SEWERAGE TREATMENT PLANT DESIGN GUIDELINES

SEWERAGE AND RECYCLED WATER PROJECTS DEPARTMENT

WASTE AND SEWERAGE AGENCY

DOCUMENT CONTROL				
DOCUMENT INFORMATION				
Document Ref#	DM-WSA-SRPD-STP1	**Document Title**		Sewage Treatment Plant (STP) Design Guidelines
Document Classification	⦿ Open data	○ Shared & Confidential	○ Shared & sensitive	○ Shared & secret
Status	Current	**Type**	DOC	
Release Date	February 2024			
Revision Date	**January 2024**			

Version History			
Version Number	**Date**	**Author(s)**	**Remarks**
1.0	January 2024	Eng. Atiq Ur Rehman Malik Ikramullah Eng. Fahed Ahmed AlAwadhi Eng. Shaikha Ahmad AlShaikh Eng. Mark Oliver Heinrich Eng. Mohammed Dhafer Ismaeel AL Bayati Eng. Usman Ismail Chaudhry Muhammad Eng. Fatima Afghan Eng. Alejandro Talana	Final

Review History				
Version Number	**Date**	**Reviewer(s)**	**Remarks**	**Signature**
1.0	January 2024	Eng. Mark Oliver Heinrich	Reviewed	

Approval History				
Version Number	**Date**	**Approver(s)**	**Remarks**	**Signature**
1.0	January 2024	Eng. Fahed Ahmed AlAwadhi	Approved	

Table of Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ANSI-HI	American National Standards Institute - Hydraulic Institute
ASCE	American Society of Civil Engineers
CAPEX	Capital Expenditure
DEWA	Dubai Electricity and Water Authority
DI	Ductile Iron
DM	Dubai Municipality
DUSUP	Dubai Supply Authority
FRC	Fibre-Reinforced Concrete
GPT	Gross Pollutant Trap
GRP	Glass-Reinforced Plastic
HDPE	High Density Polyethylene
HGL	Hydraulic Grade Line
HSE	Health, and Safety Executive of the UK
MWL	Mean Water Level
NPSH	Net Positive Suction Head
O&M	Operation and Maintenance
OL	Obvert Level
OPEX	Operational Expenditure
PE	Polyethylene
QA/QC	Quality Assurance and Quality Control
RCP	Reinforced Concrete Pipe
RTA	Roads and Transport Authority of Dubai
SRPD	Sewerage and Recycled Water Projects Department

TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
UPS	Uninterruptible Power Supply
uPVC	Unplasticised Polyvinyl Chloride
ACPH	Air changes per hour
ADF	Average daily flow
BOD	Biological oxygen demand
CAW	Combined air and water wash
COD	Chemical oxygen demand
DS	Dry solids
DWF	Dry weather flow
FOG	Fats, oil & grease
FST	Final settling tank
l/sec	Litres per second
Lpcd	Litres per capita per day
mg/L	Milligrams per litre
MLR A	Mixed liquor ratio, Available
MLR R	Mixed liquor ratio, Required
MLSS	Mixed liquor suspended solids
MPN	Most probable number
NTU	Nephelometric Turbidity Units
PDF	Peak daily flow
PHF	Peak hourly flow
PMF	Peak monthly flow

RAS	Return activate sludge
TKN	Total Kjeldahl Nitrogen
TSS	Total suspended solids
VOC	Volatile organic carbon
WSA	Waste and Sewerage Agency
PST	Primary settling tank

1. OBJECTIVES

1.1 Introduction

This Design Guidelines is for use by design consultants, contractors, and developers when planning, designing, and constructing sewage treatment plants (STP's) in Dubai Emirate. There shall be no deviation from these guidelines except where formally confirmed by Dubai Municipality (DM) in writing, assuming that such deviation from this Design Guidelines being technically justified or representing advances in knowledge or technology.

1.2 Approvals Process

The Consultant shall submit the design document to DM for review and approval. The design stage wise requirements will be collected from DM before submission of the documents.

1.3 Permanent Works

This Design Guidelines is applicable only to the design of the 'permanent works.' This includes the design of any interim solutions, which may be required until a long-term solution is available. The design of all temporary works required for the construction of the permanent and interim works shall be the responsibility of the Consultant who shall ensure that any such works do not adversely impact the permanent works.

For avoidance of doubt "permanent works" refers to structures, machines, equipment, or items required for the intended function as an STP. Dubai Municipality, however, distinguishes also between Permanent STP's and Temporary STP's depending on their expected lifetime horizon, these design guidelines apply to Permanent and Temporary STP's.

1.4 Innovation

The Consultants and Developers shall encourage the parties involved in the planning, design, and construction of STP's to devise innovative solutions and challenge conventional thinking where this could be beneficial to the project and to the Emirate of Dubai.

Required documentation and sufficient detail must be submitted to DM to allow the proposal to be appraised. The documentation must include a suitable KPI proposal to track and quantify the benefit for the Emirate of Dubai.

1.5 Copyright

Copyright of the Design Guidelines is the property of DM.

1.6 Updates

The guidelines may be revised by DM from time to time to keep up to date with technical developments and improved practices. It is the responsibility of the users to ensure that they are working to the latest issue. DM can be contacted for information on revisions. Any errors that are found or recommendations for improvement shall be notified to DM.

1.7 Reference Guidelines

The designer shall refer to DM Design Guidelines for Sewerage System Design for information on population projection, calculations or derivation of per capita flow, property connections, etc. as necessary.

1.8 Inquiries

All inquiries regarding the DM STP Design Guidelines shall be sent to DM's official incoming email (dm@dm.gov.ae) and copying the SRPD Director and the Head of Projects Planning and Development Section.

2. GENERAL DESIGN CONSIDERATION

This “Sewage Treatment Plant Design Guidelines” shall be used by design consultants, contractors, and developers when planning, designing, and constructing sewage treatment plants in the Emirate. There shall be no deviations from these guidelines except where formally agreed with DM. DM reserves the right not to accept any plants that fail to meet the minimum standards of these guidelines.

Complying with all design requirements and obtaining an approval for a temporary STP design does not constitute a “Temporary STP permit”; this must be obtained separately in three stages - during design, before commissioning, and annually while operating.

The design of sewage treatment plants (STP) is governed by numerous factors that are interlinked and extensive which include assimilative capacity of receiving streams (above and below ground), protection of public health, and propagation of fish and wildlife, etc.

In addition to the need for meeting the permissible discharge conditions, the design necessitates compliance with the criteria of being practical and cost-effective.

Sewage treatment plants shall be designed in accordance with the projected community growth. Capacities of the plant systems shall be adequate to accommodate the peak flows and loads expected during the design life of the plant. If the plant is built in stages, the minimum available spare capacity after the first stage is built shall be 15 years (excluding any stand-by allowances) thereafter the design for the subsequent stage shall be started 5 years before the plant reaches its projected full capacity.

DM is committed to using new and innovative technologies where they, in DM’s opinion, represent the best technical solution, provide low life cycle costs and value for money. All technologies will be considered for use by DM provided they have been proven in terms of performance, quality, and cost. DM will require suitable evidence and proof of such benefits based on the specific conditions found in Dubai. In case such technologies have not been used in Dubai before an adequate pilot testing may be required. Such testing must be supervised and evaluated by DM and may be conducted ideally on one of DM’s STP’s.

All design shall be based on this Design Guidelines. DM reserves the right not to grant permits or adopt any system that fails to meet the minimum standards of these guidelines.

Engineers and other disciplines using this Design Guidelines must be experienced and appropriately qualified professionals who are familiar with the planning, design, construction, operation, and maintenance of STP's. The Design Guidelines is to be utilised as guide to good practice and compliance. The Design Guidelines does not absolve users of their professional and contractual responsibilities. The Design Guidelines is not exhaustive in its coverage and is not intended to replace the proven theory listed elsewhere.

2.1 Permitting and Monitoring

The permitting and monitoring of temporary STP's and planning of permanent STP's for the Emirate of Dubai is undertaken by the Sewerage and Recycled Water Projects Department (SRPD) of Dubai Municipality. A dedicated STP Department within DM is responsible for undertaking the implementation, and operation and maintenance of the plants.

2.2 Design Horizon

A wastewater treatment facility shall ordinarily be designed to provide for the projected population in 15 years (at least). Similarly, consideration should be given to the maximum anticipated capacity of future institutions, industrial zones, etc.

Projects are normally developed through the following stages with a deliverable document at the end of each stage:

- Concept Stage
- Draft Preliminary Design
- Final Preliminary Design
- Detailed Design
- Tender Documentation
- Construction and Commissioning

2.3 Land Take

The requirement of land and its availability are critical factors in deciding the treatment technology. During the concept stage, consideration must be given to the area of land required.

The treatment facility shall be so located that for small treatment works (less than 1 MLD) a minimum of 200 m of buffer is maintained between a treatment unit and the nearest residential property and 1 km in the case of large treatment works. However, regardless of the buffer distance, an odour abatement study must be undertaken, an odour dispersion modelling must be done and technical measures to contain and treat odours must be implemented (i.e., installation of an odour control unit) subject to SRPD and ED approval.

For planning purposes, the following is an indication of the land take that is normally required:

Table 2-1 - Land requirement

Population Equivalent	Type of Works	Works Area (ha)	Total area including buffer zone (ha)
1,000	Package activated sludge	0.5	76
10,000	Activated sludge	4	100
100,000	Activated sludge	24	644
250,000	Activated sludge	40	720

2.4 Classification and Design capacity

For ease of reference, STP's shall be classified based on the design capacities as follows:

- Small STP's < 500 m^3/day
- Medium STP's > 500 < 2,500 m^3/day
- Large STP's > 2,500 m^3/day

It shall be noted that the above classification is mainly based on the potential and perceived impact of the plant to its surrounding areas, e.g., in terms of potential complaints against foul odour if not designed properly.

3. SEWAGE CHARACTERISTICS AND DESIGN PARAMETERS

Table 3-1 provides the typical inlet wastewater characteristics for designing the wastewater treatment plant.

Table 3-1 - Inlet Wastewater Characteristics

Description	Units	Ave. Annual Concentration			Peak Month Concentration		
		Small	Medium	Large	Small	Medium	Large
BOD	mg/L	270	280	290	300	320	340
COD	mg/L	500	600	700	600	700	800
Suspended solids	mg/L	250	250	300	300	300	400
Total P(1)	mg/L	8	10	12	12	15	20
TKN(1)	mg/L	40	40	50	60	60	70
Ammonia(1)	mg/L	25	30	40	40	45	50
Alkalinity(2)	mg/L	200	200	250	250	250	300
FOG	mg/L	40	40	50	60	60	60
pH	-	6.5-8.0	6.5-8.0	6.5-8.0	6.5-8.0	6.5-8.0	6.5-8.0
Temperature	°C	22-37			22-37		
Sulphide(3)	mg/L	10	15	25	20	30	40

(1) If a tanker reception facility is included at the plant, the values of TKN, Ammonia and TP will be higher and shall be derived on case-by-case basis.

(2) Minimum alkalinity can be as low as 170 mg/L which will be a limiting factor for ammonia removal. As per 'Al Awir STP Influent Average Quality Analysis January 2009 – July 2012', the average T. alkalinity is 250 mg/l.

(3) Depends on the length of the feeder sewer network.

The above concentrations and loads do not consider the loads coming from the sludge liquor returns. The side stream flows and loads shall also be taken in consideration while calculating the combined loads to the sewage treatment plant. Tanker sewage loads are not accounted for in the above table and are subject to specific analysis and DM approval.

3.1 Final Effluent Discharge Criteria

Based upon a review of reuse practices and guidelines for the treatment of wastewater around the Middle East and UAE, the values shown in Table 3-2 are recommended for the final effluent quality.

The key considerations that have been made in selection of the standards are:

- The prescribed end use or discharge point of the treated wastewater,
- Understanding of the basis of standards applied globally for similar use,
- Evaluation of current effluent standards in the other Middle East countries,
- Experience of the existing wastewater treatment plant effluent quality which provides understanding of the wastewater treatability without excessive pilot plant trials being completed.
- Compromising between the selection of an appropriate standard which does not drive the process treatment to complex and untested systems.

Table 3-2 - Design Parameters

Parameter	Units	Value	Basis	Comments
TCOD	mg/L	75	95%ile	24 Hour Composite
$TBOD_5ATU$	mg/L	10	95%ile	24 Hour Composite
TSS	mg/L	10	95%ile	24 Hour Composite
Turbidity	NTU	5	Maximum	Average 12 minute peak to compensate backwash peaks
NH4-N	mgN/l	2	95%ile	24 Hour Composite
Phosphate	mgPO4/l	25	95%ile	24 Hour Composite
Total Coliforms	MPN/100 ml	< 20	30 Day Arithmetic Mean	
E. Coli	MPN/100 ml	< 10	30 Day Arithmetic Mean	
Salmonella	MPN/100 ml	<1	30 Day Arithmetic Mean	
Viable Helminth Eggs	No/L	<1	Arithmetic Mean	
Enteric Viruses	No/50L	<1	Arithmetic Mean	

The values are based upon achieving an effluent quality that will meet the end use requirements for unrestricted irrigation. The effluent quality is achievable using the treatment process technologies specified in the Design Guidelines without the requirement to implement sophisticated process technologies. Therefore, it does not entail significant capital and operating expenditure. The effluent criteria comprehensively meet the requirements of the World Health Organisation (WHO).

A Phosphate standard of 25 mgPO4/l has been proposed to reflect the significant cost and complexity of achieving phosphorus removal through chemical or biological means without significant environmental justification. The design of a new treatment plant should however consider any future phosphorus consent and allow upgrade without significant capital expenditure. In addition, phosphorus is an essential nutrient for plant growth, and considering the nature of the available soil for growth would provide some benefit and reduce artificial fertiliser use. Should marine discharge become an essential driver then agreement on the Phosphate parameter will have to be reached with DM's Environmental Protection Department (EPD) to preferably set it as maximum 2mg/L.

4. GENERAL REQUIREMENTS

All designs both for new sewage treatment plants as well as for modifications to existing sewage plants shall be issued to DM prior to the commencement of any site works. All design shall be based on the current best practice utilising the latest methods and design software, if applicable.

4.1 Site Survey

A site survey shall be carried out which will include topographic survey, geotechnical assessment, ground works assessment and an ecological assessment. Site-specific investigations shall also be included in the survey. All survey reports to be submitted to DM.

4.2 Layout

The proposed site layout shall be submitted to DM prior to the commencement of the construction phase. It should minimise cut-and fill operations.
The designer should liaise with DM and the relevant planning authorities to ensure that the proposed landscape design is appropriate.

4.3 Hydraulic Design

The proposed hydraulic design should avoid or minimize intermediate pumping, minimise head loss, eliminate the possibility of deposition and should make the best use of existing gravity falls across the site. In addition, the following shall be observed:

- All liquid-retaining structures shall be designed with sufficient freeboard to ensure that there is no spill under any circumstances.
- All flow-splitting shall be even except as agreed otherwise.
- All devices that control and modify flow through the plant should be subject to automatic control except where agreed otherwise.

For large plants, Computational Fluid Dynamics (CFD) modelling shall be carried out by the designer for all flow splitting chambers and for tanks where the mixing regime may have to be carefully evaluated, e.g., activated sludge reactors. This is a mandatory requirement unless otherwise excluded in the TOR or instructed by DM SRPD.

4.4 Peak Factor

Based on the flow pattern for the various pumping station, the daily peak factors for both Jebel Ali STP and Warsan STP and the hourly peak factors for weekdays & weekends for both winter and summer periods have been derived and is given in Table 4-1 below:

Table 4-1 - Peak Factors

Particulars	Influent to Jebel Ali STP	Influent to Warsan STP
Yearly average flowrate (MLD)	210	310
Daily peak factor	1.73	1.30
Winter scenario:		
Weekday average flowrate (MLD)	170	298
Weekday Hourly Peak Factor	1.25	1.25
Weekend average flowrate (MLD)	142	332
Weekend Hourly Peak Factor	1.29	1.41
Summer scenario:		
Weekday Average Flowrate (MLD)	214	332
Weekday Hourly Peak Factor	1.22	1.17
Weekend Average Flowrate (MLD)	214	336
Weekend Hourly Peak Factor	1.20	1.36

The above table can be used as guidance. However, during design stage, actual population and flow projections shall be used to determine the peak factor. Moreover, the maximum pumping capacity and design horizon of the upstream stations shall also be taken into consideration to arrive at the peak factor. The following formula by Harmon shall be used to estimate the Peak Factor.

$$PF = 1 + (14/(4+\mathrm{SQRT}(P)))$$

Where: **PF** – Peak Factor

P – Population in thousands

For small STP's where the flow variation is expected to be high, a peak factor of 5 shall be used.

4.5 Standards

The design shall meet the requirements of the appropriate specifications for Civil, Structural, Mechanical and Electrical work.

The generic requirements for the main civil and structural design, environmental performance, and operation and maintenance aspects of a wastewater treatment plant are given below.

4.5.1 Civil Engineering

All design loadings (dead & live loads, wind loads, thermal loads, dynamic loads from process equipment) shall either be in accordance with specified design standards, or to the relevant UK codes or an equivalent European code.

Structural works – concrete, steel, masonry, foundations, construction joints, expansion joints, and movement joints shall either be in accordance with specified design standards, or to the relevant UK codes or an equivalent Euro code, or a recognized Good Practice Guide. All structural analysis shall be carried out using latest software.

The design of pressure pipelines thrust blocks shall comply with "Guide to the Design of Thrust Blocks for Buried Pressure Pipelines" ref: CIRIA Report 128: 1994.

It is essential that suitable materials are selected for the long-term benefit of the Client.

Process Tanks shall be provided with adequate corrosion protection in the wet zones, splash zones, exposed surfaces, and underground/groundwater exposed surfaces.

4.5.2 Environmental Performance

An Environmental Impact Assessment shall be carried out in accordance with Dubai Municipality's Environmental Dept. Guidelines. The following aspects shall be considered during the design phase:

a. The proposed design shall include estimates of chemical consumption, energy consumption, wash water consumption, noise, odour, and visual impact, etc.

b. The designer shall endeavour to minimize the carbon footprint of the plant during its lifetime and the plant should have a minimum whole life cycle cost. The designer shall supply appropriate justifications for any areas of plant design that do not comply with this principle.
c. The designer shall provide a Green House Gas Emission calculation for the plant for construction, demolition and operation period in a format that can be kept up to date throughout the plant's lifetime.
d. The designer shall calculate the capital and operational cost of the plant. This cost is to be expressed in cost per day and cost per cubic meter of sewage treated. This cost is to include all costs relating to power, consumables, manpower, spare parts etc.
e. All architectural aspects of the plant shall blend with the surrounding environment, as specified by the appropriate planning authorities.
f. The plant should be compliant with all relevant noise control legislation such as Local Order 61 and/or Federal Order 24. For noise standard inside buildings, requirements of the Occupational Safety and Health Administration (OSHA) shall be consulted and followed. The designer shall produce a model to demonstrate that the plant shall not produce noise at the plant's boundary that shall be deemed a nuisance by the appropriate regulatory authorities.
g. The plant should be compliant with all relevant odour control legislation. The designer shall produce a model to demonstrate that there will be no odour detectable at the plant's boundary. The designer shall refer to Section 7.1.1 for the required performance of the odour control system for STP's. DM reserves the right to impose more stringent requirements that what is specified in this Design Guidelines (in terms of odour level at plant boundary, etc.) if it deems necessary, e.g., if the STP location is considered critical due to presence of sensitive receptors. The designer shall carry out odour dispersion modelling to prove compliance of the odour control system using acceptable software (AERMOD, CALPUFF) and up to date meteorological database.
h. The design should include provision for offices, staff accommodation, stores, and hygiene and "black and white" separated washing facilities for O&M staff and visitors.
i. All plant consumables shall be identified and quantified. Storage facilities shall be weather protected, lockable. Chemical stores shall be fitted with a separate spill collection system and/or bunds where required.

4.5.3 Operation and Maintenance

The overall objective shall be the provision, within budget, of timely, efficient and effective operational and maintenance services, including scheduled preventative maintenance and unscheduled corrective activities. This overall objective shall address the following:

a. Maximise the overall performance of all infrastructure.
b. Increase performance levels using improved technologies and methods.
c. Perform services to the best industrial practices in terms of delivery, efficiency, workmanship, housekeeping, planning and control.
d. Cater for expansion of the wastewater collection, treatment, and disposal systems to meet future demands and deliver its required levels and quality of service.
e. Monitor and control operations and maintenance expenditure within agreed financial targets.
f. Provide the continuity of the services with minimal disruption to the flows and pumping requirements.

4.5.4 Maintenance and Failure Provision

a. The design shall include sufficient capacity and numbers of streams of process units so that the plant can cope with the failure of all items in the main process stream. Furthermore, it should be possible to remove any unit from the operational stream (e.g. for maintenance purposes) whilst maintaining the capability of treating 100% of the design mean flow.
b. All pumps, blowers, tanks and other major process units are to be operated in a duty/standby or duty/assist/standby mode. Duty-only operational systems can only be installed with the prior agreement of DM. Refer to Table 4-2 for the required spares/standby units based on the number of duty units. The minimum number of spares/standby units shall in no case be less than 1/3 of the number of duty units.
c. For small plants, standby power generation must be provided which shall offer sufficient power for operating the whole plant under standard flow conditions.
d. All equipment to be standardized as much as possible to limit spare parts requirements.

Table 4-2 – Recommended Schedule of Standby (Spare) units

Number of duty units	Number of standby units
1 - 3	1
4 - 6	2
> 6	≥ 33% of duty units

4.6 Health & Safety

The following aspects shall be considered during the design phase:

a. All systems are subject to a Health and Safety HAZOP during the design phase.

b. Health and safety is to be considered and prioritized in all design including for construction and operation phases.

c. A full Potentially Explosive Atmosphere Zoning (PEAZ) assessment of the site shall be carried out during the design phase. A report shall be issued to DM identifying the various zoned areas and the reasons for such classifications.

d. The designer shall seek to minimize the number and zoning classification of confined spaces within the plant and identify them on drawings.

4.7 Maintenance Requirements

All process items should have appropriate and safe access that will allow normal operational and maintenance activities to be carried out. All process units should be designed so that all items of equipment can be maintained whilst the plant is operational.

4.8 Deliverables

4.8.1 Drawings

The designer shall produce a full set of contract drawings. These drawings shall include but not be limited to layout plans and hydraulic flow diagram, general arrangements and P&IDs for all major processes, single line drawings for major electrical items.

4.8.2 Documents

The designer shall supply a full set of contract documents based on the procurement strategy. This shall include, as a minimum and as applicable, preliminary, and final design reports, design calculations, feasibility studies, etc. or as will be required by DM SRPD.

5. PROCESS SELECTION

Over the years, numerous treatment processes have evolved which have been used successfully around the world. Process selection involves the detailed evaluation of the various factors that must be considered when evaluating unit operations and processes and other treatment methods to meet current and future treatment objectives. The most important factors that must be evaluated in process analysis and selection, amongst others, include the following:

a. Process applicability
b. Flow rate and flow variation
c. Influent wastewater characteristics; inhibiting and unaffected constituents
d. Performance, desired effluent quality and regulatory compliance
e. Climatic constraints and environmental constraints
f. Expandability and upgrade easiness
g. Energy requirements and chemical requirements
h. Whole life cycle cost
i. Land availability
j. Operation and maintenance requirements

Key elements to be considered in the planning of a wastewater treatment facility are the selection of an appropriate site, general plant facilities layout requirements, and the future needs regarding both site selection and plant layout. Considering the effect of a wastewater treatment plant on the development of land in the area includes compliance with zoning regulations, impacts on adjacent property value, and compatibility with activities on neighbouring properties. The size of the site must be sufficient to accommodate present and anticipated future requirements.

The applicability of a process is evaluated on the basis of past experiences and data from existing plants. The variation in flow rates and the characteristics of the influent affect the type of processes. The rated capacity of the wastewater treatment plants is normally based on the average annual daily flowrate at the design year plus an allowance for future growth. However, the plants must be designed to meet several conditions that are influenced by flowrates, wastewater characteristics, and constituent concentrations, and a combination of both.

Climatic constraints represented by excessively high temperatures in Dubai shall be considered in the process selection.

5.1 Multi-criteria Analysis (MCA)

DM SRPD has preference for certain technologies based on their experience with existing STP's as listed in Section 5.2 for the list of acceptable treatment process technologies. Notwithstanding Section 5.2, DM SRPD may instruct the designer to carry out a multi criteria analysis to select the most appropriate process technology for a new STP considering the factors mentioned in Section 5. The criteria and sub criteria, weightages, and scores shall be agreed with DM SRPD. The results of the MCA shall be submitted and presented by the designer to DM SRPD.

5.2 Acceptable Process Technologies

The following treatment process technologies are acceptable based on DM's experience with the process:

- For small plants – MBR only
- For medium plants – MBR or MBBR or Extended Aeration
- For large plants – Conventional (CAS-MLE, CAS-A2O), MBR, MBBR, SBR are acceptable.

Designers may propose new technologies (especially for large plants) by providing sufficient justification to prove that the proposed process is superior, technically, and commercially, to the recommended technologies mentioned above. This includes providing, as a minimum, complete design calculations and drawings, reference plants with sufficient O&M data to support the claim, and contact details for the plants using the proposed technology. For proprietary technologies, designer is required to provide full design details that will enable DM to evaluate the proposal. Incomplete submission will result in rejection of the proposal.

5.3 Brief description of the Process Technologies

5.3.1 Conventional Activated Sludge (CAS)

The conventional activated sludge suspended growth process has been widely used for designing municipal wastewater treatment plants worldwide. The process involves the biological oxidation of organic matter (BOD and COD) and nitrification (oxidation of ammonia to nitrites then nitrates). Both processes take place in the same aeration tank. When nitrogen removal is desired thru denitrification process, an anoxic tank is added before (pre-anoxic) or after (post anoxic) the aeration tank. Sludge is returned at the head of the reactor (as Return Activated Sludge or RAS) and mixed with the incoming primary effluent flow. There is also provision to recycle nitrates to the anoxic basin to facilitate denitrification if BOD/COD is not rate limiting. The recycle also helps to dilute any “slugs” of inhibitory flows entering the ASR. The effluent from the aeration tank flows to a clarifier or final settling tanks. Waste Activated Sludge (WAS) is taken from the bottom of the clarifier and brought into the sludge or biosolids handling facilities.

The Conventional Activated Sludge has several configurations which were developed to address specific issues associated with CAS process. The configuration adopted by DM in their plants (e.g., JASTP Phase 1) is the Modified Ludzack-Ettinger (MLE) process which incorporates Nitrogen removal by having an Anoxic tank upstream of the Aeration tank and having an internal recycle stream from the Aeration tank to the inlet of the Anoxic tank. For JASTP Phase 2 under DS150/2, the MLE process was still adopted but with the option to switch to Anaerobic-Anoxic-Oxic (A2O) mode when there is requirement for Phosphorous removal. JASTP Phase 1 was likewise upgraded to have this capability of switching to A2O mode. See Figure 6-1 and Figure 6-2 which illustrate the CAS-MLE and CAS-A2O processes respectively.

5.3.2 Membrane Bioreactor (MBR)

This process employs membrane separation technology to separate the solids in the Mixed Liquor Suspended Solids (MLSS) from clear water or effluent instead of using Final Clarifiers or Secondary Settling Tanks. Hence, final clarification or secondary settling tanks are eliminated resulting in lower footprint requirement for the plant. Depending on the type of membrane used, MBR can also remove bacteria and viruses which can reduce requirement for UV and reduce consumption of Sodium Hypochlorite required for disinfection.

MBR does not require a settling stage for solids-liquid separation and produces tertiary treatment quality effluent and the best possible effluent quality especially in terms of effluent solids content. Thus requirement for tertiary filtration is eliminated further resulting in significant reduction in plant footprint. Although MBR has been commonly used to design wastewater treatment plants for some time now, this is still relatively considered as state-of-the art technology. A major disadvantage is higher costs, in terms of both CAPEX and OPEX, the latter due mainly to higher aeration requirement. Refer to Section 6.3.1 and Table 6-13 for the general design criteria applicable for the activated sludge reactor. Additional design considerations specific to MBR are as follows:

Design considerations:

- MLSS – 8,000 to 12,000 mg/l (depending on type of membrane)
- Pump to or Pump from design is acceptable.

5.3.3 Moving Bed Bioreactor (MBBR)

Moving-bed biofilm reactors use specially designed plastic carrier elements for biofilm attachment held in suspension throughout the reactor by turbulent energy imparted by aeration, liquid recirculation, or mechanical mixing energy. In most applications, the reactor is filled between one-third and two-thirds full of carriers. Perforated plates or sieves located on the effluent-end of the reactor allow treated water to pass through to the next treatment step but retain the media inside the reactor. Perhaps the most impressive aspect of an MBBR is in its versatility, allowing creative solutions by design engineers. The key differentiator for moving-bed technology when compared with other biofilm systems is that it combines many of the advantages of activated sludge with the advantages offered with biofilm systems, while, at the same time, trying to minimize the drawbacks of each.

The main advantage of the MBBR process is its compact footprint due to smaller aeration tanks. The process is also more robust against variation in influent loadings and process upset. Main disadvantage is the quality of the sludge which is somewhat floatable and will not easily settle in the secondary settling tank. However, this can be addressed by adding a flocculation process upstream of the settling tank and using lamella settlers to enhance settling. Dissolved air flotation (DAF) is also used for solids-liquid separation in the MBBR process. Refer to Section 6.3.1 and Table 6 -13 for the general design criteria applicable for the activated sludge reactor. Additional design considerations specific to MBBR are as follows:

Design considerations:

- Fill fraction: < 55% (or as recommended by biomedia manufacturer for effective mixing)
- BOD loading rates:
  - High rate (75 to 80% BOD removal) – >20 $g/m^2.d$
  - Normal rate (80 to 90% BOD removal) – 5 to 15 $g/m^2.d$
  - Low rate (preceding nitrification – 5 $g/m^2.d$
- Biocarrier or biomedia and the media sieve shall be supplied by the same manufacturer.
- Design shall include media transfer/storage (during tank cleaning)

5.3.4 Sequential Batch Reactor (SBR)

The SBR process involves a fill-and-draw, completely mixed reactor in which both aeration and clarification occur in a single reactor. Settling is initiated when aeration is turned off. When settling time is up, a decanter device is used to withdraw supernatant. The sequential phases comprise a cycle with defined time intervals to achieve certain objectives. The bulk of MLSS remains in the reactor during the cycle with periodic wasting. The phases of each cycle include:

- Fill (raw or settled wastewater fed to the reactor);
- React (aeration/mixing of the reactor contents);
- Settle (quiescent settling and separation of MLSS from the treated wastewater);
- Draw/decant (withdrawal of treated wastewater from the reactor); and
- Idle (delay period before beginning the next cycle and might include removal of waste sludge from the reactor bottom).

The idle phase may be omitted, and sludge wasted at the end of the reactor draw phase. Cycles and phases may vary with each reactor. Refer to Section 6.3.1 and Table 6-13 for the general design criteria applicable for the activated sludge reactor. Additional design considerations specific to SBR are as follows:

Design considerations:

- Minimum number of cycles at maximum flow: 3

5.3.5 Extended Aeration

For medium sized plants, Extended Aeration is an acceptable treatment process technology. Extended Aeration is a variant of the Conventional Activated Sludge process characterized by long retention time in the aeration tank and low organic loading. Refer to Section 6.3.1 Table 6-13 for the general design criteria applicable for the activated sludge reactor. Additional design considerations specific to Extended Aeration process are as follows:

Design considerations:

Retention time in Aeration tank: 20-30 h

MLSS: 2500 – 4000 mg/l

F/M ratio – 0.04 to 0.10 kg BOD/kg MLVSS.d

Volumetric loading – 0.1 to 0.3 kg BOD/m3.d

SRT – 20 to 40 d

5.3.6 Other Technologies

Other treatment process technologies that may be proposed by designers include but not limited to the following:

- Nereda
- Aerobic Granular Sludge (AGS)
- Food Chain Reactor (FCR)

Note that Nereda and AGS are both proprietary technologies based on the same principle of producing aerobic granular sludge. However, the main difference is the flow regime. Nereda operates as a batch process whilst AGS operates as a continuous flow process. FCR is also a proprietary technology developed by Organica which is in essence a biofilm process.

DM SRPD may add to this list as new technologies and innovations are introduced and proven.

6. UNIT PROCESSES

Depending on the selected treatment process from the preceding Section, the STP's shall have the following unit processes, as applicable. The design criteria for each unit process may also change based on the selected process. Where it is not provided in this Design Guidelines, the references provided herein (Metcalf & Eddy Wastewater Engineering or WEF Manual of Practice), shall be consulted by the designer.

6.1 PRETREATMENT

6.1.1 Screening Devices (Bar Racks and Screens)

Coarse bar racks and screens shall be provided to remove coarse materials from the flow stream that could damage downstream process equipment, reduce overall treatment process reliability and effectiveness, or contaminate waterways. Fine screens are sometimes used in place of or following coarse screen where greater removals of solids are required. Depending on the size, the screens can be classified as presented in Table 6-1 below:

Table 6-1 - Types of Screens

Type	Aperture size	Applications
Coarse	20mm - 50mm	Protection of plant equipment and to prevent flow blockage
Fine	1mm - 10mm	Achieve greater removal of solids

General Considerations

The following considerations shall be given while designing the screens:

- Coarse bar racks or bar screens shall precede mechanically cleaned grit chambers.
- Fine screens, if used, should follow grit removal.
- Screening devices shall be installed in a building that has adequate heat, ventilation and moisture control. Screening devices shall be separated from other equipment or offices and be provided with separate outside entrances.
- Screen channels must be equipped with ON/OFF actuated penstocks.
- Sufficient lifting equipment must be installed to lift the screening skips for removal.
- Service water must be provided for each screen and sluice trough with the required pressure (usually 4-6 bars)
- The screens should be able to handle flows when one unit is out of service so the design must be based on (n-1) conditions or a standby channel must be provided.

- Emergency bypass/overflow for screens shall be provided.
- Hydraulic jumps must be avoided in the water surface profile which will create turbulence and release excessive H_2S.
- Each screen channel must be covered with closed fitting removable covers (preferably GRP)
- Air inlet and extraction dampers must be provided on the covers
- It is advisable to have a sump in the screening channel for complete emptying of the channel during maintenance.
- Inlet and outlet arrangement of the screens must be carefully designed to avoid dead spots and hence settlements.
- Connection from the washpactors back to the screen channel must be provided for organics discharge.
- Wash water feed should be arranged using solenoid valves.

Design Criteria

Table 6-2 - Coarse Screens

Acceptable screen types	**Travelling band, rake type bar screens, multiple rake type bar screens**
Screen Operation	Automatic
Design philosophy	can be operated under (n-1) conditions or standby to be provided
Bar spacing	40-50 mm
Bar width	3-6mm (depends on the manufacturer)
Min velocity u/s screens	0.5 m/s
Velocity through screens	1.0-1.2 m/s
Slope	60°-90° (depends on the type)
Blinding factor for max head loss	50%
Maximum allowable head loss	40cm (should be checked against hydraulics)
Material	AISI 316 (L)
Screen Retention Value (SRV)*	min 35%
Automation	Differential level measurement and timer based
Wash water rate	Based on the selected screen type

*SRV: the percentage of total solids retained by a screen

Coarse screen head loss : According to Kirschmer's formula

HL =β (ω/b)1.33 x h x sinθ

HL : head loss, (m)

β : bar shape factor w : maximum cross sectional width of bars facing upstream, (m)

b : minimum clear spacing of bars, (m)

h : upstream velocity head ,(m)

θ : angle of bar screens with horizontal

Table 6-3 - Kirschmer's value of β

Bar type	β Range (Function of Opening size)
Sharp-edged rectangular	1.3 – 2.6
Rectangular with semi-circular upstream face	1.83
Circular	1.79
Rectangular with semi-circular upstream and downstream faces	1.67
Trapezoidal	1.3 – 2.5
Teardrop	0.8 – 1.5

6.1.2 Coarse Screens Handling

Table 6-4 - Coarse Screens Handling

Screening conveyance	Wet conveyance using sluice troughs or belt conveyor with service water connection
Operation	Fully automatic
Capacity	to be determined during detailed design
Screenings Handling Type	Wash-press
Material	AISI 316 (L)
Coarse screening quantity	min 0.000067 m^3/m^3 wastewater
	max 0.000201 m^3/m^3 wastewater
Screenings dry solids	15% DS
Bulk density of screenings	870 kg/m^3
Dewatered /washed screenings	40% DS
Organic content of screenings	20 mg BOD_5/ g of dry solids
Washwater rate	to be determined during the detailed design
Sluice trough min slope	1:50
Skip	5-10 m^3 (liftable by trucks)

6.1.3 Fine Screens

Fine screens require special design considerations because the high capture rate of these screens makes them more susceptible than coarse screens to blinding and damage from large objects. The main things to determine are if (1) fine screening requires prior coarse screening, (2) grit removal is required before fine screening, and (3) grease/scum removal is also required for proper operation. It is good practice to include coarse screening before fine screening. There are installations with 6 mm (1.4 in.) opening bar screens that operate successfully without coarse screening pretreatment. However, for bar screens with smaller openings or perforated fine screens, coarse screening is recommended. Determining whether to include coarse screening or grit removal is site specific. The design engineer should evaluate operating conditions to make a final determination.

Table 6-5 - Fine Screen Design Criteria

Screen Type	**Drum screens, multi rake climber type screens , perforated belt screens , Perforated band screens**
Screen Operation	Automatic
Screen surface for drum screens	Perforated or bi-directional
Design philosophy	can be operated under (n-1) conditions or standby to be provided
Spacing/Perforation	6-10 mm (For MBR, should be 1-3 mm or as per MBR supplier's recommendation)
Bar width	3-6mm (for multi-rake, depends on the manufacturer)
Min velocity u/s screens	0.5 m/s
Velocity through screens	1.0-1.2 m/s
Slope	60º-90º (depends on the type)
Blinding factor for max headloss	25%
Maximum allowable headloss	40cm (should be checked against hydraulics)
Material	AISI 316 (L)
Screen Retention Value (SRV)*	min 75%
Fine screen headloss	According to Kirschmer's formula (for bar screens, see above) According to orifice headloss formula (for drum screens having circular or rectangular openings)
Automation	Differential level measurement and timer based
Washwater rate	Based on the selected screen type

$$HL = 1 \times Q2 / (2 \times g \times C \times Ae)$$

Where:

HL : head loss, (m)

C : discharge coefficient (0.61 widely used, depends on the type of screen)

Q : flow upstream of the bar screen, (m^3/sec)

G : gravitational acceleration, (9.81 m/sec^2)

Ae : effective open area of submerged screen, (m^2)

6.1.4 Fine Screens Handling

Table 6-6 - Fine Screens Handling

Screening conveyance	Wet conveyance using sluice troughs or belt conveyor with service water connection or integral conveyance for drum screens
Operation	Fully automatic
Capacity	to be determined during detailed design
Screenings Handling Type	Separate washpactor press or integral washpactor press
Material	AISI 316 (L)
Fine screening quantity	min 0.000310 m^3/m^3 wastewater
	max 0.000930 m^3/m^3 wastewater
Screenings dry solids	15% DS
Bulk density of screenings	870 kg/m^3
Dewatered /washed screenings	40% DS
Organic content of screenings	20 mg BOD_5/ g of dry solids
Washwater rate	to be determined during detailed design
Washwater pressure	Minimum 5 bar (or as per manufacturer's requirement)
Sluice trough min slope	1:50
Skip	Minimum 2 days

6.1.5 Grit and Grease Removal

Grit removal involves settling of particles that are heavier than water which include sand, gravel, and other heavy solid materials. Grit removal units shall be located after the bar screens and before the primary sedimentation tanks. Grit chambers are provided to protect moving mechanical equipment from abrasion and accompanying abnormal wear, and reduce formation of heavy deposits in pipelines, channels, and conduits.

Design of grit chambers is commonly based on the removal of grit particles having a specific gravity of 2.65 at a settling velocity of 0.3 m/sec. A minimum velocity of 0.15 m/sec must be maintained to prevent the settling of organics with the grit. Numerous configurations are available to achieve the desired level of grit removal which includes the following:

- Aerated grit channels / chambers
- Vortex grit separators
- Detritors

General Considerations

- Inlet to the grit tanks must be equipped with ON/OFF actuated penstocks.
- Each grit tank and the connecting channels must be covered with closed fitting removable covers (preferably GRP)
- Air inlet and extraction dampers must be provided on the covers
- Sufficient lifting equipment must be installed to lift the skips for removal.
- Service water must be provided for grit fluidization, flushing and for the grit classifier.
- Grit fluidization must be done prior to pumping grit
- Grit classifier operation must be interlocked to the operation of the grit pumps.
- Discharge piping with nominal diameters of min 100mm must be used to avoid high pressure and scouring velocities that will result in wear
- Length of grit suction pipe must be minimized
- A connection must be provided from the grit classifier to the inlet of the screens to allow organics discharge
- Washwater feed should be arranged using solenoid valves.
- Tank inlet and outlet should be positioned so that the flow through the tank is perpendicular to the spiral roll pattern (in the case of longitudinal aerated grit chambers).
- The concentration of fats, oil, and grease (FOG) must be analyzed during the detailed design stage.

Design Criteria

Table 6-7 - Design Criteria for Grit Removal System – Aerated Grit Chamber

Grit Removal	
Type	Aerated combined grit and grease removal
Number	Sufficient number of multiple units must be provided to allow for cleaning, service, and repair
Detention time	5 mins @ maximum flow (excluding grease compartment)
Aeration Requirement (in case of aerated grit removal chambers)	0.4-0.6 Nm^3/min-m tank length
Blowers	1 per channel + standby, to be designed according to site conditions
Aeration Type	Coarse bubble diffusers
Grit Scraping Mechanism	Traveling bridge or screw conveyor
Grit removal Mechanism	Via centrifugal or submersible wear resistant pumps
Surface Loading	16.6 – 35.6 m^3/m^2-h
Width to Length Ratio	To be determined during detailed design
Grease removal	
Mechanism	Flotation effect created by the spiral roll pattern with aeration followed by surface skimming
Grease chamber Surface loading	25 -35 m^3/m^2-h @ maximum flow
Detention time with grease removal	max 10 minutes
Grit Handling	
Type	Grit Classifier and Washer (preferably conical type)
Grit quantity	0.04 – 0.15 m^3 / 1000 m^3 influent wastewater
Operation	Fully automatic
Capacity	To be determined during detailed design
Grit conveyance	via submersible or centrifugal wear resistant pump
Type	Surface skimming into the grease pit and then either to a discharge container or another separator depending on local regulations

Grit Removal	
Grease pumps	submersible or centrifugal type
Capacity	To be determined during detailed design
Pipe velocity	1.4 – 2 m/sec

Table 6-8 - Design Criteria for Vortex Type Grit Chamber

Grit Removal	
Type	Vortex-type Grit Chambers
Number	Sufficient number of multiple units must be provided to allow for cleaning, service, and repair
Detention time	20-30 s @ average flow
Diameter	
Upper chamber	1.2-7.2 m
Lower Chamber	0.9-1.8 m
Height	
Removal rates (based on grit with specific gravity form 2.5 to 2.65	
0.3 (50 mesh)	92-98%
0.21 (70 mesh)	80-90%
0.149 (100 mesh)	60-70%

6.1.5.1 Grit Classifier

For medium-sized STP's, the design shall include grit classifiers, either the inclined screw or escalator type, to wash grit by separating out putrescible organics. Classifiers shall be sized based on settling velocity of the particles to be settled, feed flow capacity, and grit-raking capacity. For a target particle size and flow rate, the design engineer selects a minimum pool area and overflow weir length. The design engineer checks the classifier slope to ensure removal of the desired marginal particle size. Flatter slopes will remove finer grit particles. Classifiers offered by manufacturers are inclined from 15° to 30°. In addition to slope, proper flight tip speed (r/min) and pitch (typically half or double pitch) assist in particle removal. Sectional flight construction may perform better than helicoid flights. Hardened flight edges should be used to resist the abrasive action of the grit. The screw or rake is sized to convey anticipated peak grit mass loading.

Table 6-9 - Design Criteria for Grit Classifiers

Grit Classifier	
Type	Inclined screw or escalator
Number	Sufficient number of multiple units must be provided to allow for cleaning, service, and repair
Organic content of washed grit	$\leq$ 3%
Slope/inclination of discharge screw	15% to 30%

6.1.5.2 Grit Washer

For large STP's, grit washers shall be used instead of grit classifiers. Conical grit washer technology represents advancement in grit slurry processing resulting from strict preliminary treatment residuals disposal regulations in Europe. Stainless-steel, conical-shaped vessels are used to capture grit slurry and various systems are used to wash organics from the grit. Rotating arms within the vessel slowly mix the settled grit and a washing jet at the bottom of the unit, activated by a solenoid valve on a timer, vigorously washes it. Lighter organic material continuously overflows the unit and heavier organic material is blown off at regular intervals from a midlevel overflow. These washers create grit with low organic content. The surface flow velocity, including the wash water, should be less than 25 m/h and weir overflow rate of less than 15 m /h. Design flow to these units is typically limited to 25 L/s, although higher flows can be used if the units are equipped with cyclone(s). Historically, target grit particle size has been 200 microns for these units, although one manufacturer has recently released a unit reportedly capable of capturing down to 100-micron particles. Washing provided by these units is superior to traditional cyclone classifiers with a final organic content of less than 5%.

Table 6-10 - Design criteria for Grit washers

Grit Washer	
Type	Conical
Number	Sufficient number of multiple units must be provided to allow for cleaning, service, and repair
Surface flow velocity (including washwater)	$\leq$ 25 m/h
Weir overflow rate	$\leq$ 15 m/h
Organic content of washed grit	$\leq$ 3%
Moisture content of washed grit	$\leq$ 7%

6.2 PRIMARY TREATMENT

6.2.1 Primary Sedimentation

The objective of treatment by sedimentation is to remove readily settleable solids and floating material and thus substantially reduce the incoming organic load onto the biological process that would normally require oxidation and conversion to cell mass. The decision to include primary settlement is to be driven by operational and economic reasons. The performance of the primary settlement tanks (PSTs) at Warsan and Jebel Ali STPs have shown to provide a significant level of $TBOD_5$ and TCOD reduction. The production of primary solids with high volatile solids (VS) content is also in line with the bio solids facility of anaerobic digestion such as to maximise gas production and overall VS destruction at the lowest whole-life cost. This must be taken in account when planning sludge management facility.

The selection of the type of sedimentation unit for a given application is governed by the size of the treatment facility, local site conditions and the experience and judgement of the design engineer. Accordingly, these could be:

- Circular tanks
- Rectangular tanks
- Lamella clarifiers

Circular and rectangular tanks are commonly used at large plants while lamella clarifiers are more suited to smaller plants. All sedimentation tanks shall be equipped with effluent weirs and launders to facilitate effluent collection and sludge hopper including scraper mechanism for removal of settled solids. Scum formation is common in sedimentation tanks and therefore a scum collection and removal system shall be provided for its management.

6.2.2 Emerging Primary Treatment Technologies/Methods

Emerging technologies or methods for primary treatment include microfiltration or micro-screening. Designers may propose these technologies if there are any constraints that will justify their usage (e.g., available space not suitable for primary settling tanks) or there is any distinct advantage over the acceptable primary treatment technologies that would justify it, subject to acceptance and approval of DM SRPD.

Design Rationale

In developing the design of the primary settlement process, the following shall be taken into consideration:

- Sludge residence time should be minimised to reduce the odour generation;
- For sludge removal, Chain and Flight scrapers or travelling bridge system shall be provided;
- Scum removal shall be included, with automated transfer via sludge pumps;
- In case of multiple tanks, the number of desludging pumps shall be minimised by sharing pumps between tanks;
- Easy access shall be provided to all motors to facilitate routine maintenance and repair;
- In case of multiple tanks, even flow splitting between primary settlement tanks across the range of flows is vital to ensure proper performance;
- Sufficient treatment capacity shall be provided, such that one unit can be taken off line and still achieve the desired performance under the peak process loading conditions;
- The primary sedimentation tanks shall be covered with tight fitting trafficable GRP covers and ducted to the odour control facility. This is to prevent odour release and fine sand ingress.

Design Criteria

The following section highlights the key design requirements of the primary settlement system:

Table 6-11 - Key Performance Requirements

Process Area	Parameter	Units	Value	Comments
Primary Settlement Tanks	$TBOD_5$ Removal	%	50	Composite Samples
	TCOD Removal	%	50	Composite Samples
	TSS Removal	%	60	Composite Samples
	Average DS Concentration	%DS	2.0 (max) 1.5 (average)	Daily Average

Process Design Criteria

Table 6-12 - Domestic Primary Settlement Tanks Process Units Design

Process Area	Parameter	Units	Value	Comments
Domestic PST Design	Average Design Reduction			
	$TBOD_5$	%	50%	
	TSS	%	60%	
	Tank Configuration		Rectangular/Circular	
Hydraulic Loading rates	@ Peak process Flow	m^3/m^2-h	1.5-4	2.2 (as per existing large DM STPs)
	@mean dry weather flow	m^3/m^2-h	1.0-1.5	1.3 (as per existing large DM STPs)
	Weir loading rate @ peak flow	m^3/m-h	25-30	
	Weir loading rate @ average flow	m^3/m-h	15-20	
Tank Dimensioning	Floor Slope	Degrees	1.00	1.75%
	Hydraulic Retention Time			
	Daily Average	hours	1.8-2.2	
	Process Peak	hours	1.1-1.35	
	Hydraulic Loading			
	Daily Average	$m^3/m^2/h$	1.08-1.33	
	Process Peak	$m^3/m^2/h$	1.9-2.3	
Sludge Hoppers	Design Dry Solids Concentration	%DS	2.00	
	Required Storage Period	hours	6.00	
	Hopper Slope	Degrees	60	
	Hopper Shape		Frustum of Pyramid	
Sludge Scraper	Scraper Type		Chain and Flight or scraping bridge	Depends on the type of tank

6.3 SECONDARY TREATMENT

It shall be noted that the process technologies listed under Section 5.2 and 5.3 mainly differ in the type of secondary treatment which is where the main treatment in any STP takes place. Typically, secondary treatment employs a biological process followed by a settling stage. Exception to this is the MBR process which eliminates the settling stage by the use of membranes for solid-liquid separation.

6.3.1 Activated Sludge Reactor

The biological process is used for the reduction of carbonaceous and nitrogenous organic material present in the settled wastewater. A typical activated sludge reactor uses a suspended growth reactor followed by clarification with return of thickened "activated" sludge back to the head of the reactors. In development of the design of the biological process the following shall be taken into consideration:

- The specific wastewater characteristics of the plant to be designed.
- The high wastewater temperature impact on the reaction kinetics, especially with respect to the denitrification within the final settlement tanks leading to degradation in solids removal performance.
- Minimisation of aeration power and maintenance of alkalinity buffer through denitrification.
- Improvement of microbial population dynamics through the provision of an anoxic selector zone.
- The high wastewater temperatures that impact on the oxygen transfer efficiency of the available technologies and also the materials of construction.
- Consideration of the impact of fine windblown sand on the aeration equipment.

Process Description

Activated Sludge Process

The most common suspended growth process used for municipal wastewater treatment is the activated sludge process. Activated sludge plant involves the following basic steps:

- wastewater aeration in the presence of a microbial suspension,
- solid-liquid separation following aeration,
- discharge of clarified effluent,
- wasting of excess biomass, and
- return of remaining biomass to the aeration tank

The activated sludge reactors must be configured to allow for the reduction of nitrate to nitrogen gas (denitrification) by including an internal recycle and un-aerated (anoxic) zones within each activated sludge reactor. This will not only recover alkalinity but also mitigate the problems associated with denitrification in secondary clarifiers. The common name for this configuration is the Modified Ludzack Ettinger process or MLE. NOTE: Regardless of the selected process technology, the designer shall incorporate denitrification in the STP design.

The MLE process differs from a conventional, nitrifying AS reactor through the inclusion of an internal mixed liquor recycle. The internal recycle, returns nitrate rich wastewater from the outlet of the reactor to the head of an anoxic zone, where the nitrate is used as an alternative source of oxygen. Typically, the recycle can range from 0.5 – 5.0 x Dry Weather Flow (DWF) and is dependent upon the final Nitrate concentration desired and the characteristics of the influent wastewater. A typical arrangement for an MLE plant is given in Figure 6-1 below.

In a normal AS reactor which includes an anoxic selector where RAS is mixed prior to entering the aerobic portion of the reactor, the same reaction occurs, however as the RAS rate is normally fixed to a maximum by the clarifier size, the achievable nitrate concentration is limited. The inclusion of the internal recycle serves to improve the nitrate reduction at minimal cost and reduced operational complexity.

The MLE process is a very common method of nitrate removal and is practiced throughout the world with excellent success levels and brings significant number of advantages.

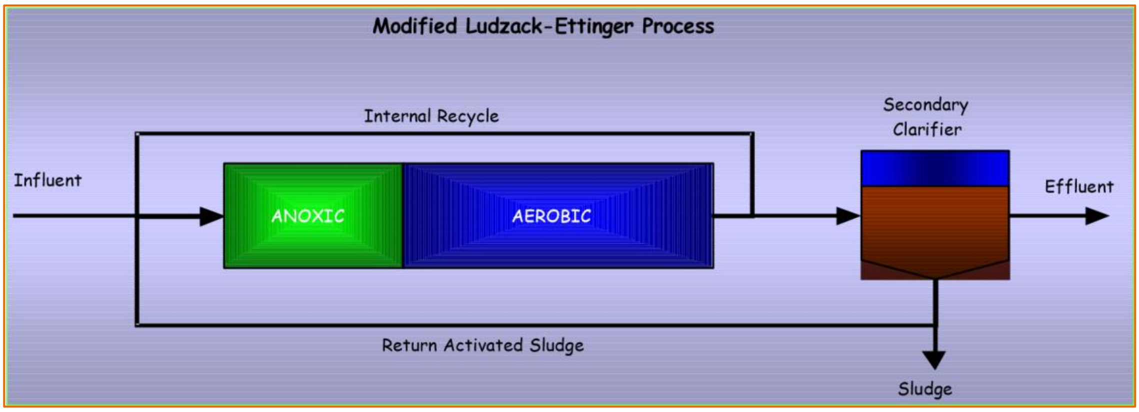

Figure 6-1 – Basic Configuration of CAS-MLE Process

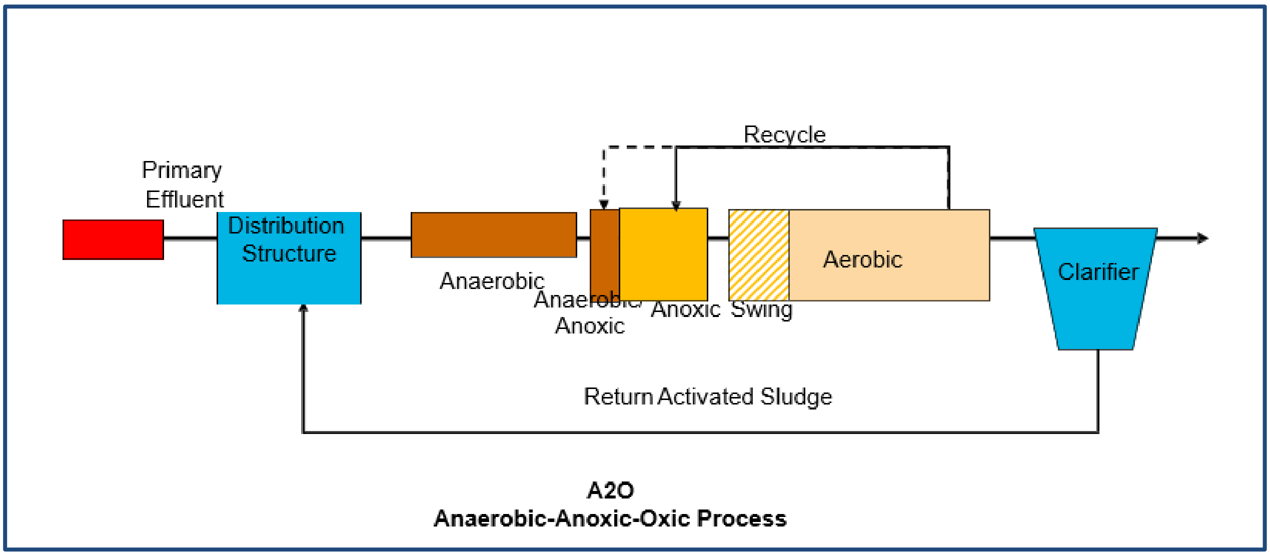

Figure 6-2 – Basic configuration of CAS-A2O Process

Reduce potential for denitrification in the Final Settlement Tanks (FSTs)

Due to the high wastewater temperatures, the level of endogenous respiration in the final tanks is likely to cause a significant reduction in the dissolved oxygen levels within the sludge blanket of the final settlement tanks. As oxygen levels decrease, nitrate will be used as an alternative source of oxygen causing the release of nitrogen gas in the form of bubbles. These nitrogen bubbles will attach to floc particles and cause them to rise to the clarifier surface and out with the effluent.

For rising solids to occur which causes severe problems, the quantity of nitrogen released should be above a certain value, where the generation of sufficient nitrogen bubbles to overcome gravitational and frictional forces is possible. It is not necessary to achieve full removal of nitrogen, but only below this critical concentration (typically 15-20 $mgNO_3$-N/l) in order to provide protection against rising solids.

Understanding this concept allows the internal recycle to be maintained at a minimum level thus reducing the required power costs for the internal recycle. By providing a recycle ratio of no more than 1.25 of the average flow, the risk of denitrification at the new STP can be reduced.

Alkalinity Return

The nitrification process results in the removal of alkalinity, with a stoichiometric requirement of 7.14 $mgCaCO_3$ per mg of Ammonia – N removed through oxidation (not assimilation for growth that can account for 7% of the TKN removed).

As by nature inlet alkalinity tends to be low in the raw sewage, achieving full nitrification may require a considerably larger alkalinity dosing operation, which would attract a large operating cost.

Oxygen Reduction

A substantial cost in wastewater treatment is the power required for ammonia oxidation. 4.3 mg of oxygen (O_2) is required for every mg of TKN converted to nitrate.

With the inclusion of the anoxic zones and internal recirculation, nitrate is used as an alternative oxygen source. For each mg of nitrate – N used, the equivalent of 2.85 mg/L of oxygen is provided. This represents a significant power saving through the simple addition of an internal recycle and anoxic zones.

Process Design Criteria

Table 6-13 shows the design criteria typically applicable to CAS-MLE process. These may vary with other process technologies. For example, MBR operates at higher MLSS concentration (≥ 10,000 mg/l) whilst for MBBR (and other biofilm processes), MLSS is not considered as a design parameter at all. Designer shall refer to Metcalf & Eddy or WEF MOP 8 for design criteria not shown here.

Table 6-14 - Activated Sludge Reactor Process Units Design Criteria

Area	Parameter	Units	Design	Comments
Aeration Basin Design Conditions				
	Influent Loads			
	Average TBOD	kg/d	To be derived with mass balance with respect to influent raw sewage loads and side stream loads and taking into consideration the removal at PST	
	Average TKN	kg/d	To be derived with mass balance with respect to influent raw sewage loads and side stream loads and taking into consideration the removal at PST	

Area	Parameter	Units	Design	Comments
	Average COD	kg/d	To be derived with mass balance with respect to influent raw sewage loads and side stream loads and taking into consideration the removal at PST	
	Sludge Age Peaking Factors		1.50	
	Average Design MLSS Concentration	mg/L	3,000-3,800	
Anoxic Selector Zone	Selector Residence Time	mins	6-8	At Average Flow (to improve sludge settleability)
	Organic Loading onto Selector Zone	kgBOD/kg MLSS	7-14	
Anoxic Zone	Design Specific Mixing Power	w/m^3	2.6-3.5	Based on shaft power
	Specific Denitrification rate	$mgNO^3/g$ VSS-h	1-1.3	
	VD/VT (volume ratio- anoxic to total volume)	-	0.20-0.35	Depending on the level nitrate removal to be achieved
	Anoxic sludge age	Days	2-5	
	Internal mixed liquor cycle flow	-	4-6 x ADWF	

Area	Parameter	Units	Design	Comments
Aerobic Zone	Aeration Method		Fine bubble diffused aeration or Mechanical submerged aeration	
	Vaer/VT (volume ratio – aeration to total)		0.60-0.80	Depends on nitrate and phosphorus removal
	Aerobic sludge age	Days	5-8	Includes nitrification safety factor
	Design overall total sludge age	Days	9-12	
	Design residual alkalinity at the outlet of the Bioreactor	meq/L	1	
MLSS Recycle	MLSS Recycle Ratio: Average Flow	-		
	Minimum – Winter	-	50-70%	
	Maximum – Summer	-	70-120%	
	Design RAS concentration	mg/L	7,000-10,000	
Aeration System	Type	-	Hyperbolic aerator/mixer or fine bubble diffused air system (FBDA)	
	Design Alpha	-	0.50-0.65 0.80-0.90	FBDA

Area	Parameter	Units	Design	Comments
				Hyperbolic aerators/mixers
	Design Beta	-	0.95	
	Design Theta		1.024	
	Max air flow to be calculated for		100% humidity and 55°C	
Consideration must be given to bypass PSTs to provide carbon for activated sludge (bypass ratio 10-30%)				

6.3.2 Enhanced Biological Phosphorous Removal (EPBR)

Anaerobic tanks are required for the biological removal of phosphorus or Enhanced Biological Phosphorous Removal (EBPR); phosphate is released by bio-accumulating bacteria in the anaerobic zone and then taken up in aerobic zone. The mixed liquor recycle supplying biomass to the anaerobic zone should be supplied from the end of the anoxic zone. It is important that the dissolved oxygen levels entering the tank are kept as close to zero as possible. The anaerobic zone should be sized based on dynamic process modelling, such that sufficient time is allowed for hydrolysis and Volatile Fatty Acids (VFAs) generation to drive the EBPR process. Furthermore, the effect of high sewage temperatures (>30°C) on the EBPR process and the subsequent requirement for additional chemical phosphorus removal and impact to bioreactor sizing must be considered. See Figure 6-2 which illustrates the CAS-A2O configuration incorporating an anaerobic tank upstream of the activated sludge reactor to drive the EPBR process.

If necessary to further meet effluent standard for Phosphorous, chemical dosing (e.g., using Ferric Chloride) may be included. Typical dosage is 15-30 mg/L as Fe (45 to 90 mg/l as $FeCl_3$) to reduce Phosphorous level by 85% to 90%.

6.3.3 Denitrification

Denitrification is the biological conversion of NO_3 to NO_2, then to N_2 gas which is released to the atmosphere. The anoxic tank is operated in an oxygen deficient mode requiring the bacteria in the biomass to use the nitrates (NO_3-N) in the returned sludge as their oxygen source to sustain their activity. The stripping of the oxygen from the nitrate compound results in the release of nitrogen gas molecules and its removal from the waste stream. The anoxic tanks also perform the task of providing some foam control by inhibiting the growth of filamentous bacteria.

To be successful in removing nitrogen to the low levels, and to control foam, the anoxic basins must have an oxygen deficient atmosphere.

Adequate alkalinity shall be maintained with minimum 1 meq/l at the plant outlet.
Baffling of the anoxic basins shall be installed to create multiple zones to be operated in series. Submersible mixers shall be included to provide agitation to keep the contents of the basins in suspension.

6.3.4 Final Settlement Tank

The function of the Final Settlement Tanks (FSTs) is twofold, the clarification of the treated flow to ensure an effluent of good quality and to thicken the Mixed Liquor Suspended Solids (MLSS) to a suitable concentration for return to the Activated Sludge Reactors (ASRs). There is also a requirement to “store” activated sludge during high flow periods. Hence, the design of an FST differs from that of a primary sedimentation tank because of the relative solids concentration of the mixed liquor and the need to thicken the solids stream.

FST can be sized using parameters such as retention time, overflow rate, weir loading rate and solids loading rate. These could either be circular tanks with radial flow or rectangular tanks with horizontal flow, however, circular tanks are preferred in UAE.

In developing the design, the following shall be taken into consideration.

- A conservative SSVI (Stirred Solids Volume Index) to be used to allow for fluctuations in the settlement characteristics of the activated sludge;
- Consideration of the scale of the treatment plant, the layout and feed arrangements of the FSTs and pipework; Especially for the pipework and electrical sleeve pipes the designer shall demonstrate in his design how pipes beneath the structure can be unclogged, maintained and repaired. Any bends beneath the structures shall have a suitable radius (minimum 3D for media pipes, 5D for electrical sleeves).
- Scum build up on any free surfaces to be considered and methods to reduce impact;

- Floating scum shall be removed from the liquid surface using a shaft less screw conveyor assembly supported from the clarifier walkway and collected scum fed to a collection tank and pumped to transfer pump sump. Scum collection screws shall be located on both sides of the clarifier central column.
- A common RAS pumping station for all FSTs;
- Full bridge scrapers to facilitate adequate rapid removal of sludge to the central hoppers; Half bridge – up to 25m tank diameter and 2/3 bridge scrapers - up to 32m tank diameter – are acceptable.

Design Criteria

Table 6-15 - Process Design Criteria for Final Settlement Tanks

Location	Sub Parameter	Units	Design	Comments
Design Parameters	Sidewall Depth	m	3.5 to 4.2 m	
	Floor Slope	Degrees	7.5	
	Hydraulic Loading	$m^3/m^2/h$	0.58-0.70	@process average flow (max allowable)
	Hydraulic Loading	$m^3/m^2/h$	0.80-0.95	@process peak flow (max allowable)
	Solids loading rate	kg/m^2-h	4-6	@average daily flow
	Solids loading rate	kg/m^2-h	6-8	@peak daily flow
	Retention Time	Hours	4.5-5.5	@process peak flow
	Hydraulic weir loading rate	m^3/m-h	8-12	@ peak flow; type of weir: V-notch
	Hydraulic weir loading rate	m^3/m-h	4-7	@average flow; type of weir: V-Notch
Energy dissipation inlet	Diameter		8-12% of the tank diameter	
Sludge Hopper	Hopper Angle	Degrees	60.00	

6.3.5 RAS Pumping Station

The function of the Return Activated Sludge (RAS) pumping station is to ensure even return of sludge to the head of the reactors.

In developing the design and layout of the RAS pumping stations, the following must be taken into consideration.

- A common RAS pumping station for all FSTs;
- If the plant is large enough not to accommodate a single RAS station, then multiple RAS stations must be grouped to serve even number of FSTs, i.e. one per four or six.
- Return activated sludge (RAS) is removed continuously from the hopper in the base of the FST to one or multiple RAS collection chambers.
- It is recommended that the flow of RAS from the FST shall be controlled by a motorised bell-mouth on the discharge of the RAS line located in the RAS collection chamber and is monitored by a Magflo flowmeter on each RAS line.
- The motorised bell-mouths shall work by raising and lowering on the discharge of the RAS pipeline, altering the differential head and hence the flowrate of RAS.
- As an alternative Weir gates for controlling flow rate of RAS shall also be evaluated.
- The selected RAS pumps shall have flat curves (i.e., pumps with low specific speeds). The designer shall submit pump performance curves issued by the manufacturer.

6.4 TERTIARY TREATMENT

Effluent after conventional secondary treatment contains residual contaminants which are present in suspended, colloidal and dissolved form. Dissolved constituents range from relatively simple inorganic ions, such as calcium, potassium, sulphate, nitrate, phosphate to several highly complex synthetic organic compounds. Tertiary treatment shall be used as a polishing stage after secondary treatment to remove residual solids. The tertiary treatment technology is selected based on end use of treated effluent and available means to dispose of the contaminants. Relevant technologies include:

- Sand filtration – Pressure filter, slow sand filters, rapid gravity filters
- Surface filtration – Disc filter, membrane filtration

Amongst these, rapid sand filtration is most commonly used at large wastewater treatment plants. Its design criteria are discussed in the following section.

It shall be noted that the MBR process produces tertiary treated effluent and does not require a final settling tank for solid separation after the activate sludge process.

Design Rationale

To meet the TSS, $TBOD_5$, turbidity and disinfection standards it is necessary to include a physical barrier process between the final settlement tanks and the disinfection system. Sand filtration coupled with chemical dosing will ensure the turbidity standards are achieved and the required prevention of protozoan breakthrough. The requirement of micro flocculation, although included here, shall be evaluated on a case by case basis.

Process description

Overview

The tertiary filtration stage consists of a number of discrete process steps to ensure the best possible plant performance, these steps consist of:

- Chemical dosing and dispersion
- Micro floc formation
- Polymer dosing and dispersion
- Filtration

It is to be noted that micro floc formation through coagulant and polymer dosing may only be required if microfiltration or ultrafiltration type membrane processes are planned to be installed downstream of sand filters.

It is recommended that separate clean and dirty backwash tanks must be provided to allow the filtration system to operate independently of the rest of the plant. The dirty backwash tanks should have the ability to provide a buffer against the high instantaneous flows and also act as a media retaining system in the event of a substantial level of media loss.

Micro-flocculation system

Table 6-16 - Micro-flocculation Process Unit Design

Parameter	Sub Parameter	Units	Design	Comments
Design Basis	Residence Time	Sec	-	
	Peak Process Flow	Sec	180	
	Type	-	Hydraulic Channel	Baffled For Energy Head losses
Operating Conditions	Residence Time			
	Average	Sec	300-350	
	Process Peak	Sec	180-200	
	Velocity			
	Average	m/s	0.48	
	Process Peak	m/s	0.83	

6.4.1 Rapid Gravity Filters

Rapid gravity filters (RGFs) are the most common choice of tertiary solids removal at large plants. During rapid gravity filtration, secondary effluent gravitates through a bed of media. The organic and suspended solids content is retained by the bed which can become blocked quickly (biological growth may also occur). If the filtration rate is increased the interval between backwashing will decrease because solids enter the filter at a higher rate and the head loss is higher because of the greater flow velocity. Also, breakthrough is more rapid because solids penetrate further into the bed under the higher flow conditions.

A coarse filter media should be provided to ensure depth filtration over surface straining. This improves the filter runtimes and allows filter capacity to be available in the event of high flow and load conditions. Backwashing should be carried out using a Combined Air and Water (CAW) wash, followed by a high rate rinse. This operation provides the optimum washing regime and ensures that the bed is returned to a clean state at the end of each backwash.

Backwash pumps and Blowers must be fitted with VFD's and flow meters to allow for a precise adjustment of the backwash rates.

Performance Requirements

Table 6-17 - Tertiary Filters Key Performance Criteria

Process Area	Parameter	Units	Value	Comments
Filtration	Effluent Turbidity			
	Average	NTU	2.00	Measured over a 24 Hour Period
	Peak	NTU	5.00	At Any Time (for unrestricted irrigation)
Coagulant Dosing	Coagulant Dose	mg/L	+/- 10% Set point	
	Static Mixer	CoV[(a)]	< 0.05 in < 5 s	Measured At Outlet of Static Mixer
Polymer Dosing	Polymer Dose	mg/L	+/- 10% Set point	
	Static Mixer	CoV	< 0.05 in < 30 s	Measured At Outlet of Static Mixer

[(a)] CoV Coefficient of Variation

Process Design Criteria

The following sections outline the process design criteria and unit sizing for the rapid gravity filtration system.

Table 6-18 – Rapid Gravity Filtration System Process Unit Design

Parameter	Sub Parameter	Units	Design	Comments
Filter Design Basis	Average Hydraulic Loading	$m^3/m^2/h$	5 – 12	All cells on line
	Peak Hydraulic Loading	$m^3/m^2/h$	12 – 13	One cell off-line backwashing
	Configuration	-	Duplex (Twin Bed or Single Bed)	Hydraulically connected a floor
	Operating Clogging Head	m	2.5-3.0	
	Total Filter Head loss Allowance	m	4-5	To include inlet, clean bed, floor losses and outlet losses
	Water Level Above Media	m	2-2.5	To prevent air blinding, the level should equal clogging head.
Media Configuration	Media Type	-	Mono Sand or Multi Layer Sand or Multi Layer Sand & Hydro Anthracite	
	Effective Size (ES)	mm	1.80	D10 size (or as per system supplier's recommendation)
	Uniformity Coefficient (UC)	mm	< 1.40	
Support Media	Type	-	Gravel	
	Size	mm	2.00	
	Total Depth	mm	50.00	To cover nozzles (or as per system supplier's recommendation)

Parameter	Sub Parameter	Units	Design	Comments
Floor Type	Floor Arrangement	-	Plenum or Dual parallel lateral type block underdrain	
	Nozzle Density	No/m²	64	Minimum
	Nozzle Slit Width	mm	No Greater Than 80% of Media ES	
Backwashing Mechanism	Backwashing Method	-	Combined Air and Water (CAW)	
	Wash water Rates		-	
	Normal Wash	m³/m²/h	30.00	
	High Rate	m³/m²/h	60.00	
	Wash water Duration	mins	-	
	Normal	Mins	6.00	
	High Rate	Mins	3.00	
	Air Rate Wash			
	Rate	m³/m²/h	70.00	
	Duration	Mins	5.00	Occurs with normal wash
Filter Operation	Filter Control Mechanism	-	Constant flow variable level / Constant level variable flow	Constant flow – variable level is commonly preferred in Dubai
Clean Backwash Tanks	No of Tanks	No.	2	For maintenance and ease of operation
Chlorine Dosing (shock chlorination)	Chlorine Residual	$mgCl_2/l$	3.00	At high-rate rinse
Due consideration shall be given to Pest breeding.				

6.4.2 Pressure Filters

For small and medium STP's, pressure filters (sand or multimedia) and disc filters shall be acceptable for tertiary filtration. Table 6-19 outlines the process design criteria and unit sizing for pressure filters:

Table 6-19 - Design criteria for Pressure Filters

Parameter	Sub Parameter	Units	Design	Comments
Filter Design Basis	Average Hydraulic Loading	$m^3/m^2/h$	5 -14	All filters on line
	Peak Hydraulic Loading	$m^3/m^2/h$	12-14	1 filter under backwash mode
	Configuration	-	Minimum of 2 filters	Each filter sized for the average daily flow
	Operating Clogging Head	m	2.5-3.0	
	Total Filter Head loss Allowance	m	4-5	To be provided by filter manufacturer
Media Configuration	Media Type	-	Mono Sand or Multi Layer Sand or Multi Layer Sand & Hydro Anthracite	
	Effective Size (ES)	mm	1.80	As per system supplier's recommendation
	Uniformity Coefficient (UC)	mm	< 1.40	
Support Media	Type	-	Gravel	
	Size	mm	2.00	
	Total Depth	mm	50.00	As per system supplier's recommendation
Backwashing Mechanism	Backwashing Method	-	Combined Air and Water (CAW)	

Parameter	Sub Parameter	Units	Design	Comments
	Wash water Rates		-	
	Normal Wash	m³/m²/h	30.00	
	High Rate	m³/m²/h	60.00	
	Wash water Duration	mins	-	
	Normal	Mins	6.00	
	High Rate	Mins	3.00	
	Air Rate Wash			
	Rate	m³/m²/h	70.00	
	Duration	Mins	5.00	Occurs with normal wash

6.4.3 Disc Filters

Table 6-20 outlines the process design criteria and unit sizing for disc filters:

Table 6-20 - Design criteria for Disc Filters (Cloth Depth Filters)

Parameter	Sub Parameter	Units	Design	Comments
Filter Design Basis	Average Hydraulic Loading (Design Filtration rate)	m³/m²/h	14.4 to 16.8	
	Peak Hydraulic Loading	m³/m²/h	48	Or as per manufacturer's recommendation
	Diameter of disc	m	0.8 to 3.05	
	Required Total Hydraulic Head	m	0.75 to 1.2	
	Clean medium headloss	m	5 to 10	
	Terminal headloss	m	0.3 to 0.5	
	No. of discs/filter	-	1 to 24	

6.5 DISINFECTION

Disinfection of wastewater protects public from potential exposure to pathogenic microorganisms that would otherwise be present in wastewater effluent which is discharged into water bodies that may be used as drinking water or reused for restricted / unrestricted irrigation, recreation purposes. It is important that wastewater be adequately treated prior to disinfection in order for any disinfectant to be effective.

Numerous technologies are available to carry out the disinfection of wastewater. The technologies that are acceptable to DM for effluent wastewater disinfection are chlorination and ozonation.

6.5.1 Chlorination

Chlorination is the most commonly practised wastewater disinfection technology. Chlorine compounds are often favoured because of their availability, effectiveness, efficiency, relatively low cost, convenience, and more importantly it also provides residual chlorine which a UV system is unable to achieve.

Chlorine gas and liquid sodium hypochlorite are the primary forms of chlorine used in wastewater treatment plants. Chlorine chemicals are generally purchased from external sources, but sodium hypochlorite is also generated on-site. These are discussed in the following sections. However, note that use of Chlorine gas is no longer acceptable to DM SRPD due to safety concerns.

Design Rationale

The function of the Chlorine dosing system is threefold a) bacterial kill b) to provide shock chlorination and c) to provide post chlorination in the plant effluent to prevent microbial regrowth within the irrigation network and also to prevent algae growth in the sand filters.

In developing the design and layout of the chlorine dosing system, the following considerations shall be made;

a. The recommended contact time of 30 minutes minimum at average flow, or 20 minutes at peak flow shall be considered
b. Concentration of chlorine for bacterial kill should take into account residual organics, ammonia and the bacterial count coming into the disinfection system
c. For shock chlorination purpose, a dosage of 3 mg/L shall be considered
d. Only a total chlorine residual will be necessary for the effluent discharge 1-1.5 mg/L depending on the length of the network

e. Duty/standby chlorinators for each dosing location to ensure sufficient redundancy (plant effluent and filter backwash water);
f. Chlorine shall be dosed downstream of the irrigation pumps to prevent bacterial growth within the irrigation network and also into the filter backwash line to prevent algae growth in the filters.

Mixing and Contacting System

Rapid mixing shall be provided to avoid developing chlorine concentration gradients (pockets) that may overdose some portion of the wastewater, potentially promoting formation of other chlorinated compounds with little or no germicidal efficiency, and under dose other portions of the wastewater, resulting in insufficient disinfection. The mixing device should achieve complete mixing in a few seconds. Mechanical mixers and energy dissipation devices (static mixers or hydraulic jumps) that dissipate hydraulic head (if available) shall be used to achieve mixing.

The contacting system shall either consist of a separate contact basin or an outfall pipe. Basins should be designed to promote plug flow to prevent short-circuiting using baffles. In addition, contact tanks should be covered, to reduce chlorine losses to volatilization. If outfall pipes are used then the pipe must be long enough to meet contact time requirements.

Chlorine Leakage

The chlorine storage tanks and dosing pumps shall be housed in an enclosed building. The chlorine storage tank and chlorine dosing pump rooms shall be ventilated at 6 Air Changes Per Hour (ACPH). Moreover, adequate safety measures shall be incorporated in the design to handle any accidental leakage of chlorine. High points shall be avoided in the piping system to prevent release of chlorine fumes.

Design Criteria

Table 6-21 - Chlorine Dosing Key Performance Requirements

Process Area	Parameter	Units	Value	Comments
Chlorine dosing to Plant Effluent	Average Chlorine Residual	mg/L	1-1.5	Depends on the length of network
	Peak Chlorine Residual	mg/L	1.5-2.5	Depends on the length of network
Chlorine Dosing to Backwash Water	Chlorine Residual	mg/L	3.0	

6.5.1.1 Sodium Hypochlorite

Over the last few decades, the use of sodium hypochlorite (also known as liquid bleach) as a disinfectant has gained popularity as it eliminates many of the safety concerns and environmental risks associated with the transport, storage, and feeding of gas chlorine. Sodium hypochlorite can either be purchased from the market or can be generated on-site depending on the requirement and its availability. Commercial-grade sodium hypochlorite is available in solution form, in strengths of 1 to 16% by weight. For wastewater disinfection, hypochlorite is usually delivered in solutions containing 10 to 15% available chlorine. Higher concentrations are not common because the chemical stability of the solution diminishes greatly with increasing strength.

On-site generation of liquid sodium hypochlorite can be a competitive chlorine source in some situations. Considerations for on-site systems include cost, concentration of the hypochlorite produced, availability of raw materials, and reliability of the process. The concentration of the sodium hypochlorite solution produced from the system is typically around 0.8%.

Design considerations:

- Sizing calculations shall consider NaOCl degradation, i.e., available chlorine to be considered shall not be more than 10%.

- Chemical tank storage capacity – not more than 14 days to avoid or minimize NaOCl degradation that can impact recycled water quality and increase cost of chemical consumption.
- Location of NaOCl dosing system shall be in shaded area or in an airconditioned and properly ventilated room.

6.5.1.2 Chlorine Contact Tank/RW Disinfection & Storage

For small and medium STP's, disinfection or chlorine dosing shall be at the chlorine contact tank which shall be located downstream of the tertiary treatment system. The following design criteria shall be used for chlorine contact tanks for small and medium-sized STP's.

Table 6-22 - Design criteria for chlorine contact tank

Process Area	Parameter	Units	Value	Comments
Chlorine Contact tank	Average Chlorine Residual	mg/L	1-1.5	Depends on the length of network*
	Peak Chlorine Residual	mg/L	1.5-2.5	Depends on the length of network*
	Retention time	h	0.5	@ Peak flow
	Configuration		Tanks to be provided with baffles to promote serpentine flow pattern	

*in the case of small STP's where the TSE discharge is not connected to DM's network, average & peak chlorine residual of 0.5 to 1.0 mg/l is acceptable.

For large plants, Chlorine contact tank CCT) is not required. Instead, the designer shall include a recycled water (RW) storage tank that will function as a CCT and disinfect the treated effluent prior to and during storage. RW storage of 6 hours/12 hours/24 hours shall be provided based on irrigation network and irrigation requirement. The RW storage tank shall have provision for bypass, drainage and isolation (as required) through the use of penstocks and/or isolation valves.

6.5.2 Ozone

Ozone acts as an effective disinfection agent through the following four mechanisms:

- It causes cell lysis by oxidation of cell walls
- It breaks down purines and pyrimidines, the building blocks of nucleic acids;
- It breaks down carbon-nitrogen bonds, leading to depolymerization of organic molecules;
- It produces hydroxyl radicals in water, which are powerful oxidants.

The effectiveness of ozone for disinfection depends on several factors, including target pathogen, the pathogen's exposure to ozone, particulate shielding, and temperature. In municipal wastewater effluent, ozone exposure, defined as the integral of ozone concentration over time, is influenced by the transferred ozone dose and the concentration and type of dissolved organic matter (DOM) present.

The disinfection process can be summarized as follows. Ozone, an unstable gas, must be generated on-site and then transferred into the treated water. Once transferred, a large portion of the initial ozone concentration rapidly decays within the first few seconds ("instantaneous demand"); the remaining concentration ("residual") decays more slowly, with a typical half- life of less than 30 seconds in municipal wastewater effluent (Metcalf & Eddy, Inc./AECOM, 2013). However, since ozone decays so quickly, and much of the actual CT is accounted for before measurement is practical, treatment trains should be designed using site-specific bench and pilot studies.

Design Criteria

Table 6-23 - Design Criteria for Ozone Disinfection

Process Area	Parameter	Units	Value	Comments
Ozone Generator	Applied power	V	6,000 – 20,000	Depends on the length of network*
	Efficiency	%	1% to 4%	Air as feed gas
	Efficiency	%	1% to 10%	Oxygen as feed gas
	Yield	% by weight	4% to 12%	Using Pure oxygen
	Recommended moisture concentration	ppm by weight	Less than 1	
	Ozone Exhaust destruction power requirement	kW per 100 scfm (3 m^3/min)	1 to 3	

Note: Due to the requirement for residual chlorine in the Recycled Water, chlorine dosing after ozonation is still required.

6.6 SLUDGE HANDLING AND TREATMENT

The constituents removed in sewage treatment plants include screenings, grit, scum and sludge. Sludge is produced from the primary clarifiers and from secondary treatment /biological treatment of the sewage. Sludge treatment shall be used to reduce water and organic content of the sludge and render the processed sludge/solids suitable for reuse or final disposal. The principal methods used primarily to remove water/moisture from the sludge are thickening, conditioning, dewatering & drying and to treat or stabilise the organic material in sludge are digestion, composting, and incineration. Amongst these, thickening, digestion, dewatering and drying are commonly used.

Design Rationale

To meet regulations of reuse and disposal of sludge, it is necessary to provide the sludge treatment. The requirement of various sludge treatment methods, although mentioned above, shall be determined on a case-by-case basis.

6.6.1 Sludge Thickening

Sludge thickening is to reduce the volume of liquid sludge to be treated subsequently. The extent to which sludge should be thickened depends upon the subsequent method of treatment and disposal. The dry solids content of the thickened sludge will depend on the type of sludge to be thickened and the thickening process used.

6.6.1.1 Gravity Thickener

Gravity Thickeners are usually circular. Dilute sludge is fed to centre feed well. The feed sludge is allowed to settle and compact. The thickened sludge is withdrawn from the conical tank bottom. A sludge collecting mechanism with deep trusses or vertical picket fence is provided. Vertical pickets promote densification. The supernatant flow is returned to the treatment.

Process Design Criteria

Table 6-24 – Gravity Thickener Unit Design Criteria - Solids Loading Rate

Type of Sludge	Unthickened Solid Concentration (%)	Solid Loading Rate (Kg/m2.d)	Thickened Solid Concentration (%)	Capture Rate (%)	Polymer usage (kg/DT)
Primary Sludge	1-6	100-150	5-10	90-92	2.2-4.4
Waste Activated Sludge	0.5-1.5	20-40	2-3	85-90	2.2-4.4
Extended Aeration Activated Sludge	0.2-1	25-40	2-3	85-90	2.2-4.4
Primary and Waste Activated Sludge	0.5-1.5	25-70	4-6	85-90	2.2-4.4

Recommended maximum hydraulic overflow rates ranges from 15.5 to 31 m^3/m^2.d for primary sludge, 4 to 8 m^3/m^2.d for waste activated sludge and 6 to 12 m^3/m^2.d for combined primary and waste-activated sludge.

To maintain aerobic conditions in gravity thickeners, when wastewater is warm (22 to 28°C), provisions should be included for adding up to 24 to 30 m^3/m^2.d of dilution water to the thickener.

6.6.1.2 Dissolved Air Flotation Thickener

Dissolved air flotation (DAF) thickeners operate by mixing a stream of liquid containing dissolved air under pressure with sludge and introducing the mixture near the bottom of a flotation tank. The associated release of pressure generates very small gas bubbles, and the gas-sludge mixture rises to the surface of the tank. Thickened sludge is removed by the action of a flight scraper.

Activated sludge are difficult to thicken by gravity alone but DAF thickening is much more effective. Polyelectrolytes are usually added to improve the thickening performance. DAF thickeners are operated continuously.

Flotation thickened sludge can be difficult to pump due to the aerated nature of the sludge. Also sludge which contain high concentrations of sulphides (or other malodorous gases) may not be suitable for DAF thickening because of odour emissions.

A solid loading rate of 10kg/m^2.h is a typical design value. DAF thickening of WAS (waste activated sludge) should produce concentrations of 4-5%ds. A polyelectrolyte dose of 0.5-2.5kg per tonne of sludge solids is typically used.

Design Rationale

The air to solids ratio is the most important factor affecting performance of the floatation thickener. The air to solids ratio at which float solids are maximised varies from 2 to 4 %. The SVI (Sludge Volume Index) is also important and should be less than 200 for better thickening performance using polymer dosages.

Process Design Criteria

Table 6-25 - Dissolved Air Flotation Unit Design Criteria – Solids Loading Rate

Type of Sludge	Solid Loading Rate (Kg/m2.h)-Without Chemical Addition	Solid Loading Rate (Kg/m2.h)- With Chemical Addition	Comments
Air-Activated Sludge	Up to 2.0	Up to 10.0	
Primary and Air Activated Sludge	Up to 2.0	Up to 10.0	
Primary Sludge	Up to 2.5	Up to 12.5	

6.6.1.3 Gravity Belt Thickener

This type of thickener uses a porous belt that moves over rollers driven by a variable-speed drive unit. Feed sludge conditioned with polyelectrolytes is distributed evenly across the width of the moving belt. As the water drains through the sludge is carried toward the discharge end of the thickener. After the thickened sludge is removed the belt travels through a wash cycle.

Gravity belt thickeners can be used to thicken raw and digested sludge. Gravity belt thickening can thicken SAS (surplus activated sludge / waste activated sludge) typically to about 5%ds if polyelectrolyte dosing is used.

Gravity belt thickeners can cause odour nuisance when treating sludge with high sulphide content. This is normally due to poor design of the sludge liquor collect on system where excessive cascading of the liquor can cause dissolution of sulphide or odorous compounds.

A hydraulic loading rate of 800 L/m.min is a typical design value. Solid loading rates range from 200 to 600 kg/m.h. A polyelectrolyte dose (for thickening of waste-activated sludge) of 3 to 7 kg per tonne of dry solids is typically used.

Process Design Criteria

Table 6-26 - Gravity Belt Thickener Design Criteria - Hydraulics Loading rate

Belt Size (Effective Dewatering Width) (m)	Hydraulic Loading Rate (L/s)	Comments
1.0	6.7-16	
1.5	9.5-24	
2.0	12.7-32	
3.0	18-47	

6.6.1.4 Rotary Drum Thickener

This type of thickener uses rotary media covered drums for thickening the sludge. The polymer is added with dilute sludge in conditioning drum/section. The conditioned sludge is then passed to rotating screen drums, which separate the flocculated solids from the water. Thickened sludge rolls out the end of the drums, while separated water decants through screen.

Process Design Criteria

Typical performance data for rotary drum thickeners are given in Table 6-27

Table 6-27 - Rotary Drum Thickener - Typical Performance Data

Type of Sludge	Unthickened Solid Concentration (%)	Water Removed (%)	Thickened Solid Concentration (%)	Capture Rate (%)	Polymer usage (kg/DT)
Primary Sludge	3-6	40-75	7-9	93-98	2.2-6.7
Waste Activated	0.5-1.0	70-90	4-9	93-99	2.2-6.7
Primary + Waste Activated	2.0-4.0	50	5-9	93-98	2.2-6.7
Aerobically Digested	0.8-2.0	70-80	4-6	90-98	2.2-6.7
Anaerobically Digested	2.5-5.0	50	5-9	90-98	2.2-6.7

6.6.1.5 Thickening Centrifuge

A centrifuge uses centrifugal force on the sludge particles to increase the rate of separation. Lighter particles are discharged with the centrate. Heavier particles pass to a thickening zone of the machine and are discharged as thick slurry.

Centrifugal thickening is analogous to gravity thickening except that centrifuges can apply a force 500 to 3000 times that of gravity. The centrifugal force causes suspended solids particles to migrate through the liquid toward or away from the centrifuge's rotation axis, depending on the difference between the liquid's and solids' densities. The increased settling velocity and short particle-settling distance accounts for a centrifuge's comparatively high capacity. Centrifuges have been used to thicken waste solids since the early 1920s, with solid-bowl conveyor centrifuges being the most widely used in this application. Variables affecting centrifuge thickening are grouped into three basic categories: performance, process, and design. Performance is measured by the thickened solids concentration, polymer and power consumption, and the suspended solids recovery in the centrate. The recovery is calculated from the thickened dry solids as a percentage of feed dry solids. Process variables that affect thickening include feed flowrate, the centrifuge's rotational speed, differential speed of the conveyor relative to the bowl, pond depth, chemical use, and the physicochemical properties of the liquid and suspended solids (e.g., solids concentration, variability in feed solids concentration, particle size and shape, particle density, temperature, and liquid viscosity). These variables are the tools that STP operators have to optimize centrifuge performance. Centrifuges operate best with a consistent feed sludge quality. Centrifuge operation is often automatically controlled. The solids capture and centrate quality is improved considerably when the feed sludge is conditioned with polymers.

A significant advantage of centrifuges is that the units are completely enclosed. As a result there are minimal odour problems associated with centrifuges. The footprint area required for centrifuge installation is relatively small.

Polymer dosages for thickening waste-activated sludge range from 0 to 4 kg per tonne of dry solids.

Table 6-28 - Design criteria for Thickening Centrifuge

Type of Sludge	Unthickened Solid Concentration (%)	Thickened Solid Concentration (%)	Capture Rate (%)	Polymer dosage (kg/DT)
Primary Sludge	3-6	4-8	90-98	0-4
Waste Activated	0.5-1.0	4-8	90-95	0-4
Primary + Waste Activated	2.0-4.0	4-8	90-95	0-4

6.6.2 Sludge Stabilization

Sludge stabilization is used to reduce pathogens, eliminate odours and to inhibit/reduce/eliminate the potential for putrefaction. Anaerobic digestion and aerobic digestion are used for sludge stabilization. Anaerobic sludge digestion with biogas production is most commonly used at large sewage treatment plants. Its design criteria are discussed in the following sections.

6.6.2.1 Anaerobic Digestion

Anaerobic digestion involves decomposition of organic matter and inorganic matter (principally sulphate) in the absence of air. Anaerobic digestion can be accomplished over a range of temperatures:

- Psychrophilic (15-20°C)
- Mesophilic (30-37°C)
- Thermophilic (55-60°C)

Psychrophilic digestion is not relevant to Dubai because ambient wastewater temperatures are too high. Mesophilic digestion is by far the most common form of anaerobic digestion and will be considered in detail in the following sections. Thermophilic digestion is feasible but there are relatively few full-scale plants in operation.

Mesophilic Anaerobic Digestion (MAD)

In mesophilic anaerobic digestion (MAD) organic matter in the sludge is decomposed in the absence of molecular oxygen.

The biochemical conversion may be considered a two-stage process with the production of volatile fatty acids as intermediates followed by the conversion of these fatty acids to methane and carbon dioxide (by methanogenic bacteria). Ammonia is also produced through the conversion of proteinaceous matter and small quantities of hydrogen sulphide and other gases are also formed.

Anaerobic digester failure can result from a sudden increase in organic loading, a sharp decrease in digestive sludge volume, an increase or decrease in temperature or the presence of an inhibitory substance.

Applicability of MAD

Although it is possible to digest SAS or humus sludge on their own, secondary sludges are less amenable to digestion than primary sludge. This is mainly because they contain more water and a low proportion of fermentable matter per unit mass of total organic matter. The proportion of organic and volatile matter in SAS which is destroyed by digestion is about 30% compared with about 50% for primary sludge.

Mode of Operation MAD

Standard-rate digestion

In the standard-rate digestion process the contents of the digester are usually unheated and unmixed. The contents of the digester are stratified enabling supernatant to be drawn off from outlets near the top and digested sludge to be drawn off from the bottom.

As a result of stratification and the lack of intimate mixing not more than 50% of a standard rate single-stage digester is used. Detention times for the standard-rate process vary from 30-60 days.

High-rate digestion

High-rate anaerobic digestion is characterised by supplementary heating and mixing uniform feed rates and sludge thickening (to about 6%ds) before digestion. Thickening the feed sludge to 6%ds may cause foaming in the digesters.

The effects of inhibitory materials on microbial activity are minimised by the completely mixed regime. Mixing also prevents surface scum layer format on and the deposition of suspended matter on the bottom of the digester.

The required retention time for the high-rate process is typically no more than 15 days.

Two stage digestion

A variation of the high-rate digester is the two-stage digester. This uses a completely mixed and heated primary digester (high-rate) followed by an unheated and unmixed secondary digester (standard-rate).

The main function of the secondary stage is to separate the digested solids from the supernatant liquor. However, some additional digest on and gas production will occur.

Although primary and secondary digester tanks are often constructed identically the second digester may be an open tank or a sludge lagoon.

Secondary digestion should provide a minimum retention time of 14 days to ensure good pathogen kill is achieved. Open tanks are often used to allow the digested sludge to cool. Some additional anaerobic digestion will occur in the secondary digester tanks and the use of open tanks allows the resulting gas to be released to atmosphere.

Process Design Criteria

The information given in the following sections are based on single-stage high-rate digesters.

Table 6-29 - Mesophilic High Rate Complete Mix Anaerobic Digester Design Criteria

Parameter	Type of Sludge	Units	Design	Comments
Volume Criteria				
	Primary Sludge	m^3/capita	0.03-0.06	
	Primary Sludge + Activated Sludge	m^3/capita	0.07-0.11	
Solid Loading Rate		Kg/m^3.d	1.6-4.8	
Solid Retention Time		d	15-20	

Table 6-30 – Anaerobic Digester Unit Design Criteria – Solids Retention Time

Operating Temperature (°C)	SRT (minimum) (d)	SRT (design) (d)	Comments
18	11	28	
24	8	20	
30	6	14	
35	4	10	
40	4	10	

Table 6-31 – Mesophilic High-Rate Complete Mix Anaerobic Digester Design Criteria - Estimated Volatile Solids Destruction

Digestion Time (d)	Volatile Solids Destruction (%)	Comments
30	65.5	
20	60.0	
15	56.0	

Mixing Requirements

Mixing is used to promote intimate contact of raw and digested sludges and to maintain a uniform temperature and solids mixture throughout the digester. Mixing discourages grit settlement, and the formation of scum layers and also helps to release gas from sludge in the lower regions of the digester. Inadequate mixing can lead to stratification within the digester and can result in incompletely digested sludge being withdrawn.

In gas recirculation systems digester gas is compressed and released in sequence through a series of open pipes either installed in the digester base or through the roof. One of the main advantages of this system is that there are no moving parts inside the digestion tank and therefore there is no requirement for access to undertake routine maintenance or repair. With appropriate roof fittings, lances may be removed for inspection without affecting the gas integrity.

Gas mixing systems may be sized based on using a gas flow rate per unit area of about 100 m^3/m^2h.
Mechanical mixing systems normally consist of a series of large diameter impellers mounted on a single shaft and driven by a motor and gearbox assembly at speeds of 10100 rpm. The impellers operate with in a central draught tube. The requirements for maintenance and repair of mixers are more.

Table 6-32 - Anaerobic Digester Unit Design Criteria - Mixing System

Parameter	Type of Mixing	Unit	Design	Comments
Unit Power	Mechanical mixing	KW/m^3 of digester volume	0.005-0.008	
Unit Gas Flow	Gas Mixing			
	Unconfined	m^3/m^3.min	0.0045-0.005	
	Confined	m^3/m^3.min	0.005-0.007	
Velocity Gradient G	All	s^{-1}	50-80	
Turnover time of tank contents	Confined gas mixing and mechanical systems	min	20-30	

Digester Heating

Digester heating is accomplished by circulating sludge and hot water through heat exchangers. These may be coils inside the digester where sludge is circulated up by gas lifts or external heat exchangers where the sludge is circulated by pumps.

Sludge circulation and water temperature must be maintained and controlled as overheating can cause the sludge to bake onto the heating surface reducing the efficiency of the heat exchanger.
Internal coil heat exchangers are preferred with suitable access for cleaning.

Sludge temperature is usually controlled by varying the flow rate through the heat exchanger with the remainder by-passing it before returning to the digester.

Gas Production, Collection and Storage

Biogas is produced in anaerobic sludge digestion. Gas typically contains of 65% methane, 30% carbon dioxide, 4% nitrogen, 0.5% hydrogen and 0.5% hydrogen sulphide gas.

Typical values of gas produced vary from 0.75 to 1.12 m^3/kg of volatile solids destroyed.
Gas is collected under the cover of the digester. Three types of covers are used – floating, fixed and membrane.

With floating roof digesters, the evolved gas collects under the gas bell where it is stored until utilised. On fixed roof digesters the gas is collected though a gas port in the roof dome and piped to a separate gas holder. Gas pipework should be fitted with strainers condensate traps and flame traps.

Where dual fuel engines are installed and the production of power is reasonably uniform throughout a period of 24 hrs, a storage capacity of 4 - 6 hours is usually sufficient. Where dual fuel engines operate on a widely fluctuating power load a storage capacity of at least 10 hrs should be provided.

Gas Utilisation

- Gas produced by digesters (biogas) is wet and high in hydrogen sulphide. Typical concentration of H_2S in the biogas in the Middle East can exceed 20,000 ppm and must be considered in the design of the systems. Fine particles of sludge may also be carried in the gas stream.
- Wet hydrogen sulphide is extremely corrosive particularly to copper. Boilers engines and other equipment should be designed to have no copper in contact with the gas.
- Before use, biogas should be treated to remove as much hydrogen sulphide as possible.
- Boilers burn biogas to directly heat water for indirectly heating digesters.
- On larger sites where gas production is consistent and reliable, combined heat and power (CHP) units which comprise a gas engine driven generator may be used to produce electricity for use on site. The engine cooling system produces hot water which is normally used for digester or building heating. If heating is not required the waste engine heat must be dissipated in an air blast cooler. The agreement of DEWA must be obtained if the generator is to operate in parallel with the mains supply.

- Dual fuel engines can run on biogas and another fuel (diesel or natural gas). They tend to be much larger than CHP units and their primary purpose is to generate electricity although waste heat from the cooling water and exhaust is often extracted to increase the overall efficiency.

Gas Filtration

The designer shall include a gas filtration system in his design to reduce particles above 5 micron as well as levels of hydrogen sulphide or siloxanes from the biogas and render it more suitable for use as fuel. Typical filters are Gravel Filters followed by Ceramic Filters, Bio scrubbers or washers and activated carbon filters. The designer shall ensure that any sludge or liquid discharge returned to the STP contains only insoluble S.

6.6.3 Sludge Dewatering

- Sludge dewatering is to reduce the moisture content of the sludge. The dewatered sludge has less volume and easier to handle during disposal.
- The dewatering processes that are commonly used include centrifuges, screw & volute presses, belt filter presses, recessed –plate filter presses, drying beds and lagoons.
- Centrifuges, Screw and Volute presses, Belt filter presses and Plate Filters are commonly used at large sewage treatment plants. Their design criteria are discussed in the following sections
- Consideration should be given to providing the required capacity with at least two machines providing further safeguards against extended breakdowns or maintenance.
- Dewatering equipment should operate as automatically as possible and the whole sludge treatment facility from sludge storage to liquor return including cake disposal should be designed to operate continuously to minimise interruptions to the operation.

6.6.3.1 Centrifuge

- Centrifuges operate by pumping sludge into a horizontal rapidly spinning tapered drum.
- Centrifugal force settles the sludge on the outside of the drum where a spiral scroll moves the sludge up the taper to where it is discharged. The liquor moves in the opposite direct on and discharges over a weir.
- Continuous process.
- Can dewater MAD sludge up to 30% dry solids.
- Can be enclosed to contain odours but makes maintenance more difficult.

- Wear parts expensive to renew.
- The most suitable flocculent and dose rate for a particular sludge and installation will usually be determined by site tests.

Table 6-33 - Design criteria for Dewatering Centrifuge

Type of Sludge	Dry Feed Solid (%)	Solid Loading Rate (l/s)	Solid Loading Rate (Kg/h)	Capture Rate (%)	Polymer (g/kg dry solids)	Cake Solids (%)
Raw Primary	3-7	1.8-3.2	360-550	95+	1-4	26-32
Waste Activated Sludge (WAS)	1-4	0.7-2.5	45-180	95+	3-10	12-20
Primary +WAS	3-6	1.3-3.2	180-320	95+	2-8	20-28
Anaerobically digested:						
Primary	3-7	1.3-3.2	360-550	95+	2-5	24-30
WAS	3-4	0.7-2.5	45-135	95+	4-10	12-20
Anaerobically digested primary/secondary sludge	3-6	1.3-3.2	180-320	95+	3-8	20-25
Aerobically digested:						
Primary + WAS thickened	4-8	0.7-3.2	135-225	95+	2-8	12-25
Oxygen-Activated WAS	1-3	0.7-2.5	90-180	95+	4-10	15-23

6.6.3.2 Screw and Volute Presses

There are presently two major types of screw presses used in municipal dewatering applications: horizontal and inclined. Inclined screw presses are at angles 10° to 20° from the horizontal. Other areas of difference pertain to solids inlet configuration, screen basket design (perforated plate or wedge wire), basket cleaning from the inside and outside (brushes and rotating wash system), and filtrate water collection. One manufacturer also provides an option in which lime and heat are added to the screw press, which then both dewaters solids and reduces pathogens to produce biosolids that potentially meet the Class A standards in 40 CFR 503.

The major elements of a screw press dewatering system are a solids feed pump, polymer makeup and feed system, polymer injection and mixing device (injection ring and mixing valve), flocculation vessel with mixer (if applicable), solids inlet headbox or pipe, screw drive mechanism, shafted screw enclosed within a screen, rectangular or circular cross-section enclosure compartment, and outlet for dewatered cake. Some horizontal screw press systems (e.g., the combined dewatering and pasteurization process) include a thickening unit before the screw press, which may be desirable for reducing the hydraulic load to the screw press, given certain feed solids characteristics in conventional applications.

Table 6-34 - Design criteria for Screw Presses

Type of Sludge	Dry Feed Solid (%)	Capture Rate (%)	Polymer (g/kg dry solids)	Cake Solids (%)
Raw Primary	3-7	90+	4-10	30-40
Waste Activated Sludge (WAS)	1-4	88-95	8.5-11	25-35
Primary +WAS	3-6	90+	5-10	20-28
Anaerobically digested:				
Primary	3-7	90+	10-17.5	22-28
WAS	3-4	88-95	8.5-17.5	15-25
Primary +WAS	3-6	90+	10-17.5	17-25
Aerobically digested WAS	1-3	88-95	8.5-17.5	15-20

6.6.3.3 Belt Filter Press

Belt presses operate by pumping sludge between two continuous filter belts which pass over and between a series of rollers which progressively increase the pressure, discharging cake at the end where the two belts separate.

- Continuous process.

- Difficult to press MAD sludge to greater than 25% dry solids.
- Prone to belt failure and misalignment.
- Lots of moving parts high maintenance requirement.
- Can be enclosed to contain odours but makes maintenance more difficult.
- The most suitable flocculants and dose rate for a particular sludge and installation will usually be determined by site tests.

Process Design Criteria

Table 6-35 – Belt Filter Press Design Criteria – Solids Loading Rate

Type of Sludge	Dry Feed Solid (%)	Solid Loading Rate per m of belt width (l/s)	Solid Loading Rate per m of belt width (Kg/h)	Polymer (g/kg dry solids)	Cake Solids (%)
Raw Primary	3-7	1.8-3.2	360-550	1-4	26-32
Waste Activated Sludge (WAS)	1-4	0.7-2.5	45-180	3-10	12-20
Primary +WAS	3-6	1.3-3.2	180-320	2-8	20-28
Anaerobically digested:					
Primary	3-7	1.3-3.2	360-550	2-5	24-30
WAS	3-4	0.7-2.5	45-135	4-10	12-20
Primary +WAS	3-6	1.3-3.2	180-320	3-8	20-25
Aerobically digested:					
Primary + WAS thickened	4-8	0.7-3.2	135-225	2-8	12-25
Oxygen-Activated WAS	1-3	0.7-2.5	90-180	4-10	15-23

6.6.3.4 Plate Filter Press

Plate presses operate by pumping sludge into a void between rectangular plates where a filter cloth retains the sludge solids allowing the liquor to drain away. When the void has been filled with sludge cake the plates are separated and the cake discharged.

- Batch process.
- Pressing cycle can vary from hours to days.
- Can press MAD sludge to greater than 30% dry solids.
- Robust process with minimal maintenance requirements.
- Difficult to contain odours during cake discharge.
- Require a lot of operator effort.
- The most suitable flocculent and dose rate for a particular sludge and installation will usually be determined by site tests.

6.6.4 Thermal/Heat Drying

Thermal drying produces a material much reduced in volume which is easily handled and can be used as a soil conditioner or as a fuel. Dried sludge is usually pasteurised (depending on the drying temperature), odourless and can be stored for some months without becoming unstable.

The sludge fed to a dryer should have been dewatered to a cake with a solids content of 20- 25%ds. Dried sludge will contain about 85-95%ds but it is more voluminous and has a lower bulk packing density (approximately 70%).

6.6.4.1 Indirect Dryers

Indirect drying involves the transfer of heat from the heating medium (steam or thermal oil) through a heat transfer material (steel) to the sludge. Indirect drying is more compact and requires a smaller gas treatment system than direct drying systems. The main inefficiencies of the system are associated with steam generation (or heating of thermal oil).

6.6.4.2 Paddle dryers

Paddle dryers have been used in industrial applications for many decades but were first applied to drying biosolids in Japan in the late 1980s. Paddle dryers consist of a stationary horizontal vessel (trough) and a series of agitators (paddles) mounted on a rotating shaft (rotor). In some systems, the trough has a jacketed shell through which a heat-transfer medium (typically hot oil or steam) circulates. The system has hollow rotor and agitators, through which the heat-transfer medium circulates. The surfaces of the trough, agitators, and rotors conduct heat to the biosolids. Dewatered biosolids typically are fed directly to the dryer by a positive-displacement pump or screw conveyor. (In these systems, feed solids typically are not mixed with recycled granules before treatment.) Granules exiting the dryer are irregularly shaped and vary in size because the agitation associated with paddles or disks can increase the concentration of fines in the product. Screens or conditioners can be used to produce a more uniformly sized product. Rotor and agitator assemblies are fabricated of carbon steel, stainless steel, or a combination of both. They also can be made of various special alloys if highly corrosive elements are present. The agitators are arranged on the shaft to intermesh, which enhances the relative contact between heated surfaces and solids, thereby increasing the heat-transfer coefficient. They also are self-cleaning. In other systems, stationary agitator ploughs or breaker bars are placed between rotating agitators to improve mixing and prevent cake buildup on the agitator surface. The temperature of the heat-transfer medium ranges from about 150°C to 205°C (300°F to 400°F). After transferring its available energy to solids, the heat-transfer medium typically is recirculated through the heating system. A high-pressure condensate return system can be used for steam to reduce energy consumption. The water vapor concentration in the vessel creates an inert environment, but enough gas (air) is drawn through the dryer to remove evaporated water so it does not condense in the system. Instead, it is exhausted from the dryer and conveyed to a condenser. Non-condensable gases then can be routed to the odor-control system.

Table 6-36 - Design criteria for Paddle-type dryers

Parameter	Unit	Value	Remarks
Dried product's solids	%	92	Class A biosolids
Dried product's bulk density	kg/m^3	7.29	
Heat energy consumption	MJ/kg H_2O	3.72	TBC with manufacturer
Power consumption	kW/dryer capacity in MT H_2O/h	85	TBC with manufacturer
Storage capacity	days	10	TBC as per design

6.6.4.3 Solar Dryers

Solar dryers represent a technology that has evolved from a somewhat emerging one to a more established technology over the past decade. In the 1990s, German researchers developed systems based on radiant (solar) energy and convective (air) drying theory that could produce solids containing no more than 10% moisture. Solar dryers typically consist of a concrete pad with low walls that is surmounted by a greenhouse-type structure. Unthickened, thickened, or dewatered solids are trucked or pumped onto the pad. A program monitors climatic variables (e.g., humidity and temperature) both inside and outside the structure and adjusts fans and louvers to provide enough ventilation for drying. An electrically powered, mobile mixer tills the solids to expose more surface for evaporation. Some tiller designs include the ability to convey granules to either end of the structure to facilitate product removal or automatic transport to the next process, to storage or to hauling vehicles. Solids may be spread in a relatively thin layer or arranged into windrows.

Stabilisation

Dried digested sludge can be considered to be completely stabilised. Dried undigested sludge can only be considered stabilised if it remains dry as once wet, it will emit an objectionable odour and provide conditions for pathogen regrowth.

Condensate

The volume of condensate is directly proportional to the loss of moisture from the sludge. Assuming that all the evaporated water is condensed and collected for sludge dried from 25%ds to 95%ds, the quantity of condensate would be 2.9 kg / kg ds.

The condensate contains BOD, volatile acids and ammonia but very few solids. Typical concentrations of BOD, COD and ammoniacal nitrogen are 250, 1000 and 250 mg/l respectively.

Condensate can be very odorous, and care must be taken to ensure that the condensate is returned to an aerobic environment to minimise odour release.

7. ODOUR CONTROL

The control of odours is a major consideration in the design and operation of wastewater collection, treatment and disposal facilities, especially with respect to the public acceptance of these facilities. In wastewater treatment facilities, consideration shall be given to the liquid and solids processing facilities separately. The headworks and preliminary treatment operations have the highest potential for release of odour, especially in the case of long collection systems where anaerobic conditions can be created. Sludge handling area is another significant source of odour. To address these issues, odour control systems have become an integral part of any wastewater treatment facility.

It is mandatory to include an odour control system for all STP's in the Dubai Emirate. To ensure adequate odour control system performance, all of the pre-treatment works including the coarse screens, fine screens, grit removal chambers, etc. must be covered with closed fitting removable GRP or other type of covers which will be resistant to heavy corrosion.

7.1 Inlet Pollutant Concentrations and Load to the Odour Control System

The inlet pollutant concentrations are a key to the selection and design of the odour control system. The major odour pollutants generated from the pumping stations and the sewage treatment plants can be listed as hydrogen sulphide (H_2S), mercaptans (R-SH), dimethyl sulphide (DMS), and volatile organic compounds (VOCs). Design inlet loads are provided in Table 7-1 for guidance only. The designer shall provide estimates based on actual site measurements unless otherwise instructed by DM.

Table 7-1 - Design Inlet Loads for Odour Control System

	Average (ppm)	Peak (ppm)
H_2S*	1000	2500
Mercaptans, R-SH	2	5
Ammonia, NH_3	1	4
Dimethyl sulphide, DMS	1	4
VOC	20	40

*Based on JASTP Phase 2 design

Once the design pollutant concentrations at the source are known then a mass balance shall be carried out to derive the resultant pollutant concentrations in the feed to the odour control system.

General Design Considerations for Odour Control Systems

The following key considerations shall be given to the odour control systems:

- The odour control system must be designed, operated, maintained, and managed under Good Industry Practice.
- Minimum air changes for various components shall be as below:

Table 7-2 - Minimum Air Changes for various components

Units	Minimum ACPH
Non-worker accessible spaces	4-6
Worker accessible spaces	12
All screening works, interconnecting channels and tanks	12
Air blowing tanks	Minimum 15-20% more than the air blown into the tanks (i.e., Process air x 1.15-1.2)

Please note aside from the above requirements the designer shall consider OSHA and NFPA 820 requirements and shall always apply the more stringent requirements in the design.

- Odour control system shall be designed with extraction fans at the downstream of the system to ensure the system operates under negative pressure.
- The discharge of treated air must be at least 6 m above the ground, minimum 3 m above the roof line of any adjacent building (i.e., any building within a 12 m radius of the stack) and not less than what the odor dispersion modelling suggests.
- All components of the odour control system must be compatible with the conditions and chemicals to which they will be subjected to during normal operation. Compounds with which the materials of construction must be compatible with are hydrogen sulphide, sulphuric acid, ammonia, dimethyl sulphide, mercaptans, and any other corrosive gases that may be present.

- Odour control system must provide redundancy in its design concept to eliminate any possibility of odorous discharge. This may be achieved by redundancy of equipment of the same kind or by a combination of odour control technologies.
- The stack must be sized tall enough (not less than 3 meter taller than the nearest interfering structure) to disperse the discharge with a minimum discharge velocity of 15 m/s.
- All odour control system shall have a polishing stage which is typically an activated carbon filter. In this regard, an Activated Carbon filter should not be used as the main treatment except for small STP's and subject to approval by DM SRPD.

7.1.1 Performance Requirements

The odour control system shall be designed to comply with the following performance requirements. DM reserves the right to impose more stringent requirements if it deems necessary, e.g., when the STP is installed in a critical location with sensitive receptors:

- Prevent odour complaints from the public by reducing concentrations of hydrogen sulphide, mercaptans, other sulphur-containing compounds and Volatile Organic Carbons (VOCs) such that those from the site are undetectable at the site boundaries.
- The odour level shall not exceed 5 OU/m^3 at 100%ile on 1 hourly average basis measured at the site boundary based on BS EN 13725:2003.
- Minimum overall H_2S removal efficiency shall be 99.9% or an outlet concentration of 5 ppb. During commissioning, it must be demonstrated that the testing equipment is capable of measuring low H_2S levels to verify compliance with this requirement.
- The discharge of odorous air at the odour control system stack under no circumstances can exceed 0.1 ppm of H_2S for more than one day. The odour control system design must stipulate for sufficient redundancy and robustness to guarantee this level of performance under all circumstances.
- The discharge of H_2S at the odour control system stack must remain below 0.05 ppm under normal operating condition at expected peak loads.

7.2 Technologies for Odor Control System

Numerous technologies are available for odour mitigation. However, considering their availability, cost effectiveness, successful track record in the given operating conditions and DM's experience on operation and maintenance, the following technologies are recommended for odour mitigation of odour:

- Wet chemical scrubber utilizing sodium hydroxide and sodium hypochlorite as the scrubbing liquor for removal of odorous compounds and neutralizing the scrubbing solutions salts to a stable condition. The chemical scrubber may be followed by an Activated Carbon (AC) filter as a polishing stage to remove the remaining VOCs.
- Bio-scrubbers and Activated Carbon filter. The biological system must remove the bulk of odorous compounds followed by a polishing AC system.
- Bio filters or bio trickling filters. These are reliable and proven technologies that have been used in many plants. The operating cost of these systems are low as they do not require any chemicals, however it cannot handle high and variable H_2S loads. Bio filters require a large footprint. Bio-trickling filters are more similar with Bio-scrubbers.
- Activated Carbon filter. This can be considered the best available technology for odour control as it can treat almost any type of odour but especially H_2S and VOC's. However, installing activated carbon filters only for large STP's can be quite costly because the carbon will need frequent replacement or replenishment. Hence, AC filters are best used as a polishing stage (to deal with residual odours after the main treatment) or for small STP's with much lower odour loads.

7.2.1 Acceptable Odour control system technologies relative to plant size

- Small plants – Activated carbon filter is acceptable unless higher odour loads require the use of other technologies. In this case, the AC filter maybe used as a polishing stage.
- Medium plants – Both bio-trickling filters and Chemical scrubbers are acceptable but chemical scrubbers must always include an activated carbon filter as a polishing stage. Activated carbon filter is not acceptable as the main odour control treatment technology.
- Large plants – Due to DM's experience with JASTP/2, the preferred technology for odour control system is the bio-trickling filter.

By default, an activated carbon filter polishing stage is mandatory (except for small plants where it is the main treatment system) unless otherwise approved by DM SRPD.

7.2.2 Wet chemical Scrubbers

The chemical scrubbers shall utilize a scrubbing solution containing sodium hydroxide and sodium hypochlorite to form a stable salt solution. The solution pH and ORP shall be monitored to control the desired levels of the chemicals in the solution. The required chemical concentrations shall be maintained by means of chemical metering pumps provided with the system. The scrubber system shall provide an automatic system of discharging the required level of the spent scrubbing solution and adding fresh soft water into the scrubber sump. This should be done by monitoring the conductivity of the scrubbing solution and via automatic valves. Continuous bleeding of the scrubbing solution or timer-based controls are not acceptable.

The chemical scrubbers shall be of counter current design with the gas moving upward and the scrubbing liquor flowing downward. Low pressure drop high mass transfer efficiency plastic random pacing must be utilized with a maximum pressure drop of 0.15 inches of water column (w.c.) per foot of packing. The maximum pressure drop through each tower must not exceed 2.5 inches of w.c.

The liquid spraying system must minimize the number of spray nozzles. For towers smaller than 2 meter in diameter a single header with a single spray nozzle must be used. The use of weir distributors is not permitted. The liquid spraying rate over the bed must not be more than 2 cubic meter per hour for each 1000 actual cubic meter per hour of malodorous air to be treated.

Scrubbing towers must be equipped with a demister section that would prevent a minimum 99% of any water droplets larger than 10 micron passing through. The pressure drop due to the mist eliminator section must not be more than 0.25 Inches of w.c. at the design gas flow rate. Parallel blade Chevron type mist eliminators or vendor’s choice meeting the specification is acceptable.

A minimum retention time of 2-5 minutes shall be provided in the chemical sump with 5 minutes as ideal retention time.

The scrubber must be equipped with corrosive resistant polyethylene or GRP duty/standby circulation pumps, and duty/standby chemical dosing pumps. Each chemical dosing pump must be optimally sized to operate at midpoint of full scale for the highest specified hydrogen sulphide concentration.

The material of construction for the scrubbers and chemical storage tanks must be suitable for the corrosive application and the environmental condition of 55°C in the shade. GRP construction is acceptable.

The circulation pumps assembly must be complete with suction and delivery isolation valves. The delivery valve must permit accurate flow regulation. Discharge pipe work must be fitted with pressure gauge, pH and ORP meter/controller and conductivity meter/controller. Valves must be provided to isolate and control water flow to all instrumentation. A flow meter must be provided on the inlet to the scrubber to permit monitoring and control of the liquid flow to the scrubber. The scrubbing process, chemical storage and chemical composition must be controlled by the PLC controller. All instrumentation including level controls must be connected to the PLC for process and automatic control. The performance of the system for hydrogen sulphide removal must be monitored by an electronic sensor with direct readout in ppm. The following must be included in the chemical scrubbing package as a minimum:

- Duty/Standby air extraction fans and associated ductwork.
- Chemical scrubbing tower and ductwork.
- Discharge stack.
- Chemical storage tanks for at least two weeks supply of each chemical.
- Duty/Standby chemical dosing pumps.
- Water softening units.
- Duty/standby recirculation pumps.
- Instrumentation, valves, pipe work and controls to complete the system.
- Motor control centre with PLC controls.

7.2.3 Activated Carbon

Carbon adsorption system may be utilized as a polishing stage to the chemical or bio scrubbers. Activated carbon is utilised to remove residual sulphur based compounds or any other non-soluble VOCs. The performance of the carbon adsorption system as a standalone unit must meet the minimum requirement of the specification namely 0.1 ppm of H_2S concentration if the pre-stage chemical or bio-scrubbers for any reason are by-passed. The carbon must be a virgin, granular activated carbon derived from bituminous coal suitable for the vapour phase adsorption and catalytic oxidation of odour causing substances. The carbon must be suitable for regeneration of its adsorptive capacity by washing with water with no other chemical added or required. No more than one regeneration per six months shall be permitted. Carbon must have a minimum operative capacity of 3 years. A system of continuous monitoring of smell in the stream of air leaving the odour control facility must indicate the required regeneration of the carbon unit. The carbon must be of acceptable quality standards in industry and have equal or similar properties shown in
Table 7-3 below:

Table 7-3 - Acceptable Specification for Activated Carbon

Properties	Limits
Apparent density (kg/cum)	>560
Mesh size (U.S. sieve) greater than 4 mesh	<15%
less than 7 mesh	<8%
Hardness number (min.)	>97
Moisture (w/w max.)	2% max.
Minimum H_2S saturation capacity	0.16 g H_2S removed /1 g carbon
H_2S breakthrough capacity	>0.09
Ash (%w)	<8
Iodine Number (mg/g)	>800
Butane Activity (%w)	>16

The carbon shall be water regenerable. Chemically impregnated carbon is not acceptable.

Adsorber vessels with single or double activated carbon bed must be designed to prevent bed fluidization. The minimum contact time for the foul air passing through the carbon bed is 2.5 seconds (empty bed contact time, EBCT). The units must be complete with bed(s) supports, nozzles, piping, valves, instrumentation and controls. The design must provide 33% stand-by capacity to be used when any of the duty vessels undergo regeneration.

7.2.4 Bioscrubbers

The bio-scrubber treatment stage contains biologically active synthetic media layers. The structured synthetic media is to facilitate the growth of bacteria necessary for biological oxidation of odorous compounds. The media must be a dual-density structured media made entirely of a synthetic, non-reactive material. Organic and/or non-synthetic inorganic media materials or any random-packed media shall not be allowed. The media is to facilitate efficient mass transfer of odour compounds and growth of bacteria used to oxidize odour compounds. Media must be designed to be compatible with all process contaminants and their by-products and must be suitable for use at pH levels as low as 1.0.

The bio-scrubber design must utilize an intermittent irrigation system consisting of a single spray nozzle per media layer to maintain a wetted surface on the media and provide chemical nutrients to the bacteria on the media. The system must be designed to allow the formation of a pH gradient within the media bed, to allow the growth of autotrophic bacteria for hydrogen sulphide oxidation, and heterotrophic bacteria for the oxidation of other Reduced Sulphur Compounds (RSCs). The reactor(s) must be configured with one fluid injection spray nozzle for each treatment layer. The spray nozzle must be located above the treatment layer and must disperse the fluid evenly over the entire treatment layer. Systems using multiple spray nozzles and/or a spray header will not be acceptable.

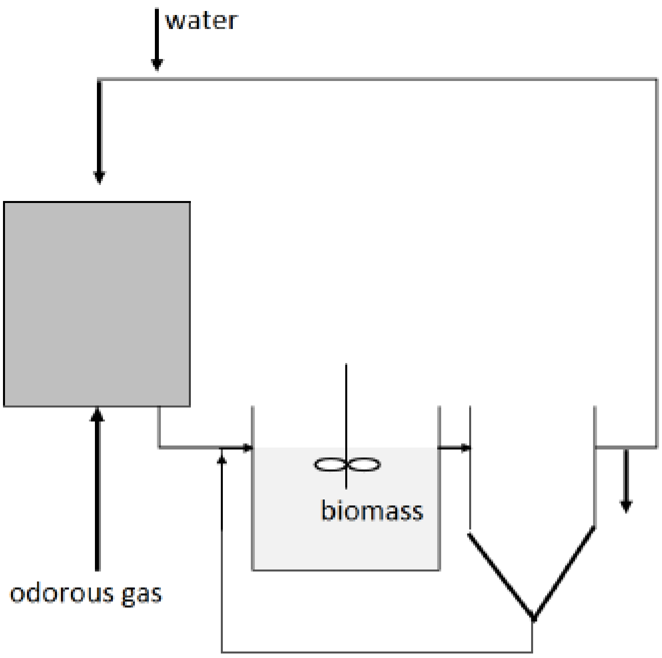

Figure 7-1 – Typical configuration of Bioscrubbers (*from WEF MOP25*)

7.2.5 Bio-trickling Filters

Bio-trickling filters shall operate in a counter-current fashion. Co-current system is not allowed. Foul air enters at the bottom of the reactor and flow upward through each of the media layers. The media bed shall be intermittently irrigated from above using suitable reclaimed plant effluent or potable water in a once through fashion. If potable water is used, essential nutrients such as Nitrogen and Phosphorous must be dosed into the irrigation water. The water then trickles through the media and is collected in a sump at the bottom of the reactor. The drain water from the system shall pass from the sump at the bottom of the reactor vessel and shall be piped to the discharge point. The system shall have the ability and features incorporated into the equipment to operate either as a single pass or as a recirculating system.

The structured media in a bio-trickling filter shall have high porosity, chemically resistant, engineered, synthetic porous material made from polyvinyl chloride or polyethylene or polyurethane. Organic media, carbon derived lava rock or lava rock media and/or random synthetic or non-synthetic inorganic media materials are not acceptable. or are usually made of some synthetic or inert material such as plastic rings. Operating conditions to be considered in the design of the biotrickling filters are provided in Table 7-4. whilst Table 7-6 indicates the design criteria for both Bioscrubbers and Bio-trickling Filters .

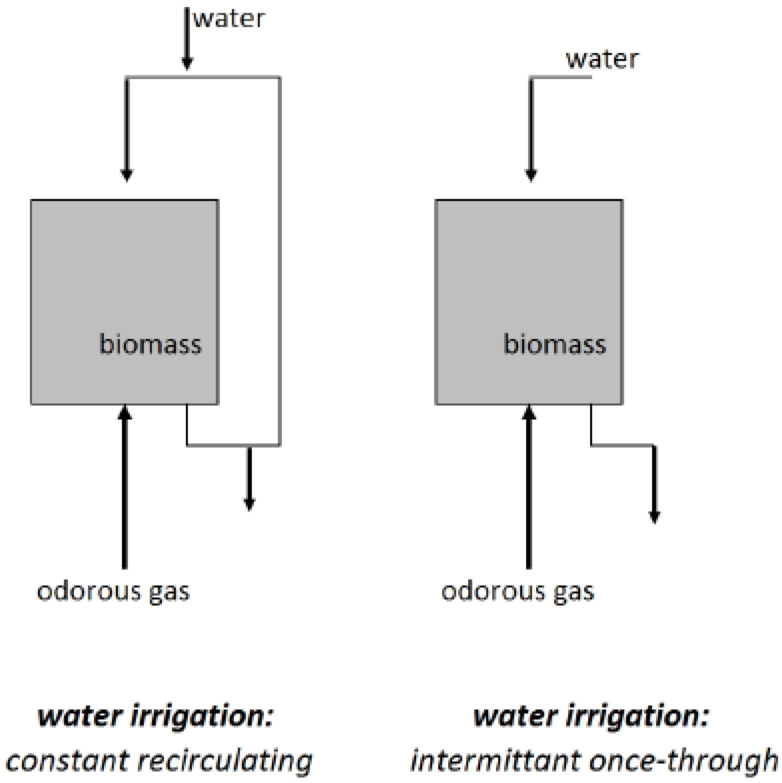

Figure 7-2 – Typical configurations of Bio-trickling filters (*from WEF MOP25*)

Table 7-5 - Operating conditions for Bio-trickling filters

Operating conditions	
Duty	Continuous air supply and odour source
Location	Outdoors
Inlet air temperature	55 to 100°F
Inlet relative humidity	60% to 100%
Contaminants	Hydrogen sulphide, Organic RSC's, Ammonia, Methyl mercaptans. Sulfuric acid generation is produced by the degradation of H_2S, hence, should be considered.

Table 7-6 - Design criteria for Bioscrubbers & Bio-trickling Filters

Design Criteria	
Pressure drop	500 - 1000Pa
Gas loading rate	1500 m^3/h per m^2 of media
Media height	5 - 6m
Average pollutant load	100 g/m^3 of media/h
Empty bed contact time (EBCT)	10 – 15s

8. PUMPS & PUMPING REQUIREMENTS

Generally, the designer shall design the plant's hydraulics with the aim of minimizing pumping requirements. However, it is understood that pumping cannot be completely avoided.

Pumps shall be selected according to the characteristics of the fluid within the stage of the treatment and the performance of the pump (head & capacity) shall be match with the system curve to ensure healthy operation conditions.

Once the pumping capacity has been determined, the type of the pump, configuration and arrangement shall be specified according to the available space. Each pumping system shall be provided with standby, the total number of the pumps shall be selected as either 2X100%, 3X50% or 4X34% of the design pumping capacity. The system head curve shall be generated by plotting the total dynamic head which is the summation of the static head and the friction losses within the piping system including all other resistant flow through valves, devices, and fittings. The system curve shall be plotted at different boundary conditions that covers the extremities under which the pumping system will be operated such as high and low static head, new and old pipe, etc. Then, the pump (centrifugal type pumps) selection shall be based to ensure that the pump will operate within the optimum operating range (as per the manufacturer recommendations) and shall not exceed the end of the cure or operate close to the shut off conditions.
All motors shall have sufficient overloading capacity of 10% to 15% more than the rated load.

The selections shall be accompanied by:

- Pump Sump design (volume, retention time, max, min operating levels, vortex protection, etc.)
- Discharge head calculation for min/max/design flow as well as NPSH (where applicable)
- Selected Pump and Plant Curves
- Sketches and literature to explain pump selection.

Table 8.1 is provided as a general guideline for pump selection. The designer shall refer to Design Guidelines for Sewerage and Irrigation for more detailed design criteria and specifications. However, in case of conflicts, the design requirements given below for the major pumps used in STP's shall take precedence over the design criteria and specifications indicated in the Design Guidelines:

Raw sewage pumps:

- Pump type : closed coupled, separately coupled or submersible centrifugal pump.
- Pump speed: low speed
- Pump curve: gradually rising curve is preferable.

RAS Pumps

- Pump type– submersible centrifugal or screw (Archimedes) pump.
- Pump speed: low to medium speed pump – variable speed pumps.
- Pump curve – gradually rising curve to steep curve – submersible pump

MLSS Pumps

- Pump type: Axial flow propeller pump or mixed flow pump.
- Pump speed: medium speed
- Pump curve: steep pump – operating points shall be beyond the instability range.

Digester Sludge Pumps

- Pump type: Rotary positive displacement pump – lobe or screw type depend on the application.
- Pump speed: Low to medium speed – fixed speed
- Pump curve: NA

Sludge Pumps

- Pump type: Rotary positive displacement pump – lobe or screw type depend on the application.
- Pump speed: low to medium speed – fixed or variable speed depends on the application.
- Pump curve: for centrifugal pump it is preferable to be gradually rising curve to steep curve.

Recycled Water Pumps

- Pump type: horizontal split-case pump
- Pump speed: medium speed
- Pump curve: gradually rising curve to steep curve.

Chemical Dosing Pumps

- pump type : diaphragm-type or peristaltic for small flows; progressive cavity for higher flows
- Pump speed: low to medium speed – fixed or variable speed depending on the application.
- Pump curve: NA

Solids handling pumps must allow free ball passage of not more than 75mm.

Table 8-1 – Pumping Requirements in STP's and Recommended Pumps

Pumping Requirement/Service	Type of Pump
Grit	Centrifugal End Suction Recess Impeller
Grit Scum	Rotary Lobe or Screw
Primary Sludge Transfer	Rotary Lobe or Screw
Pipe Gallery Sump	centrifugal, solids Handling
Scum	Rotary Lobe or Screw
PST Tank Emptying	Centrifugal, Solids Handling
ASR Scum	Submersible, Solids Handling
Return Activated Sludge (RAS)	Centrifugal, Solids Handling
Waste Activated Sludge (WAS)	Rotary Lobe or Screw
Clean Backwash Water	Centrifugal end suction
Foul Backwash Water	Centrifugal end suction
Effluent (TSE)	Horizontal Split Case Centrifugal
Recycled Effluent (RE)	Horizontal Split Case Centrifugal
Rotary Drum Thickener (RDT) Feed	Rotary Lobe or Screw
Post Thickened Primary Sludge Digester Feed	Rotary Lobe or Screw
Thickened WAS Digester Feed	Rotary Lobe or Screw
Supernatant	Horizontal End Suction Centrifugal
Centrifuge Feed	Rotary Lobe or Screw
RDT Transfer	Rotary Lobe or Screw

Pumping Requirement/Service	Type of Pump
RDT Dosing	Rotary Lobe or Screw
Gravity Belt Thickener (GBT) Transfer	Rotary Lobe or Screw
GBT Dosing	Rotary Lobe or Screw
Centrifuge Polymer Transfer	Rotary Lobe or Screw
Centrifuge Dosing	Rotary Lobe or Screw
Raw sewage	Centrifugal, solids handling
Digester recirculation	Rotary Lobe or Screw
Internal recycle (MLSS) pump	Axial flow propeller pump or mixed flow pump

9. PIPING

Pipe material for sewer pipes shall be selected based on the following factors:

- Suitability for intended use and characteristics of foul water
- Availability of material locally
- Capital cost of selected material offset against reduction or elimination of maintenance costs
- Capital cost of installation by non-disruptive methods offset by reduction in disruption to traffic and cutting of new roads
- Ground conditions such as soil and ground water characteristics
- Environmental conditions such as high temperature, poor ventilation, high level of corrosive products and sand accumulation
- Handling, transporting and installing the materials
- External loading and abrasion conditions

Recommended velocity and material of construction (MOC) for the plant's piping requirements are provided in

Table 9-1 below.

Table 9-1 - Recommended Velocity and MOC for various Pipelines

	Pipe Velocity, m/s			Pipe MOC		Comments
WASTEWATER TREATMENT PIPELINES	Minimum	Typical	Maximum	UG	AG	
Sewage Pumping						
Suction Main	0.6	0.8	1.0	GRP	SS316	Suction ID should never be less than suction ID of pump
Delivery Main	0.8	1.2	2.0*	GRP	SS316	* no more than 2.5 m/s in PS pipework
Raw Wastewater - Preliminary to Primary Treatment	0.6		1.0*	GRP	SS316	* refer to manufacturers of inlet works equipment
Primary Treatment to Secondary Treatment	0.35		1.5	GRP	SS316	>0.75 m/s at least once per day, max value to minimise headloss

	Pipe Velocity, m/s			Pipe MOC		Comments
Secondary Treatment to Tertiary Treatment/Outfall	0.35		1.5	GRP	SS316	Check requirement for purging of outfall pipeline
Sludge Gravity Lines and Drains	0.75		1.20	GRP	SS316	max value to minimise headloss
Sludge Pumping (incl. Hydrostatic Desludging)						
Primary Sludge	0.75	1.5	2.0	GRP	SS316	minimum diameter for sludge line = 150mm
RAS	0.3		0.8	GRP	SS316	lower velocities to reduce break-up of flocs
WAS/SAS	0.6	0.8	1.2	GRP	SS316	minimum diameter for sludge line = 150mm
Process air		10	15	GRP	SS316	
Biogas				GRP	SS316	
Odorous air	10	10	15	GRP	GRP	
Chemicals				GRP	GRP/PVC	May vary on type of chemicals
Fuel				GRP	GRP	
Potable Water				HDPE	HDPE	
Hot Water					SS316	
Chilled Water				CS	CS	

AG – Above Ground pipes; UG – Underground pipes

10. ELECTRICAL & INSTRUMENTATION AND CONTROL

10.1 Electrical Systems

10.1.1 Regulations

Regulations exist that dictate minimum acceptable requirements for electrical systems. The following Local Regulations shall be followed:

- DEWA - Dubai Electricity and Water Authority
- Civil Defence Authority - Dubai
- JAFZA – Jebel Ali Free Zone Authority
- Specification and Standard
- Technical societies (ISO, IEC, BS EN and BS) publish standards and recommendations to be used as a basis for design. ISO shall take precedent over IEC, which shall take precedence over BS EN, which will take precedence over BS.

10.1.2 Drawing Requirements

Electrical system drawings should thoroughly and completely depict the work required. To accomplish the desired results, the electrical drawings should include at least the drawings listed here, as follows:

- Electrical legend and general notes.
- Site plan.
- Plant power distribution plan (can be included in site plan).
- Complete electrical one-line diagram.
- Building lighting plans.
- Building power plans.
- Equipment and installation details, as required.

10.1.3 Electric Power Sources

Two separate and independent sources of electric power shall be provided at the works. The local electric utility provider, DEWA, will be the primary source of electrical power and the second source of electrical power shall be on-site generation. As a minimum, the capacity of the backup power source shall be sufficient to operate all vital components, during peak wastewater flow conditions, together with critical lighting and ventilation.

The civil infrastructure shall be designed and constructed to house DEWA supplied equipment, in accordance with the requirements of DEWA. The designer shall enter into negotiations with DEWA and procure the provision of the mains supplies for the works.

Where the standby power consumption requirements are small enough, portable trailer mounted engine generators can be used to good advantage by serving as the standby power source for several facilities. Where this option is available, provisions for ready connection to the works switchgear should be made.

10.1.4 Uninterruptible Power Supplies (UPS)

Uninterruptible power supplies shall be considered, sized, and distributed to support a variety of supervisory process controls system (SCADA or DCS) and to maintain plant operations along with plant auxiliary system i.e. telephone system, public address system, CCTV system, access control system and network computer systems. UPSs require special provisions in location, ventilation, maintenance, and interconnection to building and other electrical power and equipment systems. The sizes and locations must be provided for upfront in the design.

10.1.5 Power Distribution within the Works

The internal power distribution system shall be designed such that no single fault or loss of a power source shall result in disruption (i.e., not momentary) of electric service to more than one motor control centre.

The electrical power distribution system within the plant should be planned and designed on the following basis:

- Plant electrical loads (peak and average demand).
- Maximum fault currents available.
- Proper protective device coordination and device-fault current withstand and interrupt ratings.
- Plant physical size and distribution of electrical loads.
- Plant power factor correction requirements.
- Location of other plant utility systems and facilities.
- Reliability requirements.
- Voltage drop limitations.
- Planned future plant expansions (if decided).

- Ability to accommodate upgrades and modifications.
- Feasibility and possible economic justification for electrical demand control system.
- Life-cycle cost of major electrical equipment.
- All applicable local and international codes and regulations, and good engineering practice.

10.1.6 Coordination

Coordination between the electrical design and drawing and specifications of other disciplines (such as mechanical and structural) must be complete and accurate. There must also be complete coordination between the electrical design and specifications. Designer should ensure that the design shall be free from the following conflicts and discrepancies.

- Specification requirements for electrical equipment characteristics such as horsepower, voltage, and number of phases differ from characteristics shown on the drawings.
- Failure to adequately define and delineate the interface between the electrical system and other systems or contracts.
- Building design doors too small to permit equipment removal.
- Inadequate ventilation for heat generated by electrical equipment.
- Interference between electrical equipment installation and the installation of other equipment or utilities.
- Service to Motor Control Centres
- Equipment Type and Location

General

Failures resulting from likely causes, such as fire or flooding shall be minimized by equipment design and location. Electric switchgear and motor control centres shall be protected from sprays or moisture from liquid processing equipment and from breaks in liquid handling piping. Where practicable, the electric equipment shall be located in a separate room from the liquid processing equipment. Liquid handling piping shall not be run through this room. The electric switchgear and motor control centres shall be located above ground.

10.1.7 Motor Protection from Moisture

All outdoor motors shall be specified to weather-proof, totally enclosed type. Motors located indoors and near liquid handling piping or equipment shall be, at least, of splash-proof design. Consideration shall be given to providing heaters in motors located outdoors or in areas where condensation may occur. Indoor motors (except submersible pump) located below finish ground level shall be housed in a room or building and a drain sump pump shall be provided to handle leakages in the area.

10.1.8 Explosion Proof Equipment

Explosion proof motors, conduit systems, switches and other electrical equipment shall be used in areas where flammable liquid, gas or dust is likely to be present. Plant hazardous area zoning shall be conducted.

10.1.9 Routing of Cabling

To avoid a common mode failure, conductors to components which perform the same function in parallel shall not be routed in the same conduit or cable tray. Conduits housing such cables shall not be routed in the same underground conduit bank unless the conduits are protected (such as by encasing the conduit bank in a protective layer of concrete).

10.1.10 Motor Protection

Three-phase motors and their starters shall be protected from electric overload and short circuits on all three phases. Large motors shall be provided with condition monitoring system (vibration and temperature detectors). In general, the motor of 50 KW and above shall be provided with temperature detectors embedded in the motor windings.

Provisions of Equipment Testing

Provisions shall be included in the design of equipment requiring periodic testing, to enable the tests to be accomplished while maintaining electric power to all vital components. This requires being able to conduct tests, such as actuating and resetting automatic transfer switches, and starting and loading emergency generating equipment.

10.1.11 Maintainability

The electric distribution system and equipment shall be designed to permit inspection and maintenance of individual items without causing a controlled diversion or causing violation of the effluent limitations.

10.1.12 Emergency Power Generator Starting

The means for starting a works-based emergency power generator shall be completely independent of the normal electric power source. Air starting systems shall have an accumulator tank(s) with a volume sufficient to furnish air for starting the generator engine a minimum of three (3) times without recharging. Batteries used for starting shall have a sufficient charge to permit starting the generator engine a minimum of three (3) times without recharging. The starting system shall be appropriately alarmed and instrumented to indicate loss of readiness (e.g., loss of charge on batteries, loss of pressure in air accumulators, etc.).

10.1.13 Lighting Systems

Lighting systems are one of the most visible parts of an electrical system design and the following aspects shall be taken into consideration:

- In general, lighting levels should be approximately as recommended in the IES standards. Inadequate or too high light levels shall be avoided.
- Standard luminaires for easy lamp replacement.
- Proper choice of light source for various occupancies.
- Lamps with long start-up times e.g., mercury vapour or similar lamps shall be avoided in areas not continuously occupied.
- Light switches shall be easily accessible and not trapped behind doors.
- Adequate emergency lighting.
- Consider colour rendition when specifying lamps.
- Luminaires to be located properly.
- Adequate light with due consideration to glare, or shadows.

10.1.14 Miscellaneous

10.1.14.1 Oil-Insulated Equipment

Transformers, switches, and other oil-insulated equipment should be designed with adequate oil retention or containment facilities.

10.1.14.2 Equipment Protection

Generally, centrifuges, fixed-platform aerators, centrifugal compressors, and similar equipment should be provided with vibration detectors. High inertia drives, such as centrifuges, which have long accelerating times, may require special motors, circuit protective devices, and overload relays.

Electrical equipment must be protected from moisture and dirt. In general, major electrical equipment such as switchboards and motor control centres should be installed in a room or space dedicated exclusively to electrical equipment.

10.1.14.3 Restart

Selection of momentary versus maintained contact switches, especially in motor control circuits, needs careful consideration if restart without operator action is desirable or required. If restart without operator action is part of the design, the effect of the total motor-starting current on main and feeder circuit protective devices should be considered.

10.1.14.4 Space Requirements

Designers should consider headroom and working space requirements around equipment to meet codes, facilitate maintenance, and permit equipment removal or replacement. Also, variations in dimensions among equipment made by different manufacturers should be considered.

10.1.14.5 Utility Outlets

The designers should ensure that sufficient power outlets of the proper type are provided in the vicinity of process equipment to permit operation of power tools for maintenance.

10.2 INSTRUMENTATION AND CONTROL SYSTEMS

10.2.1 General

10.2.1.1 Regulations

The design of the treatment facilities instrumentation, control and electrical systems shall conform to applicable codes and regulations including:

- Instrument Society of America (ISA)

- Occupational Safety and Health Act (OSHA)
- Civil Defence Authority – Dubai /Jafza
- Etisalat / DU
- Specification and Standard
- Technical societies (ISO, IEC, BS EN and BS) publish standards and recommendations to be used as a basis for design. ISO shall take precedent over IEC, which shall take precedence over BS EN, which will take precedence over BS.

10.2.1.2 Drawing Requirements

Instrument and control system drawings should thoroughly and completely depict the work. The drawings, in conjunction with the specifications, must define the type of control system, the type of components in the system, process variables, scale ranges and set points, process flow rates, and the interface between the instrumentation and control system and rest of the plant. To achieve this, the instrument and control drawings should include, as a minimum, the following drawings:

- Instrumentation and control system legend and general notes.
- Process and instrumentation diagram (P&ID).
- Process flow diagram
- Plans showing location of all instrument and control system equipment and components and signal circuits, both electrical and pneumatic.
- Equipment and installation details as required.
- Instrument and Control Systems Requirements

10.2.1.3 General

A single manufacturer should be specified whenever possible, this is to overcome the issue of compatibility of diverse components of instrument and control system and other factors such as cost, required operator skill level, and owner preference.

The degree of operating reliability of instrument and control systems in sewage plants shall be discussed and agreed with the client prior to the starting of actual design depending upon the selected treatment process.

In general, the information necessary to make control decisions should be available from two sources, a primary element and a secondary element; or by inference from one or more process monitors in different but related process areas or zones. Operator intervention/override should be provided for all automated process controls.

10.2.1.4 Design Considerations

The instrumentation and control system within the plant should be planned and designed on the following basis:

- Process operational requirements.
- Control system maintainability.
- Control system stability.
- Planned future plant or process expansion.
- Economic justification of automatic versus manual control.
- Use of standard products wherever possible.
- Need for uninterruptible power supplies to instrumentation and control system.
- Local and/or remote manual controls.
- Process or equipment “fail safe” requirements.
- All applicable local and international codes and regulations, and good engineering practice.

10.2.1.5 Coordination

- Coordination between the instrumentation and control drawings and specifications and the drawings and specifications of the other disciplines (such as electrical, mechanical, and structural) must be complete and accurate. There must also be complete and accurate coordination between the instrumentation and control system drawings and specifications. Designer should ensure that the design shall be free from the following conflicts and discrepancies.
- Equipment requiring electrical power is not coordinated with electrical drawings.
- Failure to properly coordinate between instrumentation and control equipment requirements with process design.
- Failure to properly coordinate control strategies and field instrumentation required to support the strategies.
- Specification requirements for equipment characteristics are different from characteristics shown or implied in drawings.

- Control Systems
- The DCS/SCADA system should be designed using the control system functional requirements defined in the workshops with the operational staff. Some of the key functions required for a DCS/SCADA system include:
- Redundancy of the controller hardware configurations and failover sequences of the process control software and operator interfaces.
- Global database management.
- Ability to manage the total number of I/O tags.
- Data integrity and scanning processes used to acquire data.
- Historical database management.
- Control system response time.
- Data highway topologies including redundancy and self-healing capabilities.
- The control system should be designed for future growth and expansion. The future requirements if any can usually be identified along with the mechanical plan which shows future equipment.
- The software shall provide the operator interface and data management, including trending and historical functions. The software shall have a high level of continuity between the DCS/SCADA functions and field hardware.
- DCS/SCADA system should provide historical information processing and trending. The ability to export data to other software systems shall be considered for providing the historical archiving and trending functions required by the plant.
- The control system shall be designed with smart instrumentation which shall serve both the purpose of measurement of the process and provides diagnostic information direct to plant information management system.
- The control system and the instrumentation shall be coordinated to achieve required process control.
- A detailed Process and Instrumentation diagrams (P&IDs) shall be provided for the plant as per ISA standard conventions. The instrumentation symbol identification system should follow ISA standards 5.1 and 5.3.
- An instrumentation and control system must be designed with both operational reliability and maintainability. The control system design shall be free from the following conflicts and discrepancies.
- Not specifying hazardous area zoning of the plant
- Not specifying adequate equipment enclosures for adverse, hostile, or hazardous environments.
- Not specifying isolation valves on instruments connected to process piping.

- Not specifying snubbers on pressure switches.
- Failure to provide needle valves for control of operating air or hydraulics to control valves.
- Specifying float switches in very turbulent areas without stilling tube.
- Flow meters too close to bends in process pipes.
- Installation of equipment in areas difficult or impossible to reach for maintenance.
- Failure to consider operator convenience in layout or design of control system.

10.2.1.6 List of Essential Instruments

The following provides a list of essential analytical instruments that shall be provided for STP's.

- Inlet Works
- Flowmeters on inlet line/channel
- Auto Sampler on inlet channel/line to Inlet Works
- Grit Removal
- Flowmeters on air-line to grit channel
- Flowmeters on effluent line from grit channel
- Primary Sedimentation Tank
- Flowmeters on Bypass-line of Primary Sedimentation Tank (if provided)
- Flowmeters on all sludge feed lines
- Auto sampler on outlet channel/line from Primary Sedimentation Tank
- Conductivity analyser on outlet channel/line from Primary Sedimentation Tank
- pH analyser on outlet channel/line from Primary Sedimentation Tank
- Temperature transmitter on outlet channel/line from Primary Sedimentation Tank
- Activated Sludge Reactor
- Dissolved oxygen analysers on Activated Sludge Reactor
- pH analysers on Activated Sludge Reactor
- Suspended solids analysers on Activated Sludge Reactor
- Nitrate analysers on Activated Sludge Reactor
- Redox analysers on Activated Sludge Reactor
- Temperature transmitters on Activated Sludge Reactor
- Flowmeters on WAS line to sludge treatment
- Flowmeters on Scum line
- Final Settlement Tank
- Flowmeters on line to RAS collection chamber/pumping station

- Flowmeters on outlet line from RAS pumping station
- Temperature analyser in RAS pumping station
- Tertiary Filtration
- Flowmeters on inlet line to Micro Flocculation Channel
- Alkalinity analyser on inlet line to Micro Flocculation Channel
- Flowmeters clean backwash flow
- Flowmeters foul water backwash flow
- Flowmeters on air-line to tertiary filters
- UV Disinfection
- UV Transmissivity analysers on UV Distribution Channel
- Turbidity analysers on UV Distribution Channel
- pH analysers on UV Distribution Channel
- Disinfection
- Chlorine residual analyser on final effluent line
- Odour Control System
- Flow switches on foul air inlet branches
- H_2S analyser on foul air main inlet
- pH analysers on foul air main inlet
- pH analysers on solution recirculation line
- ORP analysers on solution recirculation line
- Flowmeter on solution recirculation line
- Flowmeter on solution recirculation line
- H_2S analyser on treated foul air outlet
- VOC analyser on treated foul air outlet
- Flowmeter on treated foul air outlet

11. LIST OF REFERENCES

- Hammer, M. J., 1988. Water and Wastewater Technology. s.l.:Prentice-Hall Intl. Editions.
- Innovyze, 2011. InfoSWMM PDM Users Guide, s.l.: Innovyze.
- WEF Manual of Practice (MOP) 8 - Design of Water Resource Recovery Facilities, 6th edition
- WEF Manual of Practice (MOP) 25 - Odor Emissions and Control for Collection Systems and Water Resource Recovery Facilities, 2nd edition
- Metcalf & Eddy Wastewater Engineering: Treatment and Reuse, 5th edition