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Upgrading of Safour Overloaded Activated Sludge Plant Using Hybrid Moving Bed Bio Reactor MBBR System

"Case Study "

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المخلص العربى

يهدف هذا البحث الى تطبيق نظام البيوفيلم لرفع كفاءة محطة معالجة صافور المنفذة بنظام الحماة المنشطة وذلك باستخدام تكنولوجيا مفاعل MBBR .وقد تم اختيار هذا النظام لأنه يوفر العديد من المزايا بما في ذلك إمكانية جيدة في عملية النترجة مع إزالة الفوسفور البيولوجية ،والنظام الذى يتعين تنفيذه لهذا المشروع هو مفاعل MBBR الهجين (مزيج من الحمأة المنشطة ومفاعل -MBBR)
ويتكون هذا المشروع من إعادة تأهيل محطة معالجة صافور القائمة ليتطابق السيب النهائى لها مع القانون المصري رقم ٤٨ لسنة ١٩٨٢ وزيادة طاقة المحطة من ١٠٠٠٠ م٣/يوم الى ٢٠٠٠٠ م٣/يوم .

ABSTRACT

The aim of this research was the application of a biofilm system for the upgrading of **Safour** overloaded activated sludge MWWTP using the MBBR (Moving Bed Biofilm Reactor) technology. The choice of this fixed biomass system appeared appropriate because it offers several advantages including good potential in nitrification process, The process to be implemented for this project will be a Hybrid Moving Bed Bio Reactor (combination of an activated sludge and Moving Bed Bio Reactor -MBBR) with biological phosphorus removal .
This project consists of the rehabilitation of existing Safour STP to comply with the amended Egyptian law # 48 for the year 1982 and its extension to increase the flow from 10,000 m3/d up to 20,000 m3/d.

KEYWORDS
MBBR - Moving Bed Biofilm Reactor; Treatment plant upgrade; Biological treatment

INTRODUCTION

biomass grows only on carriers, while in hybrid reactors there are both biofilm and suspended activated sludge in the same tank.
This project consists In this project, the moving bed biofilm reactors (MBBR) the biomass grows as a biofilm on small plastic carriers that move freely into the

wastewater; mixing biofilm reactors the of the rehabilitation of existing Safour STP –a full scale plant-

To comply with the amended Egyptian law # 48 for the year 1982 and its extension

To enhance the plant treatment capacity by increasing the flow from 10,000 m3/d up to 20,000 m3/d. The following are the design basis for the proposed treatment plant.

RAW INFLUENT QUALITY

Table 1. Influent wastewater characterization

Wastewater Main Parameters	*Design Values*
Average daily Flow (m^3/day)	20,000
Average flow (m^3/hr.)	833
Peak factor	2
Peak hourly flow (m^3/hr.)	1,666
Inlet BOD_5 (mg/l)	600
Inlet BOD_5 load (kg/d)	12,000
Inlet COD_{Cr} (mg/l)	900
Inlet COD_{Cr} load (kg/d)	18,000
Inlet SS (mg/l)	350
Inlet SS load (kg/d)	7,000
Inlet Ammonia (NH_4-N) (mg/l)	40
Inlet Ammonia load (NH_4-N) (kg/d)	800
Inlet TN (mg/l)	60
Inlet TN load (kg/d)	1,200
Inlet TP (mg/l)	15
Inlet TP load (kg/d)	300
pH	Between 6 and 9
Water temperature [°C]	Between 17 and 30

Table 2. Influent wastewater secondary characterizations

Wastewater Secondary Parameters	*Design Values*
TDS	< 1000 mg/l
Colored substances	Free
Sulphides	< 5mg/l
Cyanide	Nil
Phenol	Nil
Insecticides	Non-existent
Worm ova (ascaris) at 5% concentration	< 1 alive ova/100 ml

TREATED EFFLUENT QUALITY

Based on the proposed raw influent characteristics, the treated water characteristics of the plant shall achieve effluent standard as shown in the table below:

Table 3. Effluent wastewater characterizations

Parameter	*Limits*
BOD_5	< 60 mg/l
S.S	< 50 mg/l
COD_{cr}	< 80 mg/l
TN (as N)	< 10 mg/l
TP (as P)	< 2 mg/l

PROCESS TO BE IMPLEMENTED

The process to be implemented for this project will be a Hybrid Moving Bed Bio Reactor (combination of an activated sludge and Moving Bed Bio Reactor - MBBR) with biological phosphorus removal.

MBBR technology will be used for elimination of Nitrogen pollution, allowing significant reduction of volumes required for this step.

TREATMENT STEPS TO BE IMPLEMENTED

The STP proposed by the contractor will include the following minimum steps:

- Quieting chamber & Inlet flow measurement
- Mechanical coarse screening
- Aerated Grit & Grease removal
- Buffer tank
- Mechanical fine screening
- Biological treatment: Hybrid MBBR with biological phosphorus removal tanks
- Circular clarifier unit with sludge scrapping mechanism
- Biological sludge extraction and recirculation
- Disinfection
- Mechanical sludge thickening of the biological sludge
- Sludge drying beds
- Supernatant collection & recirculation

INSTRUCTION FOR THE EXISTING PLANT REHABILITATION

Because of the new water quality requirement the existing STP will have to be modified as per process design specifications detailed in chapter III. As a result, part of the flow will have to be diverted to the extension.
The contractor will follow the guidelines below in their proposal to rehabilitate the existing plant.

- Existing pretreatment (inlet chamber, screening and grit & grease removal) will not be used. The existing works will be demolished and new pretreatment works will be constructed for the whole capacity of this STP
- Existing primary settlers, biological tanks and clarifiers will be used as biological tank, following the process design specification given in part III. Existing primary settlers, biological tanks and clarifiers mechanical equipment will not be used and new equipment will be provided.
- Biological sludge recirculation structure & equipment will not be used and new equipment will be provided.
- Disinfection contact tank structure & equipment will be used.
- Sludge drying beds structure & equipment will be partially used, and part of them demolished to make place for the new treatment units.

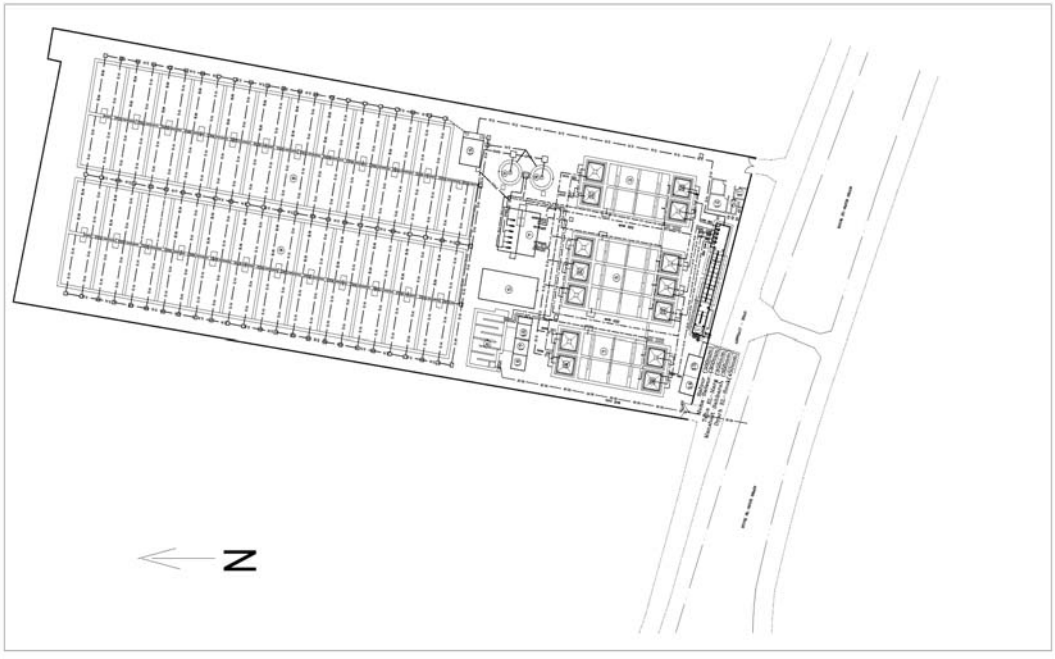

Figure 1. *Layout of the plant before the upgrading.*

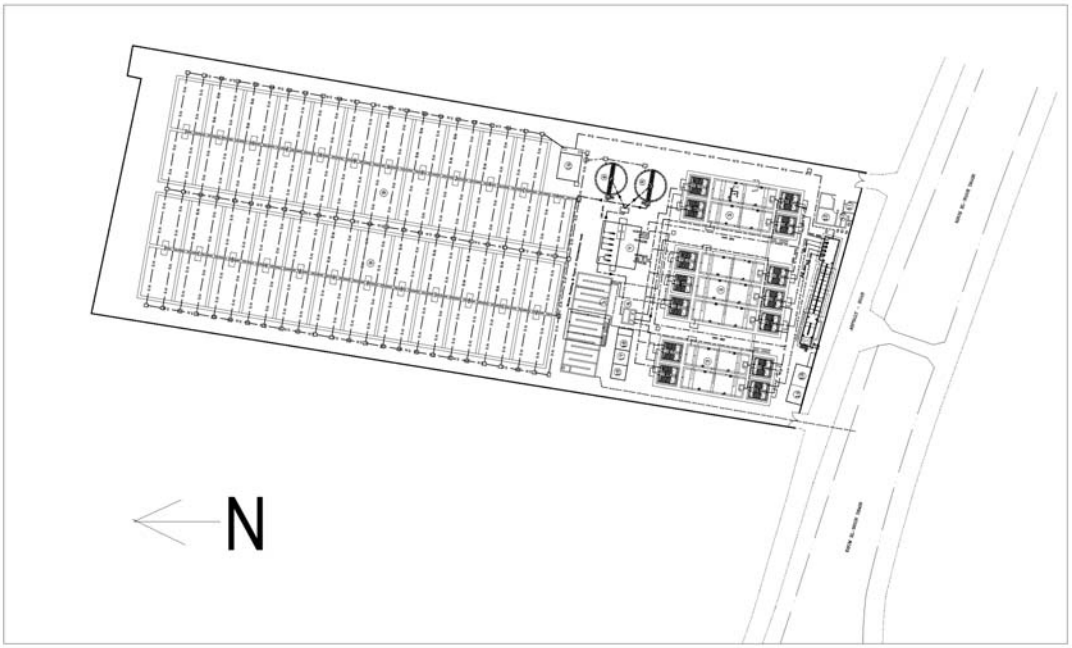

Figure 2. *Layout of the plant after the upgrading.*

PRE-TREATMENT

QUIETING CHAMBER AND FLOW MEASUREMENT

The raw incoming sewage will be received in a quieting chamber designed to decrease the velocity of inlet flow before the screen to prevent escaping of particles from screen opening.

The incoming flow shall be transmitted to the screening unit through an approach channel where measuring of the inlet flow rate is enabled via ultrasonic open channel flow meter.

- **Equipment specifications**

Flow meter

No. of units	1 (1 Duty)
Type	Open channel - Venturi

SCREENING

The incoming raw water screening shall be performed via two (1 duty / 1 standby) mechanical self-cleaning screen – inclined type. A Third manually cleaned coarse bar screen is provided as standby for emergency overflow, should the automatic screen be fouled excessively. The coarse screening is intended to protect other treatment steps from large objects.

The mechanical screen shall have a clear spacing of maximum 15 mm and are designed to treat the peak flow, while the emergency screen have an opening of 20 mm. The mechanical screen channel will be isolated by penstocks.

To ensure the maximum level of performance from the equipment, the mechanical screen operation shall be completely automatic. It operates cyclically on a clock and on detection of head loss in the screen apertures. In case the water level rise due to mechanical screen defect or excessive fouling, water will overflow to the manual screen channel without needing operator intervention, to providing a maximum level of safety.

- **Equipment specifications**

Mechanical screen

No. of units	2 (1Duty / 1 Standby)
Filtering gap	≤ 15 mm
Type	Inclined screen
Material of construction	SS 304 L
Operation	automatic operation controlled by water differential and timer

Manual coarse screen

No. of units	**1 (1 Emergency)**
Filtering gap	≤ 20 mm
Type	Manual bar, inclined
Material of construction	SS 304 L
Operation	manual

GRIT AND OIL & GREASE REMOVAL FACILITIES

The influent contains a large amount of grit and grease, which may create many problems throughout the biological treatment. To protect the equipment located downstream from the pre-treatment, a cylindro-conical aerated concrete chamber shall be provided; to allow an efficient removal of inert matter from the effluent, and retaining detritus with granular greater than 0.2 mm.

Settled grit shall be collected at the bottom of the conical part of the chamber by an air lift pump to a sand silo. The grease and oil floated on the surface of the chamber shall be collected by a rotating mechanical surface skimmer into a scum launder.

Dedicated blowers shall be used for the air required by air-lift and aeration.

- **Equipment specifications**

Grit and Grease tank

No. of units	u	2 (2 Duty)
Type		Cylindro-conical
HRT at peak flow	min	6 minimum

Design up-flow velocity	m/h	max 40 at peak flow
Grit collection		by air-lift
Grease collection		by scraper

Oil & grease Removal Air blowers

No. of units	u	2 (1 Duty + 1 standby)
Type		Positive displacement rotary
Motor arrangements		Vee-belt coupled
Material of construction		Cast iron

BUFFER TANK

To limit the peak flow going to the other structures, part of the flow will be diverted to a buffer tank. Buffer tank will be filled up during peak flow and emptied during low flow.

- **Process specifications**

Buffer tank

No. of units	u	1
buffer capacity		3 hours of the excess flow rate = 1750 m3
Maximum flow rate after the buffer tank	m3/h	1,080

FINE SCREENING

The main function of the fine screens is to stop small particles which have not been taken out by the coarse screen to protect the MBBR biological treatment from clogging. Each mechanical screen has a clear spacing of 3 mm.

To ensure the maximum level of performance from the equipment and considering the depth of the canal, the mechanical screen operation is completely automatic. It operates cyclically on a clock and on detection of head loss in the screen apertures.

- **Equipment specifications**

Mechanical screen

No. of units	u	2 (1Duty / 1 Standby)

Filtering gap Material of construction Operation	mm	≤ 3 SS 304 L automatic operation controled by water differential and timer

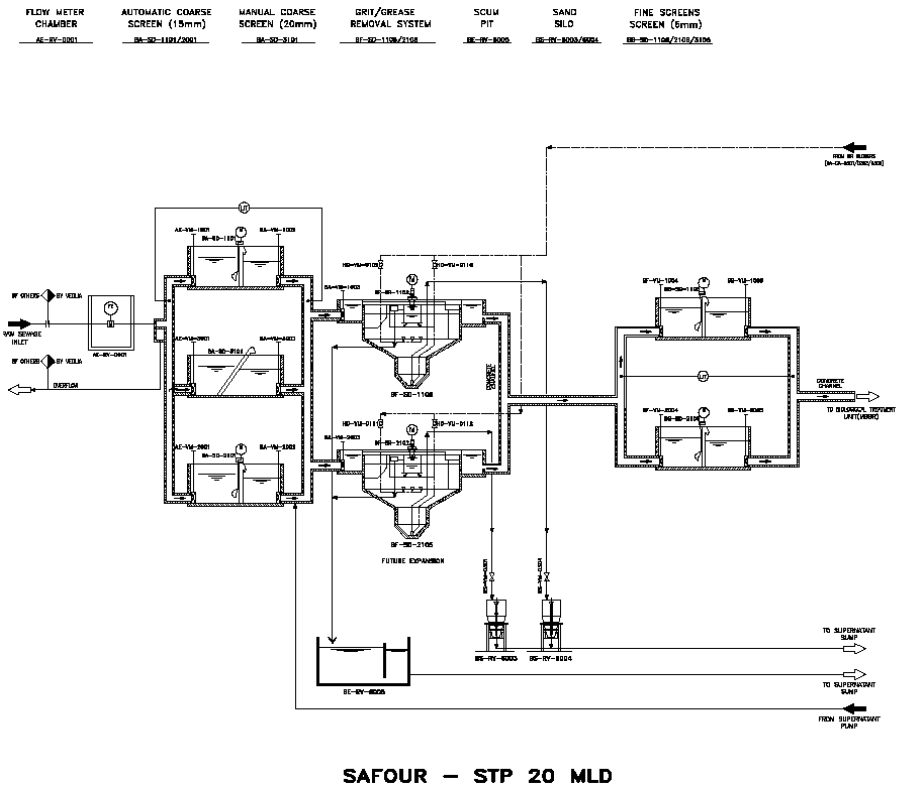

Figure 3. *P&I diagram of the pre-treatment units.*

BIOLOGICAL TREATMENT & CLARIFIERS

The existing primary settlers, aeration tanks and clarifier tanks structures will be used for the biological phosphorus removal tanks and Hybrid MBBR tanks. No additional basin is foreseen, except for the clarifiers which will be new structures.

The biological treatment will consist of 3 lines, corresponding to the 3 existing structures, while the clarification will consist of 2 lines.

BIOLOGICAL PROCESS – BIOLOGICAL PHOSPHORUS REMOVAL

Tanks will be provided for biological phosphorus removal. The purpose of these tanks is to partially remove dissolved phosphorus (orthophosphate) by biological means.

The first tank will be an anoxic tank used to denitrify any remaining nitrate in the return sludge. In second tank will be an anaerobic tank where the mixture of wastewater and activated sludge is used to produce the necessary carbon source VFA (Volatile Fatty Acid) needed for the Bio-P process:
These 2 tanks are stirred up with high-speed submersible mixers to avoid any settling and ensure a good mixing.

- **Process design specifications**

Anoxic tank

No. of units	u	1 per line
Type		anoxic tank
Nitrate concentration at outlet	mg/l	< 0.3

Anaerobic tank

No. of units	u	1 per line
Type		anaerobic tank

BIOLOGICAL PROCESS – HYBRID MBBR

This treatment shall consist of the following steps

a) Pre – Denitrification tank

The purpose of this tank is to denitrify the nitrate coming from the mixed liquor recirculation using the raw water as a carbon source. This tank is stirred up with high-speed submersible mixers to avoid any settling and ensure a good mixing.

b) Carbon Removal

The purpose of this tank is to remove most of the carbon pollution in order to be able to develop a specialized biomass for nitrification in the next compartment (Nitrification on carriers). The tank is aerated and agitated through air blowers.

c) Nitrification tank

Biological nitrification occurs in this tank. Fixed biomass is used for this step (MBBR) in order to have a very compact plant. The tank is aerated and

agitated through air blowers. Mixed liquor will be recirculation from this stage to the Pre-denitrification tank.

d) Post De-nitrification tank (post DN)

If required to reach the total nitrogen effluent water quality, a post-denitrification tank can be provided to further treat the Nitrate. In Post denitrification, the addition of external carbon source (Methanol) is required as carbon source in the water has already been consumed. Fixed biomass is used for this step, and stirred up with high-speed submersible mixers to avoid any settling and ensure a good mixing.
A ferric chloride injection system (co-precipitation) will be provided to enhance phosphorus removal.

- **Process Specifications**

Nitrification	
Nitrification rate on media	< 0.55 g N / m2.d at 10oC

MLSS	
MLSS concentration, maximum	3.5 g/l

- **Equipment Specifications**

Submersible Mixers	
Number	by contractor
Type	Rapid submersible mixers

Air blowers	
Type	Positive displacement rotary
Motor arrangements	Vee-belt coupled
Material of construction	Cast iron

Air Piping for aeration system	
Material of construction	304L
Media for MBBR tank Protected surface area	≥500 m^2/m^3
Material	High-density polyethylene

Methanol storage tank	
No. of units	1
Capacity	> 30 days

Material	Carbon steel

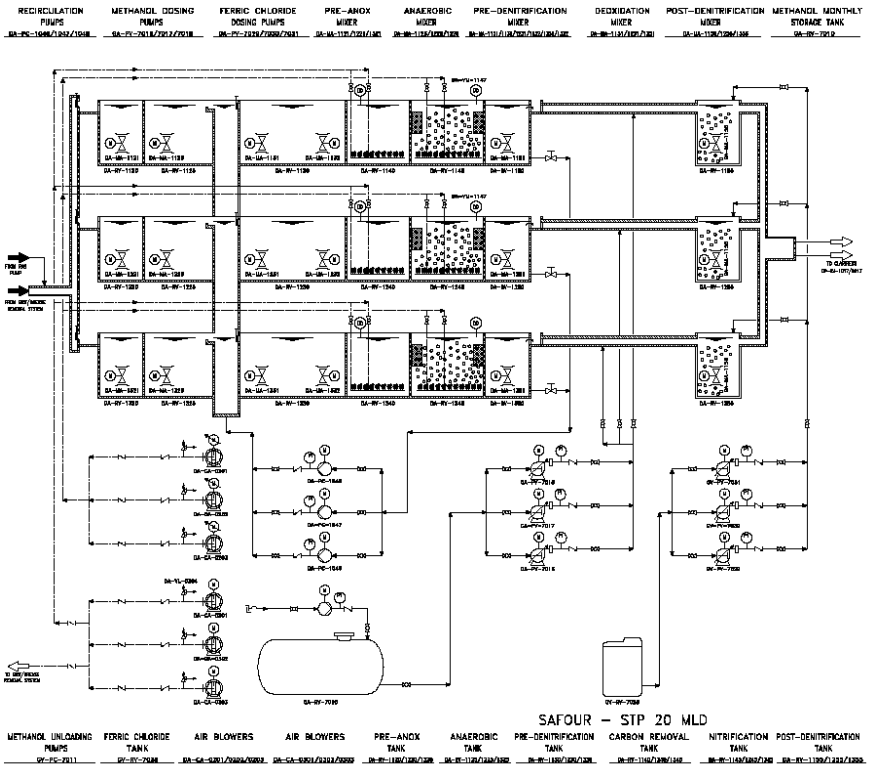

Figure 4. *P&I diagram of the Upgraded MBBR configuration*

CIRCULAR CLARIFIER

The wastewater from the biological tanks is led to secondary clarifiers where the purified water is separated from the activated sludge. The sludge particles will precipitate and the clarified water will pass the outlet weir at the periphery of the tank.

The Clarifier tank shall be equipped with a rotating sludge scraper mechanism driven by geared motor fixed to the settling tank bridge, scraping the sludge to the center of the tank, from where the sludge is led to the sludge tank. Clarifier scraper type shall be helicoidal scraper, equipped also with surface skimmer.

- **Process design specifications**

Clarifier

No. of units	2 (2 Duty)
Type	circular
maximum sludge load	8 kg MLSS/m2.h
maximum hydraulic load at peak flow	< 0.8 m/h

- **Equipment specifications**

Clarifier Bridge

Type	helicoidal scarper with surface skimmer
Material of construction	Epoxy coated above water Galvanized steel under water

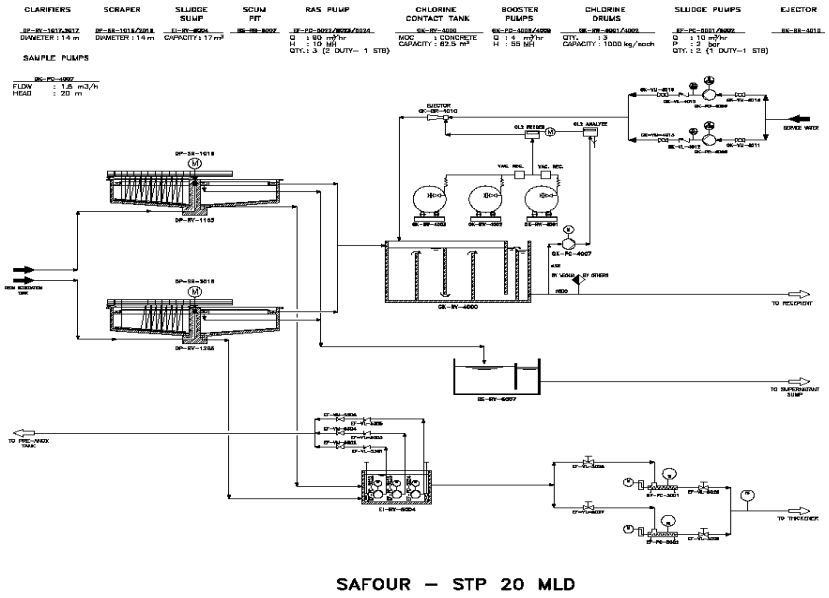

Figure 5. *P&I diagram of Circular clarifier units.*

SLUDGE RECIRCULATION

The purpose of sludge recirculation is to maintain sufficient concentration of sludge in the free biomass reactor so that the required degree of treatment can be obtained in the time interval desired.

The activated sludge is drawn-off from the bottom of the clarifiers to a sludge tank. Submersible sludge pumps transfer the sludge from the sludge pit to the

inlet of the biological tank to control and maintain a constant level of the mixed liquor suspended solids (MLSS) inside the tank.

The amount of sludge recirculated shall be proportional to the incoming flow to the plant. Recirculation pump(s) shall be supplied equipped with VFD in order to be able to control the returned flow according to the inlet flow meter.

- **Process design specifications**

Recirculation

Average flow to be recirculated	> 75% of the incoming average flow
Maximum flow to be recirculated	> 50% of the incoming peak flow

SLUDGE EXTRACTION, TREATMENT & DISPOSAL

Sludge treatment and disposal facility consist of the:

- **Mechanical sludge thickening**
- **Drying Beds**

SLUDGE THICKENING

The treatment line includes a biological phosphorus removal step. The sludge thickening step will therefore be done by mechanical thickening, in order to have a very short hydraulic retention time and avoid phosphorus release in the supernatant water, which could happen under the prolonged anoxic conditions of a gravity thickener.

The sludge coming from the clarifier, conditioned with polymer, will be mechanically dewatered with a gravity belt table (GBT). The GBT will increase the sludge concentration up to at least 40 g/l. The GBT shall be able to thicken the sludge produced in one day during the

GBT working time defined in the equipment specifications.

- **Equipment specifications**

Gravity belt thickener

No. of units	2 (1 Duty+ 1 Standby)
Maximum working hours per day	20
Material of construction	frame : SS304L
Thickened sludge concentration	> 40 g/l

DRYING BEDS

The thickened sludge is sent to the drying beds where sludge will be dried. Each drying bed is filled with fresh sludge (one by one). After filling the drying bed with fresh sludge, part of the water contained in the sludge percolates through the sand layers and is collected through an underneath piping to the supernatant pit. The Sludge remaining on top of the sand stays there for natural drying until it reaches the required dryness, and then is collected for further disposal.

- **Process specifications**

Drying beds

Maximum sludge height	cm	50

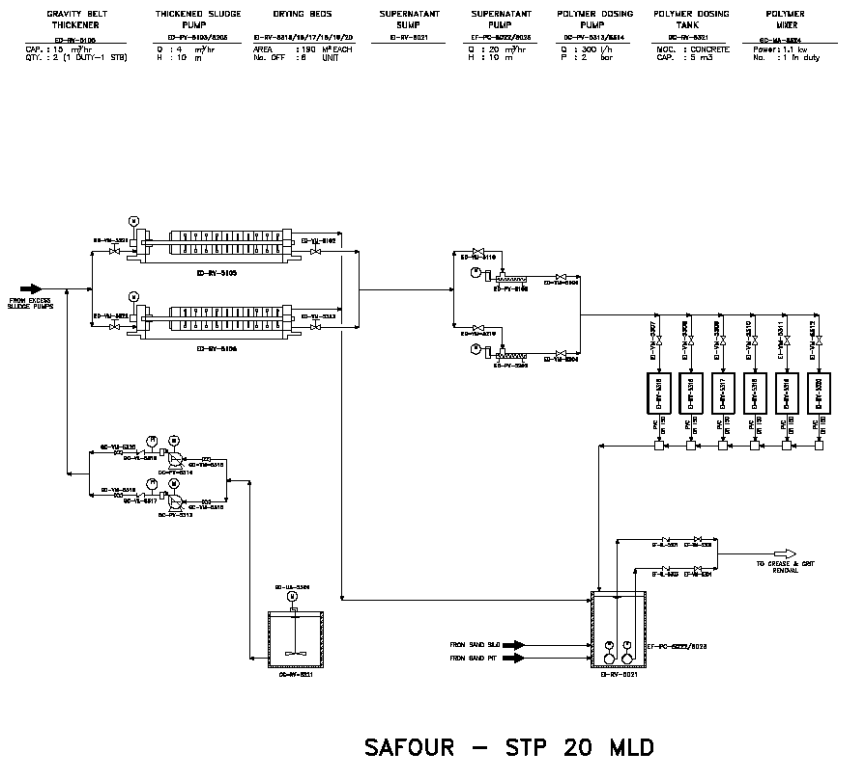

Figure 6. *P&I diagram of* Sludge *treatment & disposal units.*

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