3-1-3 Electric panels for screw pumps station

One Medium voltage main distribution board contains the flowing:

- (2) Medium voltage switch Gear 11KV. (input C.B).
- (1) Medium voltage switch Gear 11KV. (bus coupler).
- (1) Medium voltage bus riser cell.
- (2) Medium voltage switch gear 11KV. (output C.B to transformer).
- (2) Medium voltage switch gear 11KV spare .

One Medium voltage distribution board (3.15 KV) for screw pumps contains the flowing:

- (2) Medium voltage switch gear 3.15 KV. (input C.B from transformer).
- (1) Medium voltage switch gear 3.15 KV. (bus coupler).
- (2) Medium voltage switch gear 3.15 KV. (input C.B from generator).
- (8) Medium voltage switch gear starter for screw pumps (300 HP, 295 HP)
- (2) Medium voltage switch gear 3.15 KV (input C.B for service transformer 3.15 /380 KV).
- (2) Bus rise cells.

One Medium voltage panel for power factor correction (3.15 KV, 350 KVAR).

One Low voltage panel (380V) for service screw pumps and lighting buildings plant.

2-3-2 Electric panels

Medium voltage main distribution board contains the flowing:

- (2) Medium voltage switch gear 11KV. (input C.B).
- (1) Medium voltage switch gear 11KV. (bus coupler).
- (1) Medium voltage bus riser cell.
- (4) Medium voltage switch gear 11KV. (output C.B to transformer).

One Low voltage panel (380 V) for Head work (Mechanical screen & belt Conveyor units).

Twelve Low voltage panel (380 V) for Primary sedimentation basins.

Twelve Low voltage panel (380 V) for final sedimentation basins.

2-3-3 Compressor Building

Air blower building consists of one medium voltage panel with:

- (2) Medium voltage switch gear 3.15 KV. (input C.B from transformer).
- (1) Medium voltage switch gear 3.15 KV. (bus coupler).
- (3) Medium voltage switch gear 3.15 KV. (input C.B from generators).
- (10) Medium voltage switch gear starter for air blower units (900 HP).

2-3-4 Archimedean screw pump (RAS)

RAS pump panel consists of three Low voltage panel with:

- (1) (input C.B).
- (5) Star / delta starter (55 KW) for screw pumps.
- (1) MCCB 20 A for crane panel.
- (1) MCCB 20 A for lighting panel.
- (4) MCCB for services.

2-3-5 Primary sludge pumping station:

Primary sludge pump panel consists of one Low voltage panel (380 V) with:

- (1) (input C.B).
- (4) Star / delta starter (30 KW) for Excess active sludge pumps.
- (4) Star / delta starter (110 KW) for primary sludge pumps.
- (1) MCCB 20 A for crane panel.
- (1) MCCB 20 A for lighting panel.
- (4) MCCB for services.

2-3-6 Chlorination building

Chlorination pump panel contains the followings:

- (2) (input C.B).
- (2) Direct on-line starter for booster pumps.
- (2) Direct on-line starter for soda pumps
- (1) Direct on-line starter for soda mixer.
- (2) Direct on-line starter for blower.
- (2) MCCB 20 A for crane panel.
- (1) MCCB 20 A for lighting panel.
- (4) MCCB for services

2-3-7 Electric Cables

All electric cables for motors and equipment with a rated voltage of 0.6/1 kV must have a cross-sectional area appropriately sized to handle the electrical load of the connected motors and devices.

Condition and Observations

- **Electric cable for Head works panel**

Electrical cables should be neatly organized on cable trays and securely fastened to ensure they are fully covered and protected from direct sunlight exposure.

- **Electric cable for Grit removal**

Electrical cables should be organized on hanging cable holders and connected systematically to ensure flexibility. Flexible cables must be used to allow smooth and safe movement in coordination with the operation of the grit removal system.

- **Electric cable for primary & final sedimentation, aeration motor, screw pumps, and chlorination pumps**

Electrical cables should be properly arranged on cable trays and securely fastened in an organized manner to ensure they are fully covered and protected from direct sunlight exposure.

Maintenance and Spare Parts

- The electrical cables must be rearranged on the cable trays and connected in a coordinated manner, covering the cables along the path.
- Providing spare parts, including cable lugs, cups, copper connectors, cable ends, and PVC covers.
- Periodically passing through cable routes and removing materials and objects that may expose electrical cables to danger.
- Replace of damaged electrical cables with new ones with the same specifications and cross-sectional area.
- Replacement of regular electrical cables with new, flexible ones It is flexible and has the same specifications and cross-sectional area to withstand continuous movement and not be exposed to damage.

Recommendations

- Standard electrical cables should be replaced with new, flexible cables that maintain the same specifications and cross-sectional area to enhance durability and adaptability.
- Proper connection and organized coordination of electrical cables on cable trays must be ensured.
- Cable trays with covers should be fabricated from galvanized steel in various heights and sizes suitable for the cable cross-sectional area.
- All conduits must be arranged, organized, numbered, and properly connected to electrical components for safe and efficient operation.
- Worn-out and rusted cable tray covers caused by sewage gases should be replaced.
- New electrical cable trays, holders, and covers in different sizes must be supplied.
- Specialized installation tools and supports for new electrical cable holders of various sizes should be provided.
- Electrical cable holder paths should be adjusted to appropriate routes to prevent direct exposure to sewage gases.
- Damaged cable holders and covers must be replaced with new, durable ones.
- Electrical cable trays and holders should be installed in proper paths, avoiding exposure to sewage gases to improve longevity and safety.

2-3-8 Internal & External Lighting

The Internal & External lighting for internal building and streets layout with different type and size are suitable.

Recommendations

- Spare parts for floodlights and lighting poles in the station’s streets must be supplied.
- Various types of bulbs should be provided according to the station’s available spare parts.
- Periodic maintenance of the station’s lighting systems must be conducted, and damaged components should be replaced.
- Damaged light bulbs inside the station buildings are required to be replaced.
- New floodlight bulbs must be supplied to replace defective ones inside the station buildings.
- Maintenance of lighting fixtures and replacement of damaged units inside the station buildings is necessary.
- Maintenance work for floodlights and lighting poles, including the replacement of damaged bulbs in the station’s streets, must be carried out.

2-3-9 Transformers 2500, 300,7500&1500 KVA

Electrical transformers, capacity 2500, 3000, 7500 & 1500 KVA, produced by Egytravo, operating voltage 11/3.15 KV & 11/0.4 KV, transformers are in good condition.

Condition and Observations

- Electrical transformers have minor oil leaks that need to be addressed.
- The silica gel used for moisture absorption in the transformers has changed color and requires replacement.
- Manometers for monitoring transformer temperature are absent and need to be installed.

Recommendations

- The transformer oil must be filtered to ensure it is free of moisture.
- The insulation of the transformer oil should be tested.
- A manometer should be supplied and installed to measure the transformer's temperature.
- Transformers must be inspected periodically to record temperature readings and ensure they remain within permissible limits.
- Routine maintenance must be performed on transformers to detect oil leaks and monitor temperature.
- The installation of a manometer for measuring the transformer’s temperature must be completed.
- The connections of protection devices, including heat and overload systems, should be thoroughly reviewed for proper functionality.
- Insulation testing of transformer terminals must be conducted to guarantee safety and reliability.

2-3-10 All Electric Panels

Electrical panels (medium voltage panel, general distribution panel, motor operating panels and sub-panels) are in good condition.

Condition and Observations

- The breaker in the medium voltage panel is out of service and requires maintenance by a specialized company.
- Protective devices in the medium voltage panel must be calibrated by a specialized company.
- Faulty breakers in low voltage panels inside buildings need to be replaced with new ones.
- Damaged relays in low voltage panels outside buildings must be replaced with new ones.
- The operation, control, and protection circuits in low voltage panels inside and outside the buildings need to be reviewed and adjusted.
- Signs on low voltage panels outside buildings must be properly sealed to maintain their designated protection level.

Recommended Rehabilitation Works

- Spare parts for electrical panel components, including circuit breakers, overload contactors, control relays, button switches, and selector switches, must be supplied.
- The condition of electrical components should be periodically and continuously monitored, and any damaged parts must be replaced.
- Periodic maintenance of medium voltage panels should be carried out by specialized companies.

2-4 Treatment Process Assessment

This section presents a detailed analysis of the wastewater treatment process design for one module of Zenin WWTP treating 131,000 m³/day. The objective is to evaluate the treatment system's performance, calculate critical parameters, and provide design recommendations. The section also includes calculations for aeration tank sizing, operational performance, oxygen requirements, and blower sizing

2-4-1 Input Parameters

One module in the Zenein WWTP produces primary-treated effluent with following specifications:

Parameter	Value	Units
Design Wastewater Flow Rate (Q_o)/module	131,000	m³/d
Primary Effluent TSS (X_o)	44.1	g/m³
Primary Effluent BOD (S_o)	86.8	g/m³
Secondary Effluent TSS (X_e)	20	g/m³
Aeration Tank MLSS (X)	1,325	g/m³
Waste/Recycled Activated Sludge SS (X_w)	3,137	g/m³
Volatile Fraction of MLSS (%Vol)	85	%

Parameter	Value	Units
Influent TKN (TKNo)	22.92	g/m^3
Target Effluent NH4N (Ne)	14.68	g/m^3
Target Effluent BOD (Se)	20	g/m^3

2-4-1-1 Aeration Tank Volumetric Sizing

The aeration tank is designed based on a volumetric loading rate of 0.8 kg BOD/day/m³.

Parameter	Value	Units
Volumetric Loading (V_L)	0.8	kg BOD/day/m³
Aeration Tank Volume (V)	14,214	m³
Hydraulic Retention Time (HRT)	2.60	hours
Food-to-Microorganism Ratio (F:M)	0.710	kg BOD/day/kg MLVSS

2-4-1-2 Operational Calculations

The operational performance of the aeration tank was analyzed for a sludge retention time (SRT) of 3 days.

Parameter	Value	Units
Waste Activated Sludge Flow Rate (Q_w)	1,164	m³/d
Recycle Activated Sludge Flow Rate (Q_r)	92,604	m³/d
Aeration Tank F:M Ratio (F:M)	0.711	kg BOD/day/kg MLVSS

2-4-1-3 Oxygen Demand

Oxygen demand was calculated for BOD removal and nitrification processes.

Parameter	BOD Removal	BOD Removal + Nitrification	Units
Required Oxygen Flow Rate (O_2)	272	478	kg/hr
Required Air Flow Rate (Q_{air})	12,371	21,714	m³/hr
Actual Air Flow Rate (Q_{act})	14,845	26,057	m³/hr
Normalized Air Flow Rate (Q_{norm})	14,252	24,073	Nm³/hr
Blower Outlet Pressure (PB2)	1.34	1.34	bar

2-4-1-4 Blower Design Parameters

Parameter	Value	Units
Standard Oxygen Transfer Efficiency (SOTE)	20	%
Diffuser Fouling Factor (F)	0.8	-
Blower Efficiency (η)	70	%

- Blowout capacity should be designed for 26,057 m³/hr to handle peak oxygen demand for nitrification.
- Ensuring 70% blower efficiency minimizes operational costs.

2-4-2 Modelling

A comprehensive assessment of the treatment process has been conducted to evaluate the plant's current operational status and overall efficiency, validating the numerical calculations. This assessment was performed using the well-known GPS-X modeling software and included the evaluation of two different scenarios (Figure 15):

1. **Current operation scenario:** This scenario simulates the plant's current operating conditions, where the non-functional biofilters lead to an increased organic load in the aeration tank. This operation scheme results in higher aeration costs as the blowers provide 37,000 m^3/hr which is above the required capacity.
2. **Recommended operation Scenario:** This scenario proposes the most effective solution for achieving the required oxygen supply necessary for biological treatment at DO=2.0 mg/L, taking into account the current specifications and operational status of the existing aeration infrastructure.

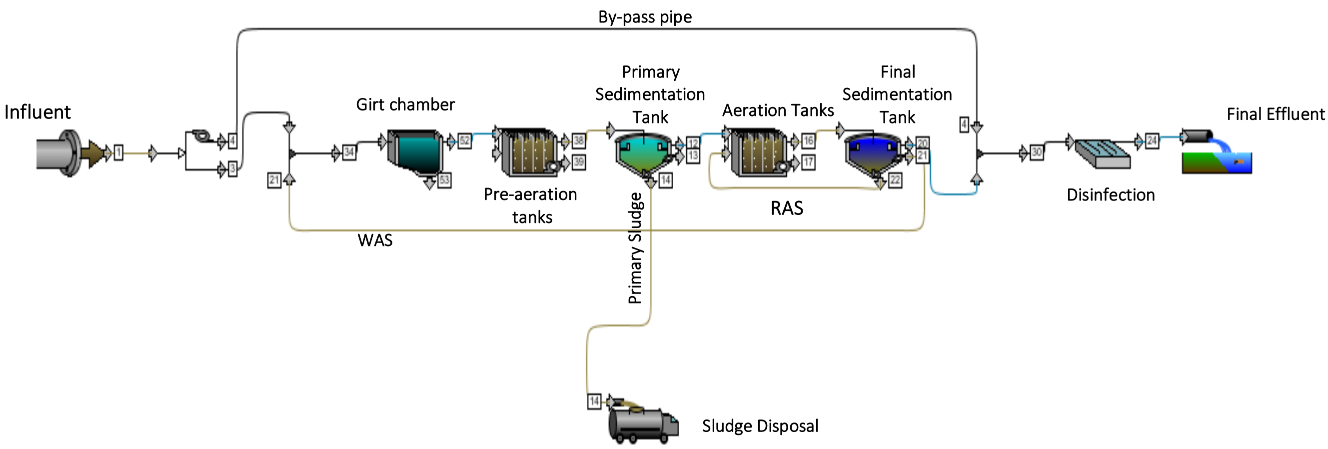


Figure 15. Flowsheet of the simulated process in Zenein WWTP

Each scenario is thoroughly analyzed and discussed to identify the best approach for achieving minimal required energy for aeration. The findings from these scenarios will also serve as the foundation for subsequent stages of the study, focusing on the environmental and financial implications of the proposed solution(s). The GPS-X models' reports are provided in Annex 5.

2-4-2-1 Current Operation Scenario

Model Setup

In the current operation scenario, the operational strategy implemented by the WWTP operators involves the roughing filter being out of service, while the blowers are operating at maximum capacity to supply oxygen to the diffusers distributed along the aeration tank. This capacity is being utilized to cover the entire 24-hour aeration period. As a result, the absence of the roughing filter may increase the load on subsequent treatment stages, requiring close monitoring of aeration efficiency and ensuring optimal energy usage.

To simulate this operational setup, one of the three modules is simulated by one tank with 22 channels, each tank measures 11,814 m^3 arranged in parallel. The influent flow was taken 131,000 m^3/d that flows to one module (equals 1/3 of the total plant's capacity), considering RAS input to the first model tank in the series. In this model, the aeration system supplies 37,000 m^3/hr/one module. The results from the model provide a detailed analysis of the mixed liquor and effluent characteristics, along with the air requirements for the blowers under these conditions.

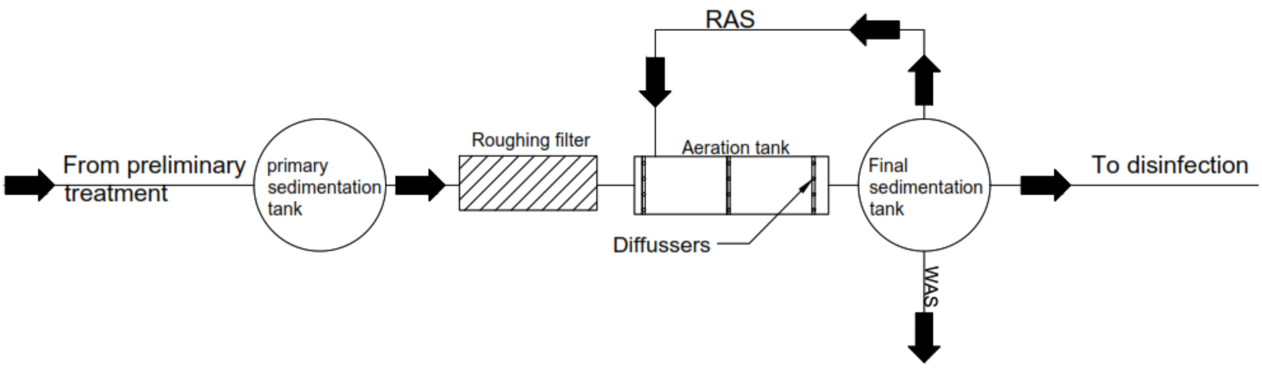


Figure 16. Process flow diagram of the investigated module in the GPS-X software

Table 3. Simulation parameters for the flow and influent characteristics

Parameter	Unit	Value
Flow (One from the three module/3=33% Plant's flow)	m^3/d	131,000
TSS	mg/L	126.6
VSS	mg/L	101.3
$cBOD_5$	mg/L	131.5
COD	mg/L	243.0
Soluble COD	mg/L	60.75
Ammonia N	mgN/L	25.0
TKN	mgN/L	40.0
TN	mgN/L	40.0

** The missing influent characteristics from Zenein WWTP's lab analysis have been assumed as typical sewage*

Model Results

- Plant's Performance

The results focus solely on the aeration tank and the final treated effluent, while the full simulation reports could be found in Annex 5. Table 5 presents the predicted effluent characteristics of the Zenein WWTP under its current operational conditions.

The effluent's TSS value is predicted to be 16.71 mg/L, which is significantly lower than the permissible limit of 50 mg/L specified by Law 48/1982. This result suggests that the WWTP effectively removes suspended particles during efficient treatment. Low TSS levels minimize the risk of water turbidity and sedimentation, which can otherwise harm aquatic ecosystems and clog waterways.

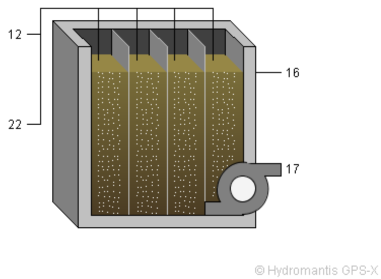
The BOD, an indicator of the organic pollutant load in the effluent, is predicted to be 12.64 mg/L. This is well below the allowable limit of 60 mg/L. Such a low BOD value reflects the plant's high efficiency in removing biodegradable organic matter, which is crucial for preventing oxygen depletion in receiving waters and supporting aquatic life. Similarly, the COD, which measures the total amount of oxidizable pollutants in the water, is predicted to be 38.25 mg/L. This value is substantially lower than the regulatory threshold of 80 mg/L. The low COD level further confirms the WWTP's capability to treat a wide range of organic and inorganic contaminants, ensuring that the effluent has minimal environmental impact.

Therefore, the predicted effluent characteristics for Zenein WWTP demonstrate excellent compliance with the standards of Law 48/1982, aligning well with the actual performance achieved in real situation.

Table 4. Predicted effluent characteristics for Zenein WWTP from the modeled current scenario

Item	Law 48/82	Predicted Value	Actual Value	Unit
TSS	50	16.71	20	mg/L
BOD	60	12.64	20	mg/L
COD	80	38.25	34.8	mg/L

The simulation parameters and results predicted for the aeration tanks provide a detailed analysis of the operational conditions and their performance in a wastewater treatment process. The mechanical aeration power is defined as 35,000 m^3/hr (amount of air supplied by the existing diffusers).



The Mixed Liquor Suspended Solids (MLSS) and Mixed Liquor Volatile Suspended Solids (MLVSS) concentrations show a good treatment indication in each channel. The average MLSS is predicted at 1421 mg/L, MLVSS is 1357 mg/L. These values reflect a good condition of biomass concentration and stable biomass activity.

The soluble COD demonstrates a consistent decline across the tank, indicating effective organic matter removal. The sCOD drops from 59.59 mg/L in the influent to 13.77 mg/L in the internal mixed liquor. This shows that the system maintains its capacity to degrade organic pollutants. These data are consistent to the F to M Ratio of 0.6 $kgBOD_5$/ (kgMLVSS.d) at volumetric organic loading rate of 0.81 $kgBOD_5/(m^3.d)$; complying with ECP's limits.

The ammonia nitrogen (NH_4-N) concentration decreases significantly from 24.55 mgN/L in the influent to less than 0.8 mgN/L. This indicates robust nitrification efficiency throughout the process. Nitrate-N concentration peaks out of the tank is predicted at 26.16 mgN/L, demonstrating the completion of the nitrification process. This consistent conversion of ammonia to nitrate underscores the system's effective nitrogen removal mechanism.

- Aeration Mechanism

Figure 17 compares the predicted DO levels in the 22 channels (simulating together one existing module) with the required DO level of 2 mg/L according to ECP. This analysis highlights the oxygen availability in the aeration process and its potential implications for system performance and energy efficiency.

From the model results, DO concentration increased from 2.2 mg/L to 3.66 mg/L from the first channel to the last one, representing a 183% increase above the required minimum level (2 ppm). These values highlight consistent over-aeration in the latter channels in the tank, which is attributed to a fixed aeration power. This scheme does not rely on dynamic adjustments based on the declining oxygen demand as the treatment process progresses.

The increasing DO levels across the channels suggest a scenario where oxygen demand diminishes due to effective pollutant removal in earlier stages. The total oxygen uptake rate (OUR) over the parts is from 72.1 $mgO_2/(L\cdot h)$ in model channels. The actual oxygen transfer rate (OTR) is 39.25 kg/h in model channels. This over-aeration may lead to unnecessary energy consumption without contributing to additional treatment efficiency. Optimizing the aeration system with automated oxygen control systems, could align oxygen supply with actual demand, reducing energy usage while maintaining treatment performance.

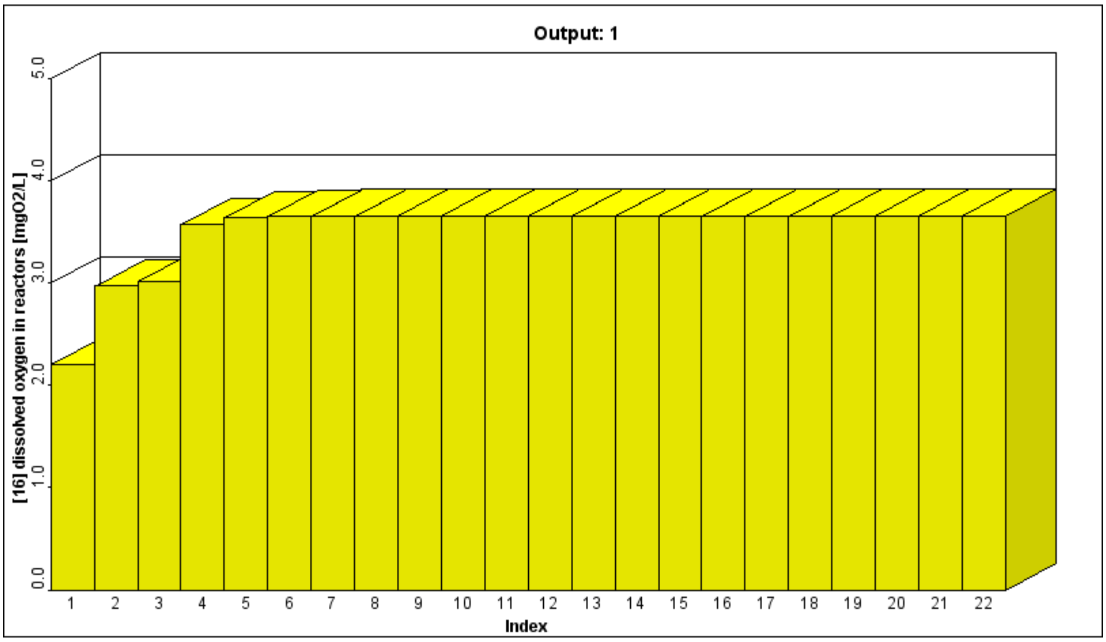


Figure 17. DO concentrations across the 22 channels representing one module

2-4-2-2 Recommended Operation Scenario

Model Setup

In the recommended operation scenario, the DO concentration in the model tanks was maintained at a constant level of 2.0 mg/L throughout the entire aeration period. Accordingly, the actual oxygen transfer rate (AOTR) in each tank was estimated using the GPS-X modeling, ensuring that the effluent quality remained nearly identical to the current operation scenario. The influent characteristics and the tank volumes were kept the same as the previous scenario.

Model Results

The model provided comparable results, specifically focusing on organics removal, nitrification, and oxygen demand. Contaminant levels decrease significantly as the wastewater moves through the model tanks. sCOD reduces from 59.65 to 13.83 mg/L as the treatment progresses, demonstrating effective organic matter removal. NH_4-N exhibits a similar trend, with a sharp decrease from 24.57 to 0.91 mg/L, largely due to nitrification. Meanwhile, NO_3-N levels increase from 0.45 to 25.16 mg/L, reflecting the conversion of NH_4-N into NO_3-N through biological nitrification.

As previously described, the DO level is maintained consistently at 2 mg/L across the channels to ensure optimal conditions for microbial activity, particularly for organics removal and nitrification. The total OUR is 70.02 $mgO_2/(L·h)$ as average value in the Tank.

2-5 Recommended Solution

Centrifugal blowers are key components in WWTPs by delivering the necessary air to support biological processes within aeration tanks. Their efficiency is influenced by factors such as flow rate, discharge pressure, and system resistance. However, previous analyses have revealed that the current aeration system is over-operated, supplying approximately 38% more oxygen than required. This over-aeration leads to excessive energy consumption and operational inefficiencies. To address this issue, optimizing blower performance by adjusting the flow rate through discharge valves is essential. This solution ensures that air delivery is properly aligned with process demands, resulting in significant energy savings and enhanced system efficiency:

Current Blower Operation

- **Current Flow Rate**: 37,000 m^3/h
- **Current Discharge Pressure**: 6.35 PSIG
- **Power Consumption**: 606 kW (813 hp)

This operational state results in excess air flow beyond the system requirements, increasing energy usage unnecessarily.

Required Blower Performance

To meet the aeration demands as determined in the recommended operation analysis:

- **Required Flow Rate**: 26,057 m^3/h
- **Required Discharge Pressure**: 8.4 PSIG

Adjusting the blower operation by controlling the discharge valves can achieve this performance, reducing energy use while maintaining process efficiency.

Proposed Adjustment and Automation

1. The butterfly valves on the blower discharge header should be partially closed manually to increase system resistance, resulting in a reduced flow rate of 26,057 m^3/h and an increased discharge pressure of 8.4 PSIG.
2. Automation integration can be achieved by connecting the butterfly valves to the DO sensors in the aeration tanks.
    - **Mechanism**:
        - The DO sensors monitor the oxygen levels in real-time.
        - Based on the DO concentration, the valve position is automatically adjusted to maintain optimal oxygen levels, ensuring precise air delivery to the aeration tanks.
        - For example, if the DO level is too high, the valve will close slightly, reducing air flow, and vice versa.
    - **Benefits of Automation**:
        - Prevents over-aeration or under-aeration.
        - Maintains system efficiency under varying load conditions.
        - Eliminates the need for frequent manual adjustments.

Energy Savings

- **Current Power Consumption**: 606 kW
- **Adjusted Power Consumption**: 485 kW
- **Power Savings**: 20%

The integration of the DO sensor with automated valve control ensures consistent energy efficiency and stable process performance.

Implementation Steps

1. High-precision butterfly valves with motorized actuators capable of interfacing with the DO sensors should be installed. The valves should then be gradually adjusted to achieve the target flow rate of 26,057 m^3/h at 8.4 PSIG.
2. DO sensors should be incorporated into the aeration tanks to enable real-time monitoring of oxygen levels. The sensor system must be calibrated to automatically adjust the valve position based on oxygen demand.
3. The discharge pressure, flow rate, and DO levels should be continuously monitored during operation to validate system performance and ensure that energy savings align with the calculated reduction of 121 kW.

Advantages of the Proposed Solution

1. A 20% reduction in blower power consumption results in substantial cost savings and reduced carbon footprint.
2. Real-time optimization of air delivery based on DO levels.
3. Improved operational stability by maintaining precise oxygen levels.
4. Reduced manual intervention and labor costs.
5. Reduced energy consumption supports the plant's sustainability goals.

Figure 18 shows the performance curve that represents the operational characteristics of a centrifugal blower used at the Zenein WWTP. It displays the relationship between inlet volume (CFM), discharge pressure (PSIG), and horsepower input. The red lines indicate a specific operating point where the blower delivers an inlet volume of approximately 26,057 m^3/hr (equivalent to around 15,340 CFM) with a discharge pressure close to 8.4 PSIG. The figure validates that the blower can effectively meet the operational requirements of the Zenein WWTP when optimized to the specified capacity and pressure. Implementing the recommended automation and control measures ensures sustainable operation, energy efficiency, and compliance with environmental regulations.

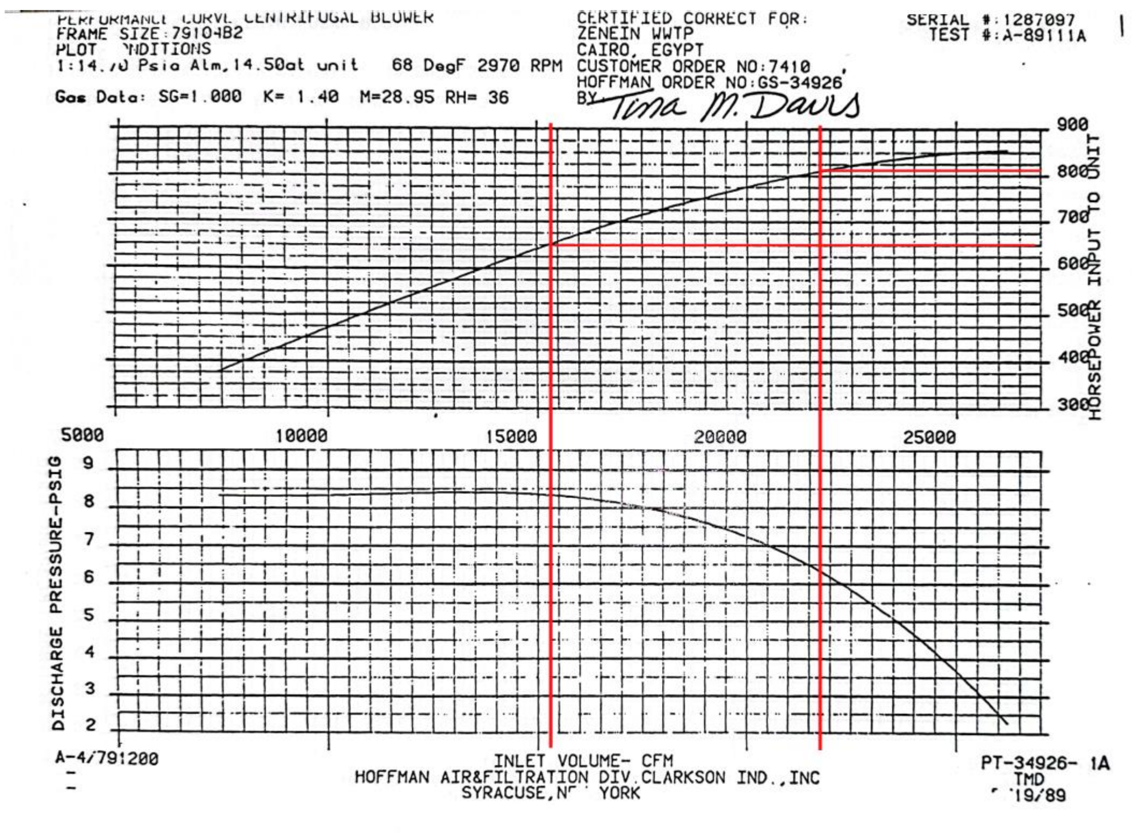


Figure 18. DO concentrations across the 22 channels representing one module

3- CONCLUSION AND RECOMMEDNATIONS

3-1 Conclusions

The collaborative study between the Holding Company for Water and Wastewater (HCWW) and the Netherlands Enterprise Agency (RVO) has successfully identified optimal aeration system upgrades for three selected WWTPs, including Zenein WWTP. By adopting a multidisciplinary approach that balances technical, financial, and environmental factors, the study offers sustainable solutions for improving wastewater treatment efficiency. The technical recommendations, such as advanced aeration controls and energy-efficient systems, are designed to enhance operational performance while reducing environmental impact. This comprehensive strategy ensures long-term sustainability and resilience in wastewater management operations.

The Zenein WWTP is a highly advanced and well-structured facility designed to manage large-scale wastewater treatment with efficiency and reliability. The plant effectively handles wastewater inflows from multiple force mains across Cairo, ensuring broad service coverage. Key treatment stages include pre-aeration, primary sedimentation, biological treatment in aeration tanks, and final clarification, followed by chlorination for disinfection.

The plant consistently meets or exceeds environmental standards set by Law No. 48/1982, with effective removal of Total Suspended Solids (TSS), Biochemical Oxygen Demand (BOD), and Chemical Oxygen Demand (COD). Additionally, compliance with pH, temperature, dissolved oxygen, and residual chlorine standards ensures environmental safety.

Operational efficiency is further enhanced by well-maintained infrastructure, including dedicated workshops, power and air supply systems, and specialized facilities for maintenance and staff welfare. Residential accommodations, a laboratory, administrative buildings, and recreational areas contribute to smooth operations. The integration of a rapid repair unit ensures ongoing reliability. Collectively, these systems and structures position the Zenein WWTP as a model for sustainable and effective wastewater management.

Through close collaboration with HCWW and EL-Giza Water and Wastewater Company representatives, the study ensures data-driven progress, supported by site visits and progress meetings. This comprehensive approach helps identify sustainable pathways to optimize the aeration systems and further enhance the operational efficiency, environmental compliance, and energy performance of the Zenein WWTP to achieve compliance with Law 48/1982 while minimizing energy consumption.

The detailed analysis of the wastewater treatment process design for one module of the Zenein WWTP, treating 131,000 m^3/day, provided valuable information about the plant's operational performance and energy efficiency. Using GPS-X modeling software too validate the numerical estimations and field analysis, two scenarios were evaluated: the current operation scenario, which highlighted inefficiencies due to non-functional biofilters resulting in excessive aeration demand, and the recommended operation scenario, which optimized oxygen supply at a dissolved oxygen level of 2.0 mg/L. The analysis demonstrated that the current aeration system operates at 37,000 m^3/hr, significantly above the required capacity, leading to higher energy costs.

The recommended scenario offers an optimal solution for enhancing the aeration system at Zenein WWTP. It involves adjusting the blower capacity to deliver 26,057 m^3/hr, effectively meeting peak oxygen demand for efficient nitrification. As a result, achieving and maintaining a blower efficiency of 70% could be crucial for reducing energy consumption and minimizing operational costs. This approach ensures maximum energy efficiency and system performance.

3-2 Recommendations

To adjust the aeration system keeping the Zenein WWTP at its original design performance while ensuring compliance with Law 48/82 with optimum energy requirements, it is recommended to install high-precision butterfly valves with motorized actuators. These actuators should be integrated with DO sensors in the aeration tanks to regulate the air supply and achieve the predicted required Actual Oxygen Transfer Rate (AOTR). The system will be controlled through a Programmable Logic Controller (PLC) connected to the Main Control Panel for real-time DO monitoring and automatic valve adjustments (Figure 19).

This setup will enable precise control over the air supplied by mechanical diffusers, each delivering 37,000 m^3/hr of air, ensuring optimal oxygen levels in the tanks. The use of actuators and automated valves will allow the adjustment of blower output, reducing motor power consumption during periods of low oxygen demand. This solution enhances energy efficiency, reduces operational costs, and supports sustainable wastewater treatment operations.

Key benefits of this approach include:

- Energy-efficient adjustment of air supply operations based on real-time DO and pollution levels.
- Elimination of the need for significant infrastructure modifications.
- All mechanical diffusers are to be operated within the tank’s channels to ensure even mixing and oxygen distribution, minimizing the risk of dead zones or inefficient biological activity.

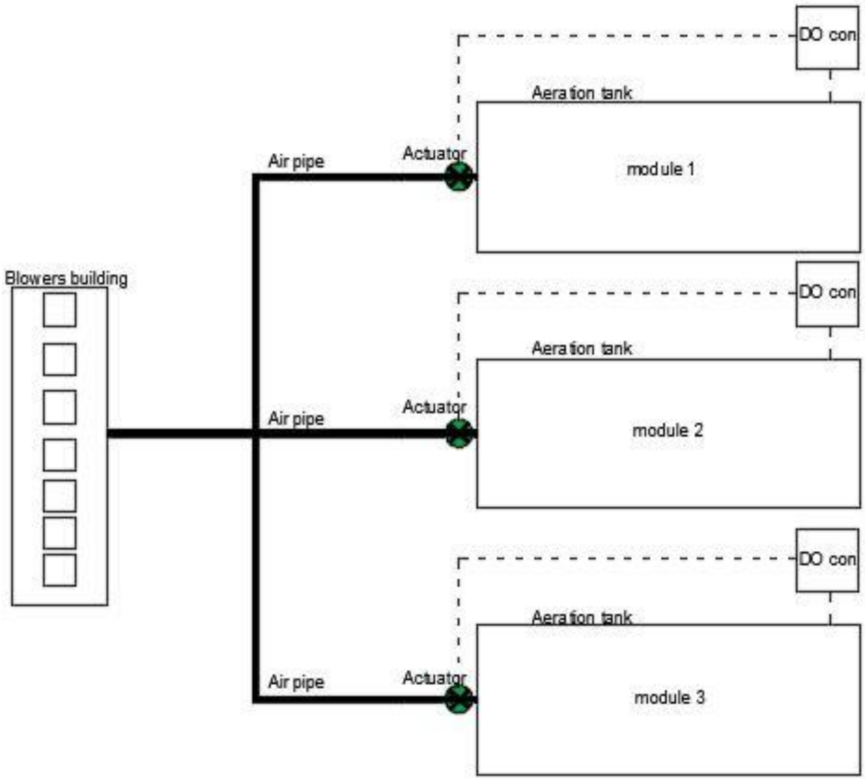


Figure 19: Installation of actuators and DO meters to control the air supply

- <u>Electromechanical Works</u>

On the other hand, Table 8 outlines the recommended rehabilitation works for various electromechanical units at the Zenein WWTP. These recommendations focus on enhancing operational efficiency, ensuring system reliability, and addressing existing deficiencies across mechanical and electrical components. Each unit's proposed actions are designed to meet regulatory standards and support sustainable plant performance.

Table 5. Recommended electromechanical rehabilitation works for Zenein WWTP's Units

Unit	Rehabilitation works
Zenein Pumping Station Complex	- Existing lower bearings should be replaced with sealed, durable types to minimize wear and extend lifespan. - Protective shields should be installed around lower bearings to prevent damage from solids and debris. - Regular lubrication and inspection schedules should be implemented to maintain optimal bearing performance.

Unit	Rehabilitation works
Screens	- Addition of a washing system for the screens that could enhance efficiency by reducing manual cleaning requirements and improving hygiene standards
Grit Removal System	- The grit removal system should be upgraded to a fully automated process with modern equipment. - A functional sand silo system and automated conveyors should be installed for grit handling. - Manual handling and the use of wheeled loaders should be minimized through automation.
Pre-Aeration Tanks	- Sensors should be installed for real-time monitoring of grease/scum levels and air supply. - The aeration system should be upgraded to high-efficiency coarse bubble air diffusers.
Primary Sedimentation Tanks	- Scraper blades and components should be upgraded to corrosion-resistant materials to reduce wear. - Adjustable effluent weirs or insert plates should be installed for better flow control and clarity. - Automated or semi-automated tank cleaning systems should be implemented to improve maintenance efficiency.
Aeration Tanks	- Coarse bubble diffusers should be replaced with fine or medium bubble diffusers to enhance oxygen transfer and reduce energy consumption. - DO probes, flow meters, and automated controls should be installed to optimize aeration rates, with VFDs used to adjust blower airflow based on real-time conditions. - A structured preventive maintenance plan should be developed for diffusers, pipes, and controls to prevent failures and maintain long-term efficiency.
Final Sedimentation Tanks	- Adjustable weirs or inserts should be installed to enhance operational flexibility and improve effluent quality during variable flow conditions. - Corrosion-resistant materials should be used for scraper blades and components to reduce wear and lower maintenance costs. - Automated or semi-automated cleaning systems, like brushing mechanisms or spray nozzles, should be added to maintain tank cleanliness and reduce manual labor. - Sludge collection efficiency should be regularly monitored, with adjustments made to baffle and scraper systems to optimize sedimentation performance.

<table>
<tr><th>Unit</th><th>Rehabilitation works</th></tr>
<tr><td rowspan="4">Electrical Works</td><td>Electrical Cables and Trays

- Standard electrical cables should be replaced with new, flexible ones of the same specifications to improve durability and adaptability.
- Proper connection and organized coordination of electrical cables on cable trays must be ensured.
- Cable trays with covers should be fabricated from galvanized steel in various sizes to fit the cable cross-sectional area.
- Worn-out and rusted cable tray covers caused by sewage gases must be replaced.
- New electrical cable trays, holders, and covers in different sizes should be supplied and installed along secure paths to avoid exposure to sewage gases.</td></tr>
<tr><td>Lighting Systems

- Spare parts for floodlights and lighting poles in the station's streets must be supplied.
- Various types of bulbs should be provided according to the station's spare inventory.
- Periodic maintenance of lighting systems and replacement of damaged components must be conducted.
- Damaged light bulbs and floodlight bulbs inside station buildings must be replaced.
- Maintenance of lighting fixtures and poles, including the replacement of damaged bulbs, is essential.</td></tr>
<tr><td>Transformer Maintenance

- Transformer oil must be filtered to remove moisture, and insulation must be tested.
- A manometer must be installed to monitor transformer temperature.
- Routine inspections should be conducted to monitor oil leaks and temperature levels.
- Protection device connections must be reviewed for proper functioning.
- Insulation testing of transformer terminals should be conducted for safety and reliability.</td></tr>
<tr><td>Electrical Panels

- Spare parts for electrical panel components, including circuit breakers and relays, must be supplied.
- Continuous monitoring and replacement of damaged electrical components are necessary</td></tr>
</table>

Unit	Rehabilitation works
	- Medium voltage panels must undergo periodic maintenance by specialized companies.

Implementing these recommendations will enable decision-makers to optimize the performance of the Zenein WWTP, ensuring full compliance with environmental regulations while significantly lowering operational expenses. These improvements will enhance the plant's efficiency and reliability, contributing to more effective wastewater treatment processes. Additionally, adopting these strategies will support the transition to sustainable wastewater management practices, aligning the facility with long-term environmental and economic goals.

4- ANNEXES

Annex 1: Life Cycle Assessment Report (Executive Summary)

Annex 2: Terms of References - Technical study for the understanding and environment-friendly upgrading of the aeration regimes with automation at Egyptian WWTP’s

Annex 3: Law 48/82, Details to be Followed Regarding the WWTP’s Effluents Quality

Annex 4: The Laboratory Analyses Log by the Kafr El-Sheikh Water and Wastewater Company

Annex 5: The GPS-X Software Models’ Reports

Annex 1: Life Cycle Assessment Report (Executive Summary)

Our reference R001-1286661OJH-V01-kzo-NL

Executive summary

Efficient wastewater treatment is increasingly important in Egypt because of climate change and drinking water security. However, many Egyptian wastewater treatment plants (WWTPs) are financially as well as environmentally unsustainable. Life cycle assessment (LCA) is a standardized method to show which aspects of a product or service cause the largest environmental impact. This knowledge is vital for a targeted approach in the country's water treatment strategy to minimize e.g. greenhouse gas emissions, electricity use and to optimize sludge management.

The purpose of this study is to support the development of a nationwide strategy for mitigating climate change effects on wastewater treatment and sludge management. The environmental performance of three Egyptian WWTPs as well as a total of four improvement scenarios are analysed using LCA methodology. Subsequently, the cost-effectiveness of the improvement scenarios is perfunctorily explored for one WWTP.

The LCA was executed for three WWTPs. The selection was based on size, lay-out and available data. All three WWTPs perform both primary (physical) treatment and secondary (biological) treatment. The selected WWTPs are (1) Zenin WWTP (Cairo) which receives 450,000 m^3 wastewater per day, (2) Sakha WWTP (Sakha, Kafr el Sheikh) which receives 70,000 m^3 wastewater per day and (3) Qaha WWTP (Qaha, Qalyubiya) which is the smallest of the three WWTPs and receives 6,000 m^3 wastewater per day. Sakha WWTP is equipped with a co-digestion bioreactor, which is partly fed with municipal sludge from Sakha WWTP and partly with cow and chicken manure.

The LCA results showed that the largest cause of negative environmental impact among all three WWTPs is water treatment and not sludge treatment. The main cause of this is electricity use during (secondary) aeration, which is the main electricity use at the WWTPs. Currently, all electricity from the grid in Egypt is grey (fossil-based) electricity and this results in a more negative environmental impact. With regards to sludge treatment, the transport of wet sludge to the sludge drying beds causes most impact (again as a result of the usage of grey electricity). Co-digestion (specifically for Sakha WWTP) strongly decreases the negative environmental impact. However, the impact of digestate transport or other flows on the side of the external party operating the co-digestion reactor is not included.

Four improvement scenarios have been chosen in close collaboration with HCWW. Two of them are water treatment related and the other two are related to sludge treatment:

1. Replace 20 % of total electricity demand with green electricity
2. Automize aeration to decrease electricity use during aeration by 1/3th
3. Decrease sludge drying duration by implementation of solar thermal collector panels
4. Send all sludge at Sakha WWTP to co-digestion reactor

3/54

Our reference R001-1286661OJH-V01-kzo-NL

Major findings:

- The biggest cause of environmental impact during water treatment is electricity use. Currently, all electricity from the grid in Egypt is grey (fossil-based) electricity and this results in a negative environmental impact. The main electricity use occurs during aeration. Other main impacts during water treatment are use of chlorine gas and emission of nitrous oxide, N_2O (estimated using N_2O model)
- The environmental impact per m^3 of water is largest for Qaha WWTP, which is the smallest of the three WWTPs. Smaller WWTPs using more electricity per m^3 of water than bigger ones is also seen in The Netherlands, but the difference is not as high as seen now at Qaha WWTP. Qaha WWTP should be benchmarked against other small WWTPs in Egypt to check its validity. However, it is a first indication that in order to treat wastewater more efficiently it would be wise to combine smaller WWTPs in larger plants and for new to be built WWTPs prevent building small plants if possible. An integral approach should of course be maintained which justifies the location specific situation
- The main impact during sludge treatment is due to electricity used to transport sludge to sludge drying beds where it remains on average 40 days. Sludge emits methane while drying (estimated best- and worst case based on literature) but this does not strongly affect the total environmental impact
- Automization of aeration seems to be a proper improvement as it saves 1,500,000 kg CO_2-equivalents per year against an indicative cost of 0.05 EP per kg CO_2-equivalents
- Implementation of 20 % electricity by solar panels saves up to 18 % of CO_2 emissions and an estimated 500,000 EP per year as it lowers the amount of grey electricity to be bought. Cost wise the solar panels result in a positive payback period (payback shorter than lifetime) resulting in a yearly saving. However, the payback period is quite long being around 16.5 – 18.5 years depending on solar panel location (desert or Nile Delta). This as a result of the current low price for grey energy
- Sludge co-digestion at Sakha WWTP converts sludge to electricity, which reduces the total impact of sludge treatment. Sludge co-digestion of the full amount of sludge at Sakha WWTP is more beneficial than using drying beds. However, we did not take into account environmental impacts and required investments by external parties operating the digester and taking care of the distribution of the liquid digestate
- Solar thermal collector panels are both environmentally as well as economically not a viable option because of the amount of heat required to increase evaporation. This requires many solar thermal collector panels and more land area than is rendered by less required sludge drying beds

Proposed first steps towards more sustainable WWTPs in Egyptian context

The LCA methodology enabled some interesting insights in the environmental footprint of water and sludge treatment. Based on the results of the current study, the first focus in Egypt in relation to WWTPs should be to lower the amount of electricity needed and decrease the amount of grey electricity. This will result in a considerable improvement.

Our reference R001-1286661OJH-V01-kzo-NL

The saving on electricity can be realised by the implementation of an automized aeration which potentially decreases the electricity demand for aeration by 1/3th. First steps to take in relation to this is to install an automized aeration regime at a WWTP and test it in practice. If the test is successful further application can be enrolled throughout Egypt where application at big WWTPs should be the first step as the biggest gain in less environmental impact can be obtained there. Decreasing the amount of grey electricity can be achieved by increasing the amount of green energy. Solar panels can be placed to lower the grey electricity demand further and to decrease reliance on fossil resources, CO_2 impact and ozone layer depletion. Instead of solar panels, it might also be possible to use windmills or hydro power. Another good option is to increase the amount of sludge being (co-)digested in Egypt to produce biogas which can be converted with a combined heat and power installation to green electricity. Replacing grey fossil-based electricity does not only apply to the WWTPs of course. It is (or should be) a nationwide point of concern in reducing the amount of greenhouse gases emitted.
Secondary or concurrently the focus should be on improvement of the sludge treatment, including the final destinations of the produced products (e.g. dried sludge, liquid digestate, effluent).

Annex 2: Terms of References - Technical study for the understanding and environment-friendly upgrading of the aeration regimes with automation at Egyptian WWTP's

PARTNERS VOOR WATER

- Extensive knowledge in international wastewater treatment practices and typical types of equipment
- Working experience in countries with comparative challenges, preferably experience in Egypt or elders
- Excellent reporting and presenting skills

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HCWW

            - Redox measurements
    - Central/remote control
        - Type and specifications of a central 'display-based control' or similar (if applicable)
        - Specifications of the current monitoring/central protocol
    - Any other essential information that is required for the upgrading of the aeration regimes at the three WWTP's
- Conclusions and Recommendations from the implementing team.
- A scenario analysis of (combined) optimal technical, environmental impact (CO2-eg.) and cost analysis of aeration automation and technical upgrade options.
- The combine technical and scenario analysis study has to have sufficient quality to serve as basis for the development of a large-scale implementation of automated aeration regimes at the three WWTP's.
- An executive summary (2 pages maximum) in simple, non-scientific language that highlights the main findings of the study, and the potential impact after implementation of the offered upgrade scenarios.

6. Timeline /planning

The foreseen planning of this study in 2022 is as follows:

Activity	Planning
Kick-off meeting between the HCWW representative, the consultant(s) and RVO (online)	7 October
Two progress meetings between the HCWW representative, the consultant(s) and RVO (online)	2-weekly
Debriefing meeting between the HCWW representative, the international consultant(s), the local consultant, and RVO (online).	15 November
Final report submitted	3 December

7. Qualifications of consultant

- Proven track record of engineering expertise in relation to Egyptian WWTP's (for the aeration regime specifications study module)
- Proven track record of masterplan-type studies with a multidisciplinary character (for the upgrading pathways analysis module)
- In the case of a team, at least one senior level sanitation expert

4

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environmentally most optimal technical aeration upgrade pathways.

For the technical and protocol research of the aeration regimes, data collection will be the prime activity of the study's **consultant**. For the scenario analysis module, the consultant is expected to identify and explain the type of equipment needed and the impact of the upgrading in operations, emissions and costs.

The consultant will cooperate with HCWW's appointed contact person to manage site visits and data acquisition in the shortest time possible.

To allow for a quality control and to further clarify the need of HCWW, biweekly meetings are included with HCWW and RVO representatives in the research and analysis periods.

The total research and scenario analysis period is set at six weeks.

5. Deliverables

The technical specification results and the optimal pathway models must be delivered in a detailed report, which can be later presented to decision-makers and stakeholders. The report is to have the following characteristics:

- Max. 50 pages.
- Technical specifications of the aeration regime and all essential auxiliary equipment at the three WWTPs including – amongst other parameters
    - Full technical specifications of the aerators including
        - Type
        - Brand
        - Capacity
        - Operational parameters
        - Technical state
    - Controlling mechanisms
        - Is there frequency control - can aerator ne adjusted or only on/off
        - Is there an air compressor (if yes, what are its specifications)
        - Existence of in-line sequencing or similar
    - The specifications of the control mechanisms
        - Are there meters to monitor the flow quality
            - DO/O2 meters and
            - NH3/4+ meters

3

Analysis (LCA) study on selected Egyptian WWPT's found that the automation of WWTP aeration regimes may offer a cost-effective upgrade to reduce operational costs and CO2-eg. emissions simultaneously.

3. Objective

This study is to serve as a preliminary research into the future upgrading of the aeration regimes at the WWTP's of

- Zenin (Cairo; 450.000 m3 wastewater / day)
- Sakha (Kafr el Sheikh; 70.000 m3 wastewater / day)
- Qaha (Qalyubiya; 6.000 m3 wastewater/day)

The main objective of the study is the detailed mapping of the baseline equipment and the offering of optimal upgrade scenarios with regard to the hardware and operational costs fo future hardware, the reduced environmental impact and possible improvement in treatment quality. The delivered study must of sufficient to understand the costs and technical upgrading needed to improve the aeration performance at the viewed locations.

The two sub-objectives include

1. The full specifications of the aeration and essential auxiliary equipment at the three WWTP's and the related protocols for aeration and
2. The development of multidisciplinary upgrade scenarios for the local hardware, including at least 2-3 technical upgrade scenarios for the locations.

4. Scope of the work

In order to determine the optimal upgrades for the three WWTPs, a technical specifications study of the current (baseline) equipment and protocols is required.

Because an optimal upgrade considers cheaper operations, lesser environmental impact (expressed as CO2-eq.) and improved wastewater treatment quality, RVO also seeks to understand the most optimal scenarios of upgrading.

Therefore the scope of work includes two modules, namely

1. Identifying and listing of all relevant hardware data and operational protocols of the aeration treatments of the three WWTP's;
2. Multidisciplinary scenario analysis regarding the financially, operationally and

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TERMS OF REFERENCE

Technical study for the understanding and environment-friendly upgrading of the aeration regimes with automation at Egyptian WWTP's

1. Introduction

The *Partners voor Water* (PvW) initiative is part of the bilateral cooperation between Egypt and the Netherlands on water sectoral challenges and opportunities. The interdepartmental programme of four Dutch ministries and their local counterparts aims to strengthen the cooperation on water and delta management between the partner countries on a number of water-related topics, with a priority on the water and agriculture nexus, coastal protection and water supply & sanitation sectors.

This technical study is requested to support a specific niche within the water & sanitation sector in Egypt.

2. Background

Over the past 2 decades, the Egyptian government has faced tremendous challenges to provide safe sanitation practices. The majority of investments are primarily focusing on providing large centralized sanitation-related services and infrastructure in the major cities, which are characterized by high capital investments and high operation and maintenance (O&M) costs.

Decisions about wastewater projects are primarily influenced by direct capital and operating costs as long as the design is meeting local standards, while life-cycle cost and life-cycle environmental impacts are rarely considered.

Current wastewater treatment plant (WWTP) operations imply high environmental and operational costs, Also, with the current technical operations, the full costs of treatment cannot be financed by the end-user fees, making wastewater treatment facilities financially unsustainable. In some cases, a strategic upgrade of treatment steps may be able to reduce both the environmental impact and the operational expenses.

The Holding Company for Water and Waste Water (HCWW, the Egyptian state authority to operate and maintain WWTP's) prioritizes the improvement of WWTPs. A recent Life-Cycle

Annex 3: Law 48/82, Details to be Followed Regarding the WWTP's Effluents Quality

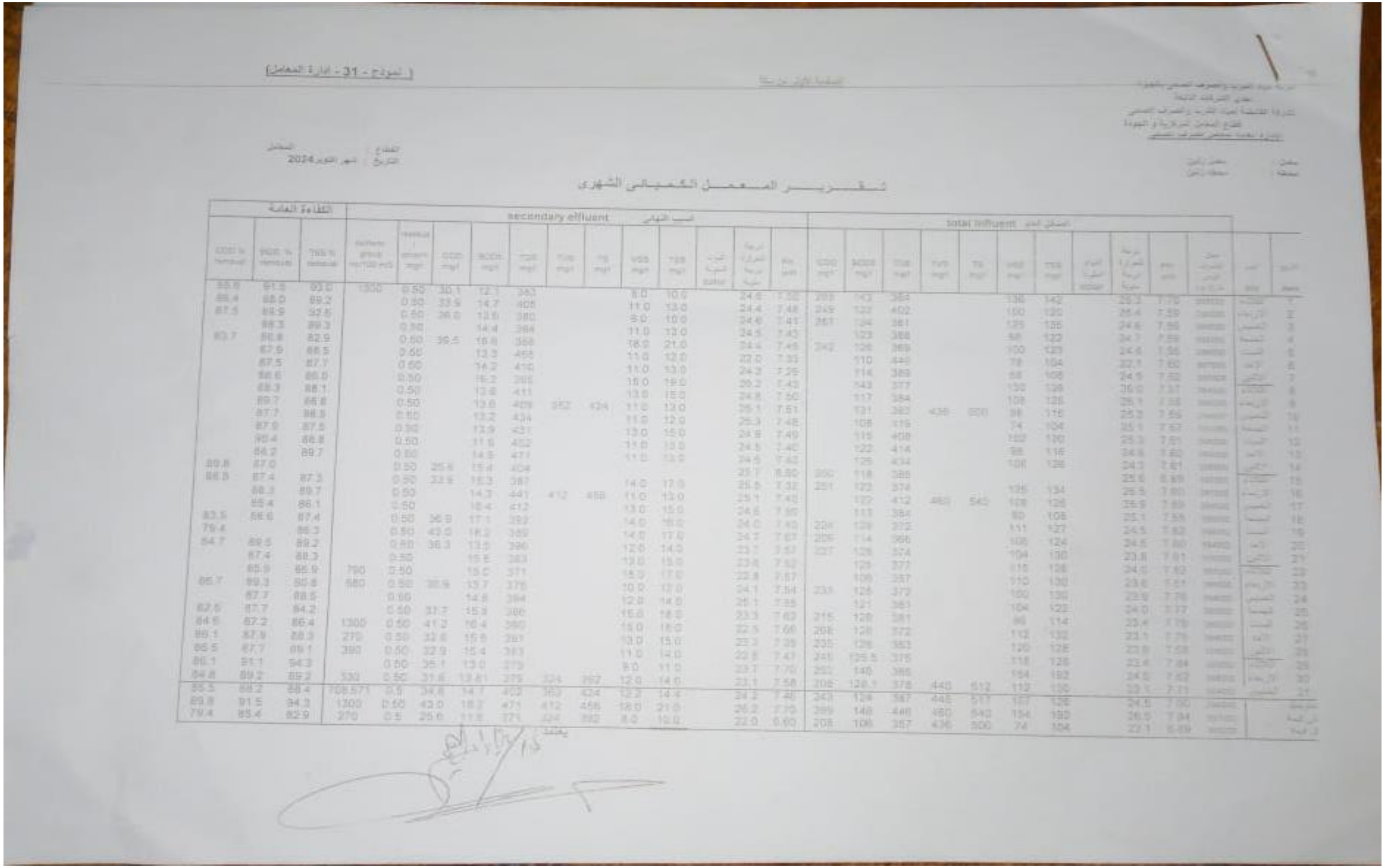
مادة ٥٢ - يجب أن تتوافر فى مياه الصرف الصحى المعالج والمخلفات الصناعية السائلة المعالجة التى يرخص بصرفها إلى مسطحات غير العذبة – المعايير والمواصفات الآتية :

البيـــــــــــــان	الحد الأقصى لمعايير المخلفات الصناعية السائلة المعالجة التى يتم صرفها على	
	مياه الصرف الصحى المعالج	المياه الصناعية السائلة المعالجة
درجة الحرارة	لا تزيد عن ٣ درجات مئوية من المجرى المائى المستقبل	لا تزيد عن ٣ درجات مئوية عن المجرى المائى المستقبل
الأس الإيدروجينى	٦-٩	٦-٩
الأكسجين الحيوى الممتص	٦٠	٦٠
الأكسجين الكيميائى المستهلك (دايكرومات)	٨٠	٨٠
الأكسجين الذائب	لايقل عن ٤	لايقل عن ٤
الزيوت والشحوم	١٠	١٠
المواد الصلبة الذائبة الكلية	لا تزيد عن ٢٠٠٠ ولا تزيد عن ٥٠٠٠ بالمناطق الساحلية	لا تزيد عن ٢٠٠٠
المواد العالقة	٥٠	٥٠
الكبريتيدات (as H2S)	١	١
السيانيد الحر	٠,١	٠,١
الفسفور الكلى (TP) as P (*)	–	–
النشادر NH_3 as (N) (*)	–	–
النتروجين الكلى (TN) as N (*)	–	–
الفينول	٠,٠٥	٠,٠٥
الزئبق	٠,٠٠١	٠,٠٠١
الرصاص	٠,١	٠,١
الكادميوم	٠,٠٠٣	٠,٠٠٣
الزرنيخ	٠,٠٥	٠,٠٥
سيلينيوم	٠,١	٠,١

البيـــــــــــان	الحد الأقصى لمعايير المخلفات الصناعية السائلة المعالجة التى يتم صرفها على	
	مياه الصرف الصحى المعالج	المياه الصناعية السائلة المعالجة
الكروم	٠,١	٠,١
النحاس	٠,٥	٠,٥
النيكل	٠,٥	٠,٥
الزنك	٢	٢
الحديد	٣,٥	١
العد الاحتمالى للمجموعة القولونية فى ١٠٠سم٣	٥٠٠٠	١٠٠٠
بويضات الديدان (الإسكارس)(*)	–	–
المبيدات بأنواعها		
ألدرين، داى إلدرين Aldrin and dieldrin	لا يزيد عن ٠,٠١٥	لا يزيد عن ٠,٠١٥
الأكلور Alachlor	لا يزيد عن ٠,١	لا يزيد عن ٠,١
الديكارب Aldicarb	لا يزيد عن ٠,٥	لا يزيد عن ٠,٥
أترازين Atrazine	لا يزيد عن ٠,١	لا يزيد عن ٠,١
بنتازون Bentazone	لا يزيد عن ٠,١٥	لا يزيد عن ٠,١٥
كاربوفيوران Carbofuran	لا يزيد عن ٠,٣٥	لا يزيد عن ٠,٣٥
كلوردان Chlordane	لا يزيد عن ٠,٠١	لا يزيد عن ٠,٠١
٢ ، ٤ داى كلوروبروب 2,4 - Dichoroprop	لا يزيد عن ٠,٥	لا يزيد عن ٠,٥
	لا يزيد عن ٠,٤٥	لا يزيد عن ٠,٤٥
فينوبروب Fenoprop	لا يزيد عن ٠,٥	لا يزيد عن ٠,٥
ميكوبروب Mecoprop	لا يزيد عن ٠,٤٥	لا يزيد عن ٠,٤٥

(*) معايير يتم دراستهـــا بواسطة مجمـــوعة عمـــل يتم تشكيلها بقـــرار وزير الموارد المائيـــة والرى من وزارات الصحـــة والسكان ، الدولة لشئون البيئـــة ، مرافق مياه الشرب والصرف الصحى ، الموارد المائية والرى .

Annex 4: The Laboratory Analyses Log by the El-Giza Water and Wastewater Company



(نموذج - 31 - ادارة المعامل)

الشهر: اكتوبر 2024

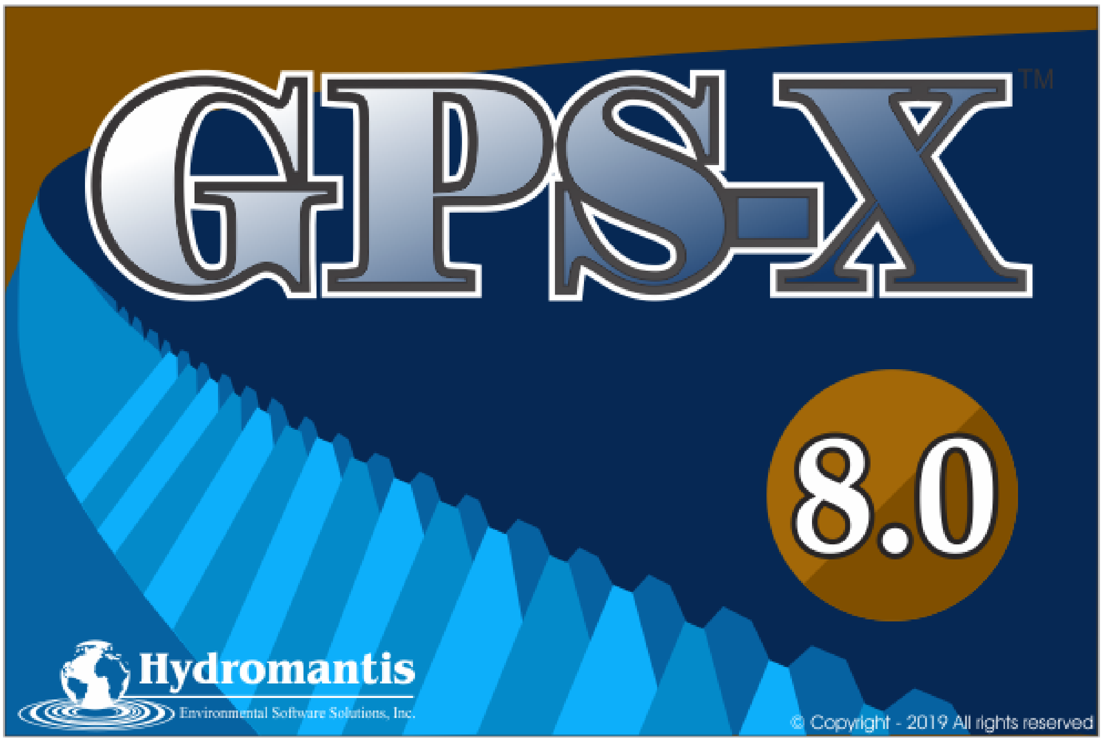
تقرير المعمل الكيميائي الشهري

Date	COD % removal	BOD % removal	TSS % removal	Coliform group m/100 ml	Residual chlorine mg/l	COD mg/l	BOD5 mg/l	TDS mg/l	TVS mg/l	TS mg/l	VSS mg/l	TSS mg/l	Temp	pH unit
	الكفاءة العامة			secondary effluent السيب النهائي										
1	89.6	91.6	93.0	1300	0.55	30.1	12.1	363			8.0	10.0	24.5	7.52
2	85.4	88.0	89.2		0.50	33.9	14.7	405			11.0	13.0	24.4	7.48
3	87.5	88.9	92.6		0.50	36.0	12.6	380			9.0	10.0	24.6	7.41
4		88.3	89.3		0.50		14.4	384			11.0	13.0	24.5	7.43
5	83.7	86.8	82.9		0.50	36.5	16.6	368			18.0	21.0	24.4	7.45
6		87.9	88.5		0.60		13.3	465			11.0	12.0	22.0	7.33
7		87.5	87.7		0.60		14.2	410			11.0	13.0	24.2	7.26
8		86.6	86.0		0.50		16.2	366			16.0	19.0	26.2	7.43
9		88.3	88.1		0.50		13.6	411			13.0	15.0	24.8	7.50
10		89.7	86.8		0.50		13.6	409	352	424	11.0	13.0	25.1	7.61
11		87.7	88.5		0.50		13.2	434			11.0	12.0	25.3	7.48
12		87.9	87.5		0.50		13.9	431			13.0	15.0	24.9	7.49
13		90.4	88.8		0.50		11.6	452			11.0	13.0	24.5	7.40
14		84.2	89.7		0.50		14.5	471			11.0	13.0	24.5	7.62
15	89.8	87.0			0.50	25.6	15.4	404					25.7	6.80
16	86.5	87.4	87.3		0.50	33.6	15.3	387			14.0	17.0	25.5	7.32
17		88.3	89.7		0.50		14.3	441	412	458	11.0	13.0	25.1	7.45
18		85.4	86.1		0.50		16.4	412			13.0	15.0	24.6	7.50
19	83.5	86.6	87.4		0.50	36.9	17.1	392			14.0	16.0	24.0	7.40
20	79.4		86.3		0.50	43.0	18.2	389			14.0	17.0	24.7	7.67
21	84.7	89.5	89.2		0.60	36.3	13.5	390			12.0	14.0	23.1	7.57
22		87.4	88.3		0.50		15.6	383			13.0	15.0	23.6	7.52
23		85.9	86.9	790	0.50		15.0	371			15.0	17.0	22.8	7.67
24	86.7	89.3	90.8	680	0.50	30.9	13.7	376			10.0	12.0	24.1	7.54
25		87.7	88.5		0.60		14.8	384			12.0	14.0	25.1	7.55
26	82.5	87.7	84.2		0.50	37.7	15.9	366			15.0	18.0	23.3	7.62
27	84.6	87.2	86.4	1300	0.50	41.2	16.4	380			15.0	18.0	22.5	7.66
28	86.1	87.9	88.3	270	0.50	32.6	15.6	391			13.0	15.0	23.2	7.35
29	85.5	87.7	89.1	390	0.50	32.9	15.4	383			11.0	14.0	22.8	7.47
30	86.1	91.1	94.3		0.50	35.1	13.0	379			9.0	11.0	23.7	7.70
31	84.8	89.2	89.2	530	0.50	31.6	13.81	375	324	392	12.0	14.0	23.1	7.58
متوسط	85.5	88.2	88.4	706.571	0.5	34.6	14.7	402	353	424	12.2	14.4	24.2	7.40
أ. قيمة	89.8	91.5	94.3	1300	0.60	43.0	18.2	471	412	458	18.0	21.0	26.2	7.70
أ. قيمة	79.4	85.4	82.9	270	0.5	25.6	11.6	371	324	392	8.0	10.0	22.0	6.80

Date	COD mg/l	BOD5 mg/l	TDS mg/l	TVS mg/l	TS mg/l	VSS mg/l	TSS mg/l	Temp	pH unit
	total influent الداخل العام								
1	289	143	364			136	142	25.3	7.70
2	249	122	402			100	120	25.4	7.59
3	261	124	381			125	135	24.6	7.55
4		123	388			98	122	24.7	7.59
5	242	126	369			100	123	24.6	7.56
6		110	440			78	104	22.1	7.60
7		114	389			68	108	24.5	7.62
8		143	377			130	139	26.0	7.37
9		117	384			108	126	25.1	7.38
10		131	382	436	500	98	116	25.3	7.56
11		108	419			74	104	25.1	7.57
12		115	408			102	120	25.3	7.61
13		122	414			98	116	24.8	7.60
14		125	434			108	126	24.3	7.61
15	250	118	385					25.6	6.69
16	251	122	374			135	134	26.5	7.60
17		122	412	460	540	108	126	25.9	7.59
18		113	384			90	108	25.1	7.55
19	204	129	372			111	127	24.5	7.62
20	206	114	366			106	124	24.5	7.60
21	237	128	374			104	130	23.8	7.61
22		125	377			115	128	24.0	7.62
23		106	357			110	130	23.6	7.51
24	231	125	372			100	130	23.9	7.76
25		121	383			104	122	24.0	7.77
26	215	129	381			96	114	23.4	7.75
27	208	128	372			112	132	23.1	7.75
28	235	128	383			120	128	23.8	7.58
29	245	125.5	375			118	128	23.4	7.84
30	252	140	386			154	192	24.0	7.62
31	208	128.1	378	440	512	112	130	23.1	7.71
متوسط	243	124	387	445	517	107	126	24.5	7.60
أ. قيمة	289	148	446	460	540	154	192	26.5	7.84
أ. قيمة	208	106	357	436	500	74	104	22.1	6.69

يعتمد

Annex 5: The GPS-X Software Models' Reports

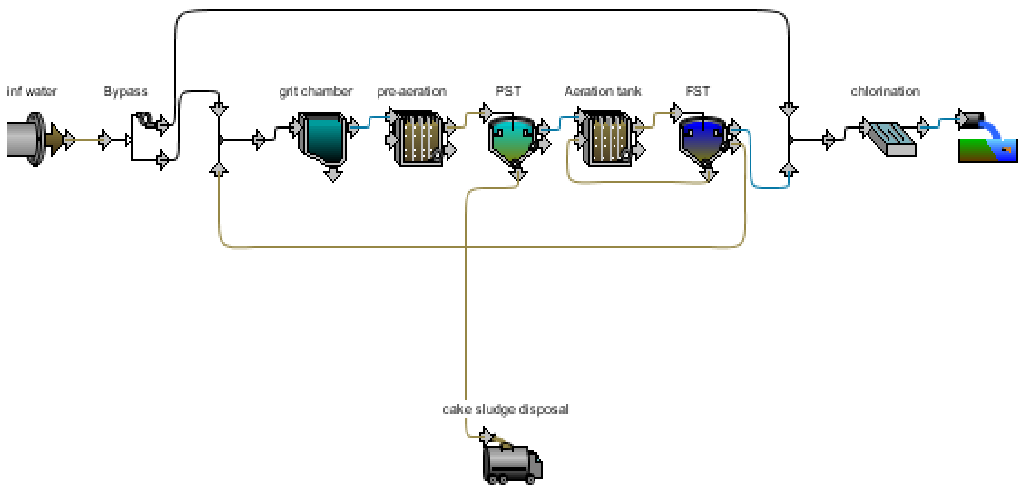


Report

Sun Jan 05 16:57:02 EET 2025

Current Operation Scenario

Layout



Inputs

Wastewater Influent

Variable	Unit	Value
[1] total COD	gCOD/m3	243.0
[1] VSS/TSS ratio	gVSS/gTSS	0.8
[1] influent flow	m3/d	131000

Plug-Flow Tank

Variable	Unit	Value
[38] tank depth	m	2.56
[38] specify oxygen transfer by...		Entering Airflow
[38] diffuser type		Coarse Bubble
[38] influent fractions	-	0.25
[38] recycle fractions	-	0.25
[38] HRT lower limit	hour	4.0
[38] HRT upper limit	hour	8.0
[38] MLSS lower limit	mg/L	1000.0
[38] MLSS upper limit	mg/L	3000.0

Circular Primary Clarifier

Variable	Unit	Value
[12] clarifier type		Sloping Bottom
[12] surface	m2	4072.0
[12] water depth at sidewall	m	2.7
[12] water depth at center	m	3.7
[14] underflow rate	L/s	160.0
[12] HRT lower limit	hour	2.0
[12] HRT upper limit	hour	4.0

Plug-Flow Tank

Variable	Unit	Value
[16] number of reactors		22
[16] tank depth	m	3.3
[16] maximum volume	m3	11814.0
[16] specify oxygen transfer by...		Entering Airflow

Variable	Unit	Value
[16] total air flow into aeration tank	m3/hr	37000.0
[16] diffuser type		Coarse Bubble
[16] standard oxygen transfer efficiency	-	0.2
[16] method of specifying diffuser setup		Enter Number of Diffusers
[16] HRT lower limit	hr	4.0
[16] HRT upper limit	hr	8.0
[16] MLSS lower limit	g/m3	1000.0
[16] MLSS upper limit	g/m3	3000.0

Circular Secondary Clarifier

Variable	Unit	Value
[20] clarifier type		Sloping Bottom
[20] surface	m2	4072.0
[20] water depth at sidewall	m	2.9
[20] water depth at center	m	3.9
[22] underflow rate	m3/d	92604.0
[21] pumped flow	m3/d	1164.0
[20] HRT lower limit	hour	2.0
[20] HRT upper limit	hour	3.0

Chemical Disinfection

Variable	Unit	Value
[24] volume	m3	900.0

System

Variable	Unit	Value
use set point SRT to estimate waste flow		On
SRT set point	d	3.0
liquid temperature	C	24.5
blower inlet air temperature	C	24.5

Controls

Input: 1

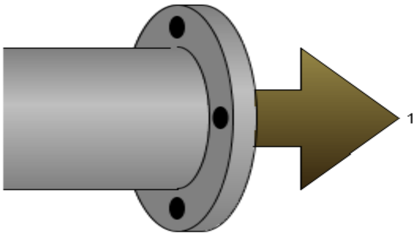
Variable	Unit	Value
[22] underflow rate	m3/d	92604.0

Outputs

Wastewater Influent

Simulation Parameters

		1
VSS/TSS Ratio	-	0.8



Simulation Results

		1
Flow	m3/d	131000
TSS	mg/L	126.6
VSS	mg/L	101.3
cBOD5	mg/L	131.5
COD	mg/L	243.0
Soluble COD	mg/L	60.75
Ammonia N	mgN/L	25.0
TKN	mgN/L	40.0
TN	mgN/L	40.0
Alkalinity	mgCaCO3/L	350.0
DO	mgO2/L	0.0

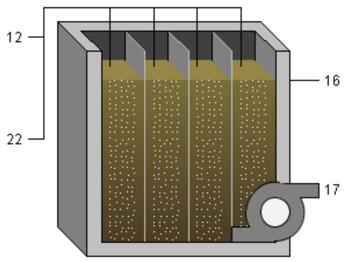
Mass Flows

		1	Total In	Total Out
TSS	kg/d	16580	-	-
COD	kg/d	31830	-	-
TN	kg/d	5240	-	-

Pre-Aeration tank

Aeration tank (Plug-Flow Tank)

Simulation Parameters



		16(1-22)	16
Tank Depth	m	-	3.3
Maximum Volume	m3	-	11810
Volume Fractions	-	0.045	-
Air Flow into Aeration Tank	m3/d	-	888000
Distribution of Air Flow to Aeration Tank	-	0.045	-

Simulation Results

		12	16(1-22)	16
MLSS	mg/L	69.1	1421	1421
MLVSS	mg/L	66.28	1357	1357
Soluble COD	mg/L	59.59	13.79	13.77
Ammonia N	mgN/L	24.55	0.8477	0.8029
Nitrite/Nitrate N	mgN/L	0.4838	25.97	26.16
Alkalinity	mgCaCO3/L	346.6	167.5	166.6
HRT	h	-	1.353	-
DO	mgO2/L	-	3.87	-
Total OUR	mgO2/(L.h)	-	72.1	-
Nitrification Rate	mgN/(L.h)	-	11.21	-
Nitrate Util. Rate	mgN/ (L.h)	-	0.2277	-

		12	16(1-22)	16
Air Flow	m3/h	-	1682	-
SOTE	%	-	20.0	-
Actual OTR	kg/h	-	39.25	-

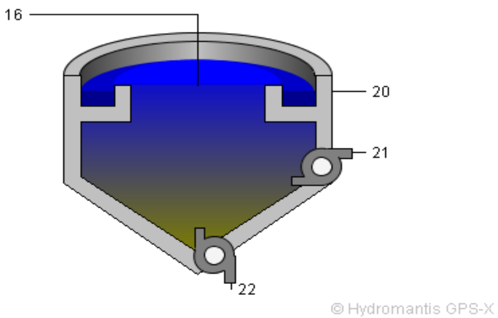
operational Variables

		16
Total Air Flow	m3/h	37000
Total Actual OTR	kg/h	863.0
F to M Ratio	kgBOD5/(kgMLVSS.d)	0.6026
Vol. Org. Loading	kgBOD5/(m3.d)	0.8175
RAS Recycle Ratio	%	79.18

Mass Flows

		12	22	16	17	Total In	Total Out
TSS	kg/d	8082	290400	297700	0.0	298500	297700
COD	kg/d	18440	411700	423600	0.0	430100	423600
TN	kg/d	4021	30480	34430	0.0	34500	34430

Final sedimentation tank



Simulation Parameters

		20
Feed Point from Bottom	m	1.0
Surface	m2	4072
Water Depth at Sidewall	m	2.9
Water Depth at Center	m	3.9

Simulation Results

		16	20	21	22
Flow	m3/d	209600	115200	1784	92600
TSS	mg/L	1421	14.8	3136	3136
VSS	mg/L	1357	14.13	2995	2995
cBOD5	mg/L	913.0	10.57	2014	2014
COD	mg/L	2021	34.69	4446	4446
Ammonia N	mgN/L	0.8029	0.8029	0.8029	0.8029
Nitrite/Nitrate N	mgN/L	26.16	26.16	26.16	26.16
TKN	mgN/L	138.2	3.076	303.0	303.0
TN	mgN/L	164.3	29.24	329.1	329.1
Alkalinity	mgCaCO3/L	166.6	166.6	166.6	166.6
DO	mgO2/L	3.912	3.912	0.0	0.0

Operational Variables

		20	22	21
HRT	h	1.508	-	-
Surf. Overflow Rate	m3/(m2.d)	28.28	-	-
Solids Loading Rate	kg/(m2.d)	73.11	-	-
Water Level	m	3.9	-	-
Sludge Blanket Height	m	0.6796	-	-
RAS Flow	m3/d	-	92600	-
RAS Solids	mg/L	-	3136	-
WAS Flow	m3/d	-	-	1784
WAS Solids	mg/L	-	-	3136
WAS Production	kg/d	-	-	5595

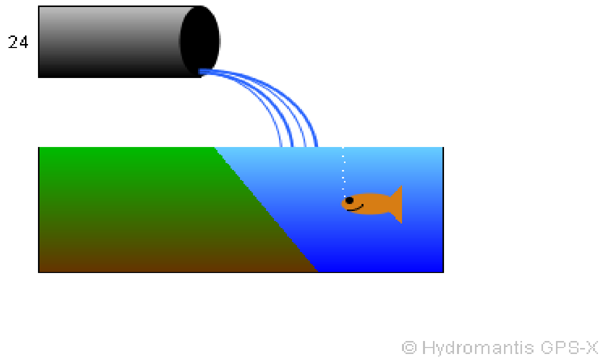
Mass Flows

		16	20	21	22	Total In	Total Out
TSS	kg/d	297700	1704	5595	290400	297700	297700
COD	kg/d	423600	3995	7931	411700	423600	423600
TN	kg/d	34430	3368	587.2	30480	34430	34430

Wastewater Outfall

Simulation Results

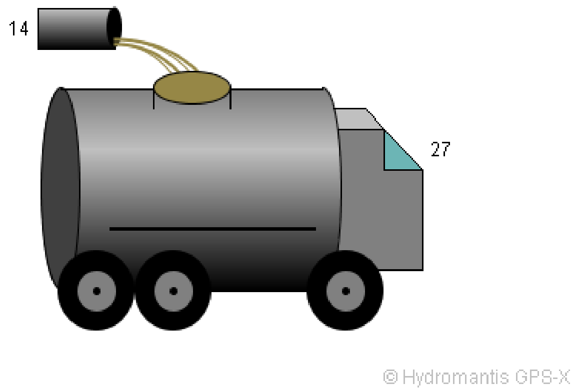
		24
Flow	m3/d	117200
TSS	mg/L	16.71
VSS	mg/L	15.62
cBOD5	mg/L	12.63
COD	mg/L	38.24
Ammonia N	mgN/L	1.216
Nitrite/Nitrate N	mgN/L	25.72
TKN	mgN/L	3.706
TN	mgN/L	29.42
Alkalinity	mgCaCO3/L	169.7
DO	mgO2/L	3.846

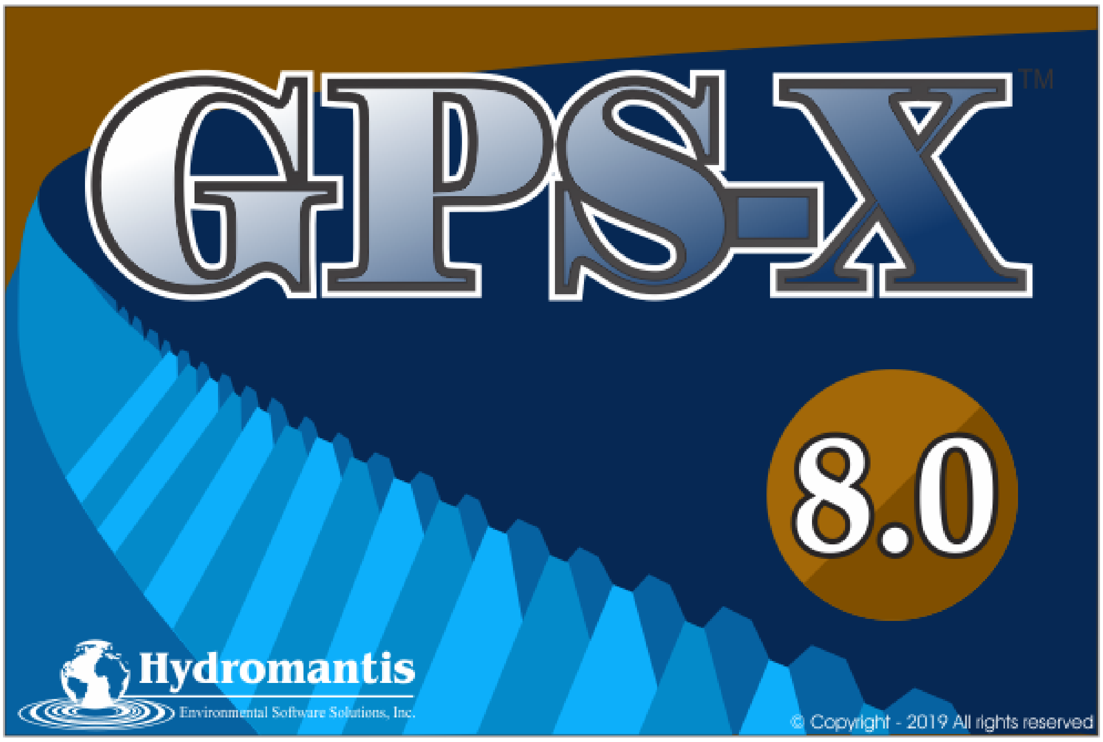


Cake Sludge Disposal

Simulation Results

		14
Flow	m3/d	13820
TSS	mg/L	1016
VSS	mg/L	974.7
cBOD5	mg/L	785.2
COD	mg/L	1502
Ammonia N	mgN/L	24.55
Nitrite/Nitrate N	mgN/L	0.4838
TKN	mgN/L	124.4
TN	mgN/L	124.9
Alkalinity	mgCaCO3/L	346.6
DO	mgO2/L	6.185



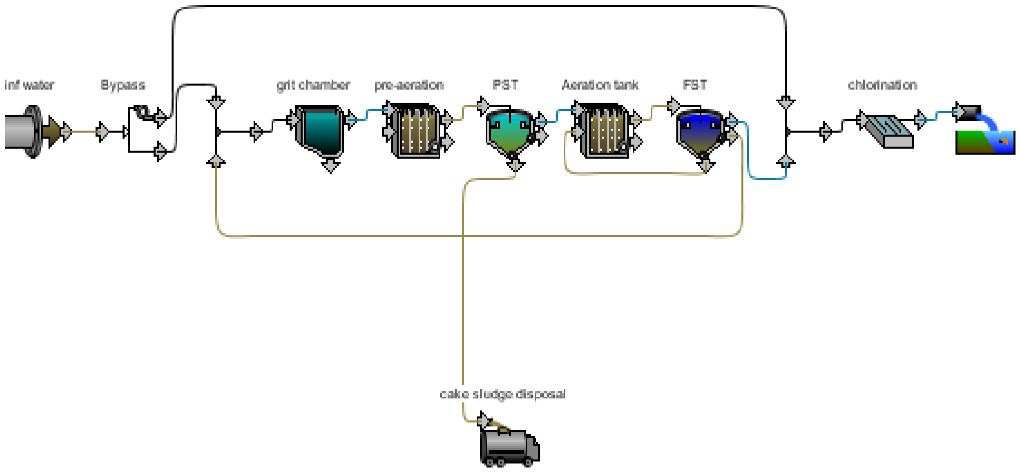


Report

Mon Jan 06 11:26:39 EET 2025

Recommended Operation Scenario

Layout



Inputs

Wastewater Influent

Variable	Unit	Value
[1] total COD	gCOD/m3	243.0
[1] VSS/TSS ratio	gVSS/gTSS	0.8
[1] influent flow	m3/d	131000

Pre-aeration Tank

Variable	Unit	Value
[38] tank depth	m	2.56
[38] total air flow into aeration tank	m3/hr	2500.0
[38] diffuser type		Coarse Bubble
[38] influent fractions	-	0.25
[38] recycle fractions	-	0.25
[38] HRT lower limit	hour	4.0
[38] HRT upper limit	hour	8.0
[38] MLSS lower limit	mg/L	1000.0
[38] MLSS upper limit	mg/L	3000.0

PST

Variable	Unit	Value
[12] clarifier type		Sloping Bottom
[12] surface	m2	4072.0
[12] water depth at sidewall	m	2.7
[12] water depth at center	m	3.7
[prisludge] underflow rate	L/s	214.0
[12] HRT lower limit	hour	2.0
[12] HRT upper limit	hour	4.0

Aeration tank

Variable	Unit	Value
[16] number of reactors		22
[16] tank depth	m	3.3
[16] maximum volume	m3	11814.0
[16] total air flow into aeration tank	m3/hr	37000.0

Variable	Unit	Value
[16] diffuser type		Coarse Bubble
[16] standard oxygen transfer efficiency	-	0.2
[16] method of specifying diffuser setup		Enter Number of Diffusers
[16] influent fractions	-	0.0454545
[16] recycle fractions	-	0.0454545
[16] HRT lower limit	hr	4.0
[16] HRT upper limit	hr	8.0
[16] MLSS lower limit	g/m3	1000.0
[16] MLSS upper limit	g/m3	3000.0

FST

Variable	Unit	Default	Value
[20] clarifier type		Flat Bottom	Sloping Bottom
[20] surface	m2	100.0	4072.0
[20] water depth at sidewall	m	3.0	2.9
[20] water depth at center	m	3.5	3.9
[mlss] underflow rate	m3/d	2000.0	92604.0
[21] pumped flow	m3/d	40.0	1164.0
[20] HRT lower limit	hour	0.504	2.0
[20] HRT upper limit	hour	12.0	3.0

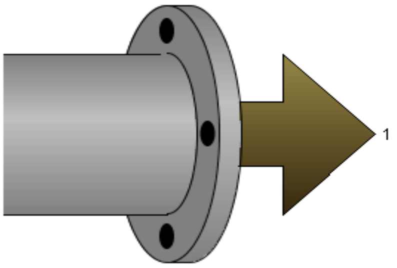
Chlorination

Variable	Unit	Value
[24] volume	m3	900.0

System

Variable	Unit	Value
use set point SRT to estimate waste flow		On
SRT set point	d	3.0
liquid temperature	C	24.5
blower inlet air temperature	C	24.5
energy price	$/KWh	0.045

Outputs
Wastewater Influent



Simulation Parameters

		1
VSS/TSS Ratio	-	0.8

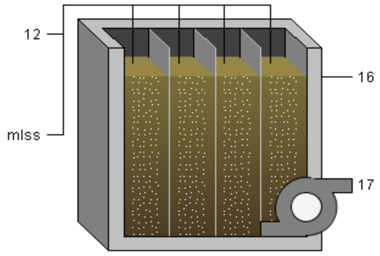
Simulation Results

		1
Flow	m3/d	131000
TSS	mg/L	126.6
VSS	mg/L	101.3
cBOD5	mg/L	131.5
COD	mg/L	243.0
Soluble COD	mg/L	60.75
Ammonia N	mgN/L	25.0
TKN	mgN/L	40.0
TN	mgN/L	40.0
Alkalinity	mgCaCO3/L	350.0
DO	mgO2/L	0.0

Mass Flows

		1	Total In	Total Out
TSS	kg/d	16580	-	-
COD	kg/d	31830	-	-
TN	kg/d	5240	-	-

Aeration tank



Simulation Parameters

		16(1-22)	16
Tank Depth	m	-	3.3
Maximum Volume	m3	-	11810
Volume Fractions	-	0.04545	-
DO Setpoint	mgO2/L	2.0	-

Simulation Results

		12	16(1-22)	16
MLSS	mg/L	67.64	1367	1367
MLVSS	mg/L	64.89	1305	1305
Soluble COD	mg/L	59.65	13.83	13.83
Ammonia N	mgN/L	24.57	0.9088	0.9087
Nitrite/Nitrate N	mgN/L	0.4528	25.55	25.55
Alkalinity	mgCaCO3/L	346.8	169.6	169.6
HRT	h	-	5.00	-
DO	mgO2/L	-	1.994	1.996
Total OUR	mgO2/(L.h)	-	70.02	-
Nitrification Rate	mgN/(L.h)	-	10.88	-
Nitrate Util. Rate	mgN/(L.h)	-	0.4217	-
Air Flow	m3/h	-	26100	-
SOTE	%	-	20.0	-
Actual OTR	kg/h	-	37.95	-

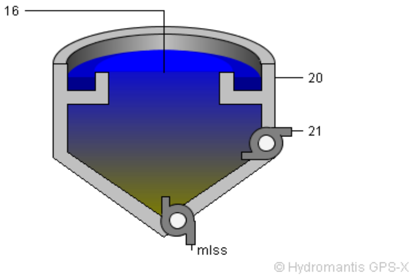
Operational Variables

		16
Total Air Flow	m3/h	26000
Total Actual OTR	kg/h	834.9
F to M Ratio	kgBOD5/(kgMLVSS.d)	0.6054
Vol. Org. Loading	kgBOD5/(m3.d)	0.7902
RAS Recycle Ratio	%	81.01

Mass Flows

		12	mlss	16	17	Total In	Total Out
TSS	kg/d	7732	275800	282800	0.0	283500	282800
COD	kg/d	17800	391100	402600	0.0	408900	402600
TN	kg/d	3913	29030	32830	0.0	32950	32830

Final Sedimentation Tank



Simulation Parameters

		20
Feed Point from Bottom	m	1.0
Surface	m2	4072
Water Depth at Sidewall	m	2.9
Water Depth at Center	m	3.9

Simulation Results

		16	20	21	mlss
Flow	m3/d	206900	112500	1807	92600
TSS	mg/L	1367	14.41	2978	2978
VSS	mg/L	1305	13.76	2844	2844
cBOD5	mg/L	881.7	10.39	1920	1920
COD	mg/L	1946	34.2	4224	4224
Ammonia N	mgN/L	0.9087	0.9087	0.9087	0.9087
Nitrite/Nitrate N	mgN/L	25.55	25.55	25.55	25.55
TKN	mgN/L	133.1	3.147	288.0	288.0
TN	mgN/L	158.7	28.7	313.5	313.5
Alkalinity	mgCaCO3/L	169.6	169.6	169.6	169.6
DO	mgO2/L	1.995	1.995	0.0	0.0

Operational Variables

		20	mlss	21
HRT	h	1.527	-	-
Surf. Overflow Rate	m3/(m2.d)	27.63	-	-
Solids Loading Rate	kg/(m2.d)	69.45	-	-
Water Level	m	3.9	-	-
Sludge Blanket Height	m	0.6431	-	-
RAS Flow	m3/d	-	92600	-
RAS Solids	mg/L	-	2978	-
WAS Flow	m3/d	-	-	1807
WAS Solids	mg/L	-	-	2978
WAS Production	kg/d	-	-	5382

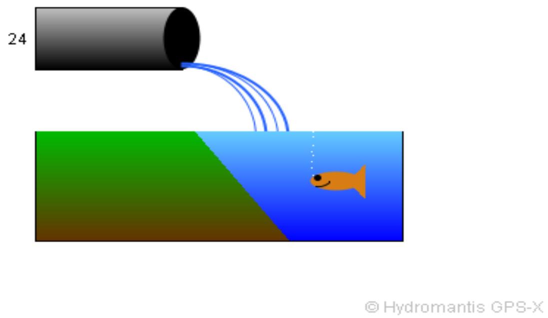
Mass Flows

		16	20	21	mlss	Total In	Total Out
TSS	kg/d	282800	1621	5382	275800	282800	282800
COD	kg/d	402600	3848	7633	391100	402600	402600
TN	kg/d	32830	3229	566.6	29030	32830	32830

Wastewater Outfall

Simulation Results

		24
Flow	m3/d	112500
TSS	mg/L	14.41
VSS	mg/L	13.76
cBOD5	mg/L	10.39
COD	mg/L	34.2
Ammonia N	mgN/L	0.9087
Nitrite/Nitrate N	mgN/L	25.55
TKN	mgN/L	3.147
TN	mgN/L	28.7
Alkalinity	mgCaCO3/L	169.6
DO	mgO2/L	1.995



Cake sludge disposal

Simulation Results

		prisludge
Flow	m3/d	18490
TSS	mg/L	781.0
VSS	mg/L	749.2
cBOD5	mg/L	612.2
COD	mg/L	1169
Ammonia N	mgN/L	24.57
Nitrite/Nitrate N	mgN/L	0.4528
TKN	mgN/L	101.9
TN	mgN/L	102.4
Alkalinity	mgCaCO3/L	346.8
DO	mgO2/L	2.003