Section 4

Requirements for Physical Design
4.1 Introduction

The induced physical, chemical and biological reactions that occur in a sewage treatment plant (STP) lead to waste emissions in the following forms:

a) Gases and vapours, some of which contain obnoxious compounds, including bacteria and viruses.
b) Noise.
c) Odour.
d) Vibration.
e) Unwanted solid matter.
f) Undesirable by-product liquors containing highly concentrated pollutants.
g) Heat.

As such, a sewage treatment plant can degrade the amenity of its surroundings, especially in residential areas.

Careful consideration of siting is required to minimise nuisance to the public. Sufficient land needs to be set aside during the planning stage to take into account regional treatment plant development and the proper sewerage planning for housing, commercial and institutional developments.

This section sets out the important factors and considerations associated with the identification of proper sites to locate sewage treatment plants. Typical workflows in the site for sewage treatment plants are illustrated in Figures 4.1 and 4.2. It also addresses the selection of appropriate treatment concepts and sufficient land area requirements for treatment plants in relation to the effluent standards.

4.2 Treatment Plant Siting

4.2.1 Buffer Zones

Suitable buffer distances should separate a sewage treatment plant from its surrounding areas. Buffer Guidelines for the Siting and Zoning of Industries as recommended by the Department of Environment (DOE) should be referred to during the planning of suitable location for treatment plants. The buffer distances recommended in the guidelines depend on the category of industry being considered.
The provision of buffer zones is essentially an environmental requirement controlled by the relevant planning authority. The agreement of the Local Planning Department on buffer zone and plant siting should be sought at an early stage in the Town and Country planning procedures.

The buffer zone requirements for treatment plants to be observed under this Guideline are as follows. Refer to Figures 4.3 and 4.4 in this section for further clarification.

a) Minimum distance of 30 m from the fence of the treatment plant to the nearest habitable building property line within residential and commercial development.

b) Minimum distance of 20 m from the fence of the treatment plant to the nearest property line within industrial development.

c) Minimum distance of 10 m from the fence of the treatment plant to the nearest habitable building property line if the proposed treatment plant is fully enclosed. A fully enclosed plant is defined in section 7.3.1.

d) A minimum distance of 10 m from the fence of the treatment plant to the nearest habitable building property line if the proposed treatment plant is covered or buried. However, this reduction in buffer requirement does not apply if the nearby habitable buildings are of high rise type. A covered or buried plant is defined in section 7.4.1.

e) Plants with PE less than 150 but are provided with proper odour and noise mitigation measure may have a 10 m reduced buffer at the discretion of the Commission.

The buffer zone can be used for any purpose except permanent habitable buildings. For example, the buffer zone maybe used as a drainage reserve, road or highway reserve, transmission reserve, utility reserve or public park.

In the case where buffer area is to be regularly used by the residents such as car park and playgrounds, proper precautions during design stage must be taken to minimise nuisance such as odour, noise and unpleasant sight to the surrounding environmental. Adequate and proper screening, odour containment and treatment facilities must be provided at the sewage treatment plant to address these issues.
4.2.2 Siting Criteria

The following criteria shall be observed when siting treatment plants.

a) Plants shall be located as far as possible from habitable building to minimise nuisance to the surrounding.

b) Plants shall be located at the lowest point of a sewerage catchment basin so that sewage can gravitate into the plant.

c) Plants shall be located near to a suitable watercourse that is able to receive and assimilate treated effluent from the plant without reducing beneficial uses of the water course downstream.

d) Plants shall be located on an area that is relatively flat or with relatively mild slope across the site that would be useful in promoting efficient hydraulics.

e) The shape of the land area selected shall be such as to minimise the extent of unusable area within the lot.

f) Plants shall not be located in an area that will result in long term operational problems or rapid deterioration of the assets.

g) Plants shall have proper access road leading to it.

h) Plants shall be sited away from the followings:
   i) Existing cemeteries and gazetted reserves for cemetery.
   ii) Religious centres.
   iii) Eating places.

i) Plants shall be located such that sewers are easily connected/ conveyed to the proposed site.

j) If temporary treatment plants are to be provided, they shall be located as near as possible to public trunk sewers.

k) For safety reasons, plants shall be located away from children playgrounds.

Emergency bypass shall be provided either at the last manhole or wet-well. The bypass shall discharge to the nearest drain which shall have sufficient capacity to cater for the discharge during rainfall.

4.2.3 Environmental Impact Assessment

An environmental appraisal or environmental impact assessment (EIA) study shall follow Environmental Quality (Prescribed Activities) (Environmental Impact Assessment) Order, 1987 under Section 34A of the Environmental Quality Act, 1974 (the EIA Order, 1987 and the
The type and scope of the study will depend on the classification of the plant and the environmental sensitivity of the locality being considered. EIA shall be conducted in compliance with Volume 2 of the MSIG.

### 4.2.4 Hazard and Operability Studies

Hazard and Operability (HAZOP) study shall be conducted in compliance with Volume 2 of the MSIG. The type and scope of the study will depend on the classification of the plant.

### 4.3 Treatment Plant Sizing

#### 4.3.1 Modular Units

Stage development of a STP is governed to a large extent by the timeframe of the overall development plan of the catchments and the size, shape and soil condition of the land reserved for the STP. Modular units will be constructed to cater for the stage development. In determining the appropriate number of modules and corresponding timing for a staged development, it is crucial for the designer to estimate the flow capacity build-up over the entire development phases. The modules must have sufficient capacity to treat the sewage to meet the efficient discharge standard, without compromising the economical viability of operation and maintenance. Too many modules and unit processes will definitely increase equipment maintenance. On the other hand, inadequate modules will result in an inefficient treatment performance due to insufficient capacity and flexibility during the early stage.

<table>
<thead>
<tr>
<th>STP Classifications</th>
<th>No. of Modules</th>
<th>No. of Trains</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1 (&lt;1,000PE)</td>
<td>1</td>
<td>N/a</td>
</tr>
<tr>
<td>Class 2 (1,001PE – 5000PE)</td>
<td>1</td>
<td>Max 2</td>
</tr>
<tr>
<td>Class 3 (5,001PE – 20,000PE)</td>
<td>Min. 2, Max. 3</td>
<td>Max 2 for each Module</td>
</tr>
<tr>
<td>Class 4 (&gt;20,000PE)</td>
<td>Min. 4, Max. 10</td>
<td>Max 2 for each Module</td>
</tr>
</tbody>
</table>

Table 4.1 indicates the modularisation requirements in accordance to sewage treatment plant classes to attain an efficient modularisation of sewage treatment plant development. Each module shall be of equal size.
and of similar treatment process. If the proposed process is different from the original system, special approval is required from the Commission. Certain unit processes are subject to the modularisation requirements in Table 4.1 while other unit processes are designed for the ultimate phase during the first stage of the development. An example of this is the headworks of a STP designed for the ultimate phase while the secondary processes are added progressively as the future phases come on-line.

Modular treatment plants that are designed with two (2) or more parallel streams must be provided with pipeworks and valves to isolate each stream of unit process during maintenance and major shut down without interfering normal operation of the remaining stream.

**4.3.2 Standby Units**

To avoid significant down time in sewage treatment and overloading of the process units, standby units shall be provided for the following processes:

a) Inlet Works/Pumps  
b) Screen Facilities  
c) Grit Chambers  
d) Biological Treatment  
e) Secondary Clarifiers  
f) Sludge Facilities

The common standby mechanical equipments are as follows:-

a) Pumps (raw sewage, effluent, sludge, etc)  
b) Mechanical screens  
c) Blowers  
d) Any other mechanical equipment

Detailed requirements of standby units shall follow the requirements in Section 5.

**4.3.3 Back-up Capacity**

The back-up capacity provided shall be such that when one unit process is taken out of operation, the remaining units shall not be overloaded beyond 50% of their rated capacities.
4.3.4 Design Flow

It is recommended that unit processes that are designed on average flow basis are sized to allow for infiltration in accordance with MS 1228. Conveyance networks shall be sized to cater for peak flows, except for those networks located downstream of an equalisation tank. All unit processes shall be designed based on the maximum ultimate design flow.

4.4 Land Area Requirements

The recommended land area requirements for various sewage treatment plants capacities are derived from relevant treatment process concepts and also taken into consideration other design criteria.

The land area requirements and buffer allowance for temporary sewage treatment plants maybe reduced at the discretion of the Commission on a case by case basis.

4.4.1 Class 1 and 2 Plants

The recommended land area requirements for Class 1 and 2 plants (up to 5000 PE) are given in Table 4.2 and Table 4.3 respectively. The net area does not include the 30 m buffer zone surrounding the plant, but does include appropriate set backs and access paths within the plant. The area requirements given are sufficient to achieve an effluent conforming to Standard A discharge requirements. It is important that allowance is made for sufficient buffers in planning approvals, to avoid future complaints in relation to the siting of the plant.

4.4.2 Mechanised Class 3 to 4 Plants

For Class 3 and 4 plants with mechanised systems, the recommended land area requirements are given in Table 4.4 and 4.5. These systems are to be used in normal developed and urbanised areas. The net area does not include the 30 m buffer zone surrounding the plant, but does include appropriate set backs and access paths within the plant. The area requirements given are sufficient to achieve an effluent conforming to Standard A discharge requirements. It is important that allowance is made for sufficient buffers in planning approvals, to avoid future complaints in relation to the siting of the plant.
4.4.3 Aerated Lagoons and Stabilisation Ponds

For aerated lagoon and stabilisation pond treatment systems, the recommended land area is as shown in Table 4.6. Sufficient buffer areas shall be allowed for surrounding the plant as per paragraph 4.2.1.

4.4.4 Imperfect Sites

The recommended land area requirements represent an ideal case, where it is possible to locate the STP within a rectangular land area that is relatively flat. In practice, the allocated land may be irregular in shape, sited in low lying or undulating to steep valley terrain. For such cases, suitable adjustments to the land area requirement have to be made.

Thus, the shape and elevations of the land allocated for the STP development must be determined during planning stage so that the configuration of the STP can be planned properly in order to allocate adequate land for the purpose. This also enables estimates for additional land required. It may also be required to cut or fill operations to level the land.

4.4.5 Reduced Land Areas for STPs

The area requirements, as stipulated in Table 4.2, 4.3, 4.4, 4.5 and 4.6, must be adhered to as strictly as possible. The required areas in these tables include appropriate setbacks and access paths within the plant. However the areas have not include any buffer zone surrounding each plant as indicated in Section 4.2.1.

In developments where land is really a constraint the Commission may consider for a reduced land area requirement. The project proponent will have to demonstrate clearly the need for a reduced land area before an approval can be granted. For this case, detailed design calculations of all unit processes, together with the proposed layout, shall be submitted at the planning stage for consideration of approval by the Commission. Otherwise, the land area required under these guidelines must be followed.
### Table 4.2 Land Area Requirements for Class 1

<table>
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<th>Population Equivalent</th>
<th>Land Area Requirement</th>
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<td>(m²)</td>
<td>(acre)</td>
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<tr>
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<td>210</td>
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<td>150</td>
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**Note:** * The required area only includes appropriate setbacks and access paths within the plant but not the buffer zone surrounding each plant as indicated in Section 4.2.1.
### Table 4.3 Land Area Requirement for Class 2

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### Table 4.4 Land Area Requirements for Mechanised Class 3 Plants

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<td>9000</td>
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</tr>
<tr>
<td>20 000</td>
<td>1.19</td>
</tr>
</tbody>
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**Note:** * The required area only includes appropriate setbacks and access paths within the plant but not the buffer zone surrounding each plant as indicated in Section 4.2.1.
Table 4.5  Land Area Requirements for Mechanised Class 4 Plants

<table>
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<th>Population Equivalent</th>
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<th>Land Area Requirement * (acre)</th>
</tr>
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<td>1.19</td>
<td>2.95</td>
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<tr>
<td>25 000</td>
<td>1.37</td>
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<td>1.81</td>
<td>4.48</td>
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<td>40 000</td>
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</tr>
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<td>2.12</td>
<td>5.25</td>
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<td>50 000</td>
<td>2.23</td>
<td>5.52</td>
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<td>2.37</td>
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<td>60 000</td>
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<td>450 000</td>
<td>9.36</td>
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</tr>
</tbody>
</table>

**Note:** * The required area only includes appropriate setbacks and access paths within the plant but not the buffer zone surrounding each plant as indicated in Section 4.2.1.
Table 4.6  Required Land Area for Stabilisation Pond and Aerated Lagoons

<table>
<thead>
<tr>
<th>Population Equivalent</th>
<th>Standard A*</th>
<th>Standard B*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(ha)</td>
<td>(acre)</td>
</tr>
<tr>
<td>2000</td>
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<td>1.18</td>
</tr>
<tr>
<td>3000</td>
<td>0.69</td>
<td>1.69</td>
</tr>
<tr>
<td>4000</td>
<td>0.89</td>
<td>2.20</td>
</tr>
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</tr>
<tr>
<td>130 000</td>
<td>20.38</td>
<td>50.4</td>
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</tbody>
</table>
### Table 4.6 Required Land Area for Stabilisation Pond and Aerated Lagoons (Continued)

<table>
<thead>
<tr>
<th>Population Equivalent</th>
<th>Standard A*</th>
<th>Standard B*</th>
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</thead>
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<tr>
<td></td>
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**Note:** * The required area only includes appropriate setbacks and access paths within the plant but not the buffer zone surrounding each plant as indicated in Section 4.2.1.
Figure 4.1 STP Land Area Requirements for Planning Layout
Approval for New Development

Start

Determine catchment served

Determine ultimate PE

Identified effluent requirement

Apply sitting criteria

Is development > 2000 PE?

Is development in urban area?

N

Use land area from Table 4.2
(Class 1 plants)

N

Use land area from Table 4.6
(pond systems)

Y

Use land area from Table 4.3, 4 and 5
(Class 2 to 4 plants)

End
Figure 4.2  STP Land Area Requirements for Structure Plans

Start

Local plan formulation

Perform the next two steps concurrently

Determine natural drainage catchments

Calculate ultimate catchment PE

Determine suitable receiving waters

Identify effluent standards

Look up land area requirements in Tables 4.2, 4.3, 4.4 or 4.5

Table 4.2: Up to 1000 PE

Table 4.3, 4 and 5: Greater than 1000 PE for urban areas

Table 4.5: For remote area siting of STP

Apply siting criteria

Select and zone suitable site

Consider multi-use of buffer areas

Reserve land for STP

End
**Figure 4.3 Guidelines For Buffer Zone**

- **Plants Situated In Residential / Commercial Areas**
  - Treatment Plant Site
  - Buffer Zone 30m Min.
  - Residential / Commercial Plot
  - STW Fence
  - Beautification
  - Access And Screening
  - Property Boundary

- **Plants Situated In Industrial Areas**
  - Treatment Plant Site
  - Buffer Zone 20m Min.
  - Industrial Plot
  - STW Fence
  - Factory Fence
  - Access And Screening

- **Plants Situated In Residential / Commercial Areas**
  - Treatment Plant Site
  - Buffer Zone 10m Min.
  - Residential / Commercial Plot
  - STW Fence
  - Property Boundary
  - Access And Screening

- **Plants Situated In Residential / Commercial Areas**
  - Treatment Plant Site
  - Buffer Zone 10m Min.
  - Residential / Commercial Plot
  - STW Fence
  - Property Boundary
  - Access And Screening

- **Plants Situated In Residential / Commercial Areas**
  - Treatment Plant Site
  - Buffer Zone 30m Min.
  - Residential / High Rise
  - STW Fence
  - Property Boundary
  - Access And Screening

**Note:** The buffer area can be used for roads, drains, utility reserve, agricultural or other similar purposes.
Buffer areas can be used for roads, drains, utility reserve, public parks, housing of animals or other non-permanent purposes other than permanent habitable buildings.

The land shall be relatively flat and of a regular shape. Any unusable area within the plot shall be minimised.

Note:

30m Surround for Residential and Commercial Development
20m Surround for Industrial Development
10m Surround for Fully-Enclosed Plants

STP LAND AREA REQUIREMENT

Legend:
- +: Treatment plant
- O: Buffer
- D: Drain
- U: Utility
- R: Road
- H: Housing
- A: Agriculture
- P: Public Park
4.5 Mechanical and Electrical Requirements

Some general guidelines on the design and installation of mechanical and electrical equipment are outlined below.

4.5.1 Mechanical Installation

I) Design Considerations

The designer shall consider incorporating the following criteria:

a) The design shall simplify the equipment required, control system, maintenance and operational procedures, while fulfilling the intended performance and standard of service.

b) The brand and models of major drive equipment (e.g.: pumps, blowers, aerators, clarifier scrappers, etc.) shall be those approved by the Commission.

c) The types and makes of equipment provided throughout the facility shall be standardised, whenever possible.

d) Only new and genuine equipment shall be provided.

e) Equipment sizing and selection shall minimise energy and other consumables costs.

f) The minimum economic life of equipment.

g) Material selection shall be in accordance with the Commission specifications or/and other relevant international standards.

h) Components shall be robust and suitable for use. Where thin metal sheeting is used, it shall be stiffened to minimise distortion.

i) Water storage tanks shall not be placed on the roof top of any control room; all water supply system shall be homed with separate entrance.

II) Installation

a) The base frame of rotational equipment or any equipment that may induce vibration shall be provided with anti-vibration mount.

b) All moving parts shall be designed and installed in a manner that is inherently safe to operate.

c) Foundations shall be adequately designed to include all dynamic load and anchored to withstand all loads imposed by the equipment. Reinforced concrete foundations are preferred.
d) Equipment shall be accurately located, levelled and secured by holding down bolts. Non-shrink grout shall then be used to complete the foundation. In some cases, a resilient connection to the foundation is required, in which case, the manufacturers instructions shall be followed.

e) Holding down bolts shall be of stainless steel and shall be of a minimum Grade 316 if in contact with sewage.

f) Puddle collar is required for all pipe passing through all walls.

g) Appropriate joints shall be provided in all pipeworks to facilitate the removal of equipment, meters, valves and other special items without dismantling the entire pipeline.

h) Valves shall be provided for isolation purpose.

i) Outdoor and dry installation pump shall be provided with housing.

j) The designer must ensure that the unit processes are arranged in such a way to prevent/reduce criss-crossing of piping works, unnecessary bends, choking of interconnected pipe and excessive hydraulic losses through the system.

k) The platform level of mechanical equipment and controllers of any process unit shall be located above design flood level.

4.5.2 Vibration

All revolving parts shall be properly balanced both statically and dynamically so that in running up to, at full normal operating speeds, and at any loads up to the maximum there shall be no undue vibration anywhere in the machine or transmitted to the adjacent structure. The criteria adopted for vibration severity shall be the RMS value of the vibration velocity in millimeters per second.

The bare frame of rotational equipment or any equipment that may induce vibration shall be provided with anti-vibration mount. Where rotational equipment or equipment which may induce vibration is connected to piping, then vibration isolator shall be provided.

4.5.3 Noise

Noise levels from machinery shall comply with the Factories and Machinery (Noise Exposure) Regulations 1989 and Occupational Health and Safety Act. Noise control measures and appropriate safety protection for operators must be provided where necessary.
Noise control measures shall be implemented to control the generated noise level to below 65 dB at a distance of 2 m from the boundary of the housed noise source at all times. Additionally, the general noise levels generated shall be measured 10 m from any point of the plant site within the nearest public space and/or occupied space to an acceptable level stipulated by the appropriate regulators. Silencers and acoustic enclosures shall be provided as required to achieve the above noise level reduction.

Enclosures used to achieve these noise reductions shall permit ready access to the equipment for routine maintenance. Adequate air ventilation shall be provided to allow cooling of the enclosure to prevent overheating of the equipment/motors.

Noise level measurement shall be made with a sound level meter which complies with BS EN 60651 and which is fitted with an ‘A’ weighting network. The sound pressure level shall be measured in dB (A).

Noise level for all electronically operated electrical device such as soft starters, variable speed drives and others shall be conform to IEC, EN. Thus it shall fulfil all EMC Immunity requirements complying with EN50082-1, EN50082-2, EN50082-3.

4.5.4 Safety Around Equipment

All designs and equipment shall be made and installed with safety in mind. Nothing in this Design Guidelines shall remove the designer’s obligation to incorporate equipment or designs that would increase the safety of the plant.

The installation layout and equipment design shall not allow any item of equipment to be so positioned that danger could arise to operating personnel and equipment during normal operation and maintenance. Particular attention shall be paid to the positioning of switch board, control panel, cables, switch gears, lighting, small power, rotational equipment, other electrical equipment and accessories.

All facilities shall be designed to comply with the Occupational Safety and Health Act 514, 1994; properly designed treatment plants will enable the operator to safely handle the treatment plant throughout its design life. The plant shall also be designed to comply with other related Acts such as IEE, Akta Bekalan Elektrik 1990 (Akta 448) and Peraturan-Peraturan Elektrik 1994.

Safety level for all electronically operated electrical device such as soft starters, variable speed drive and others shall conform to IEC, EN, UL, NFC and VDE. Thus it shall fulfill EN 50178, EN 60204-1, EN 60950 (2000, 3rd edition), IEC 61800-5.

Where appropriate, IEE and Akta 448 (1990) and Peraturan Elektrik 1994 must be complied within all electrical installation.
The following shall be provided:

a) All moving parts shall be protected by suitable guards. Where inspection is required, an open mesh with frame and suitably supported maybe used. The maximum aperture of the mesh shall be 6 mm.

b) All guards shall be readily removable and replaceable to they correct orientation only. However the guard shall be designed with features to prevent accidental dislocation from its’ original position. The fasteners when dropped during dismantling, must be easily retrievable and should not damage any equipment or endanger personnel, else fixed fasteners shall be used.

c) An emergency stop button, preferably of mushroom head type shall be located adjacent to all equipment. More than one emergency stop button shall be used, if access around the item is restricted.

d) Long items, such as conveyor belts, shall have an emergency lanyard applied to each accessible length of conveyor.

e) Surfaces which are greater than 50°C shall be guarded.

f) Permanent warning signs shall be posted at visible location at all dangerous areas and shall clearly indicate the nature of risk at that area. This includes warning signage at digesters area, high tension room, low voltage room, generator room and other hazardous areas.

g) Clear working space as recommended in Figure 4.5 shall be provided.

h) Automatic CO₂ discharge triggered by heat and smoke sensors shall be installed in high voltage switch room, transformer room, low voltage switch room and generator room.

i) High tension room shall have signage to clearly indicate the purpose of the room and also safety signage to prevent unauthorised entry.
4.5.5 Motors, Controllers and Motor Starters

I) Motors

a) Provide readily replaceable anti-condensation heaters for motors that do not require frequent operation.

b) At least three thermistors to be provided for motors which are \( \geq 50 \) kW.

c) Electrical motors should be rated as continuous run.

d) Motors \( \geq 22kW \) shall be protected with soft starter or variable speed drive.

e) Where water hammer prevails, frequency inverter shall be provided.

f) The appropriate cooling system based on the requirements of the equipment shall be provided.

II) Controllers

a) Start push buttons to be green and recessed

b) Stop push buttons to be red and recessed
c) Emergency stop push button to be red and mushroom head type

d) ON signal lamps to be green

e) OFF signal lamps to be red

f) Trip signal lamps to be amber

III) Motor Starters

a) Up to 3.7 kW – Direct-On-Line starters

b) Above 3.7 and up to 7.5 kW – Star/Delta starters

c) Above 7.5 and up to 22 kW – Auto-transformer starters

d) More than 22 kW – Soft starter

e) Above 50 kW – Variable speed drive is preferred

Soft starting of motors above 30kW or greater in size is necessary to minimise power disturbances (e.g. power surge) and process disturbances (e.g. water hammer). Variable speed drive shall be considered at application where variable capacity maybe need to enhance the process flexibility, for example, aeration device and blowers.

4.5.6 Power Supply Systems

Power supply to sewage treatment plants shall be as follows:

<table>
<thead>
<tr>
<th>Category</th>
<th>Supply Requirements</th>
<th>Sewage Treatment Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Single incomer with properly design control overflow system during power failure (all electrical control system shall be located above design flood level)</td>
<td>All Class 1, 2 and 3 STPs</td>
</tr>
</tbody>
</table>
| B        | B1) Single incomer with diesel generators for back-up supply.  
          | B2) Single incomer with control overflow system and genset contribution fee. | STP Class 4 |

a) Where a SCADA system is provided and essential parameters are to be monitored during power supply interruptions, a DC supply or a UPS (uninterrupted power supply) must be provided.
b) Batteries/UPS shall have the capacity to operate the SCADA system for a minimum 6 hrs during power failure to safe last event, to monitor the essential parameters and to enable early warning system.

c) No direct tapping of power is allowed from distribution board (DB). Proper protection shall be provided for any direct connection from switchboard. Earth leakage current breaker (ELCB) shall be provided for DB.

d) The power system distribution shall be designed to achieve a minimum power factor of 0.9. For phase development, the plant and power system distribution shall be designed for maximum load and installed in appropriate modular unit to ensure that the minimum power factor is achievable at all phases of operation.

e) Equipment shall be protected by either moulded case circuit breaker (MCCB) or miniature circuit breaker (MCB) based on its suitability. Electrical design calculations shall be provided to justify each selection.

f) Every control circuit shall be protected with separate MCB.

g) TNB meter panels shall be installed close to the site entrance or adjacent to but physically separated from the main switchboard. Suitable flexible steel conduit with approved adaptors shall be supplied and fitted between the main switchboard.

h) All metering panel shall be located flush with the fence and door opening from outside to enable TNB inspector to read the kWh and kVAhr reading.

i) Provide earthing connected with Current Transformer (CT) for Large Power Consumer (LPC) (i.e. consumption with more than 100A or 10kW).

j) To provide earthing connected to ELCB/RCCB/ELR or Over Current & Earth Fault relay to protect overcurrent and surge current to all wiring connected to TNB metering panel for Large Power Customer (LPC) or Ordinary Power Customer (OPC). Test for earthing system shall be below or equal 1 Ohm.

### 4.5.7 Back-up Generator

a) If diesel generators are to be provided they shall be used for essential loads only (these include influent pumping in pump station, feeding pumps in balancing tank, decanter for SBR; minimum 30% aeration requirement; emergency services system, essential lighting and ventilation system.

b) Where generators are installed, they must be accompanied with the necessary supporting systems, including automatic cut-in
in the event of mains failure, fuel storage and transfer; and if installed indoors, including ventilation, fire detection/protection and working alarms.

c) In the event of power interruption/failure; when diesel generators are used, the SCADA shall be powered by UPS or DC battery.

d) For plants $\geq 100 000$ PE, the capacity of the back-up generator may vary provided detail calculation must be provided to justify that sewage can be kept in aerobic condition for a maximum duration of 6 hours.

e) Gen-set shall be sized to the incoming TNB voltage requirement.

4.5.8 Switchgear and Control Gear Assemblies

a) For simplicity, separate the Supply Authority Metering from the main switchboard.
b) Electro galvanised plates to be used to protect materials against corrosion due to high humidity.
c) Panel isolators and door locks to be capable of padlocking open with 6 mmc - hasp padlock.
d) Use separate panel boards for general purpose light and power.
e) Group all motor starting equipment for an area into multi-motor, starter control board.
f) Cabinets are to be constructed to prevent the ingress of insects and vermin.
g) For incomer above 400 A, provide over current and earth fault protection on all starter circuits in excess of 200 A.
h) Where a circuit has a main and standby supply, provide an isolator in each supply circuit.
i) Junction boxes for submersible pumps and float controls shall be above the floor or any possibility of flood level and must not be located in the wet well.

4.5.9 Control Cabinets

(I) General

a) Provide 900 mm minimum clearance between an open door and any fixed object.
b) Provide 900 mm clearance between open cabinet doors of facing cabinets.
c) Front access cubicles to have the electrical clearance distances between door mounted equipment and gear tray mounted equipment as specified in the regulations.

d) Mount all equipment inside cabinets on gear trays.

e) All cabinets to have a base frame, at least 50 mm high.

f) All control panels shall be provided with phase sequence relay.

g) All control rooms shall be isolated from invasive environment of the sewerage system, where carbonisation, corrosion or condensation may occurs that lead to short-circuiting.

h) Height to be no greater than 1600 mm internally.

i) Mount cabinet on reinforced concrete plinth, 200 mm minimum above ground.

j) Provide a reinforced concrete paved area for the full width of the cabinet and extending 1 m in front of the cabinet doors, when they are opened.

k) Cable entry from the top only.

l) Provide forced ventilation fan for cubicles housing PLC equipment.

m) Provide ventilation for variable speed drives and soft starters.

n) Natural ventilation is suitable for direct-on-line, star-delta and auto transformer starters.

o) The minimum acceptable IP rating and tests required shall be clearly specified.

(II) Outdoor Cabinets

a) Self contained, free-standing, weatherproof cabinets to be constructed of marine grade aluminium, stainless steel grade 316 or glass reinforced plastic.

b) Mount control indication and alarm facilities on internal doors enclosing compartments housing electrical plant and equipment.

c) Provide external doors with security locking facilities.

d) Provide double roofs on cabinets to reduce solar effects.

e) Wall mounted outdoor weather proof control panel shall come with an awning extended by at least 2 m from the wall.

f) Floor mounted outdoor weather proof control panel shall come with a roof extended 2 m from the panel.

g) External weather proof control panel of equal and more than 100 A shall be provided with permanent CO₂ fire extinguisher.
4.5.10 Control Requirements

This section outlines the general philosophy on control requirements for the whole facilities.

<table>
<thead>
<tr>
<th>NO.</th>
<th>TYPE OF PLANT</th>
<th>EWS + PC (monitoring) / Data Logger</th>
<th>SCADA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Network Pumping Station (NPS)</td>
<td>&lt; 100 000 PE</td>
<td>≥ 100 000 PE</td>
</tr>
<tr>
<td>2a.</td>
<td>Sewage Treatment Plant</td>
<td>Class 3 STPs</td>
<td>Class 4 STPs</td>
</tr>
<tr>
<td>2b.</td>
<td>Sewage Treatment Plant requires full automation, e.g. sequencing batch reactor.</td>
<td>Class 1, 2 and 3</td>
<td>Class 4 STPs</td>
</tr>
<tr>
<td>2c.</td>
<td>Sewage Treatment Plant (Standard A)</td>
<td>Class 1, 2 and 3</td>
<td>Class 4 STPs</td>
</tr>
</tbody>
</table>

**Notes:**
- EWS – Early Warning System
- SCADA – Supervisory Control and Data Acquisition

I) General Considerations

a) PLC shall restart automatically once the power supply reinstate after a power supply interruption.

b) PLC shall be equipped with manual over-ride features.

c) Continuously running drives shall restart automatically after a power supply interruption.

d) Plant to have time delayed restarting sequences for equipment to avoid overloading power supply.

e) Transducers shall be used to sense the signal for related warning alarms.

f) Trip and shutdown to be measured by separate relays.

g) The operating status and condition of the process shall be verified by measuring appropriate performance indicator and not by inference.

h) SCADA room shall be air-conditioned.

i) Telephone line must be laid during construction for all sewerage works to be equipped with SCADA.
II) Manual Control

a) Interlocks shall be provided to prevent damage to the equipment during equipment start up, for example, bearing overload, overheated, temperature, loss of cooling water, no flow when operating.

b) Selector switches to be provided at one location so that an equipment can be manually operated from that location.

III) Drive Systems

a) Each drive must be independently provided with the following features:
   i. ON - starts and runs the drive
   ii. OFF - stops the drive
   iii. AUTO - operates the drive in accordance with automatic control system

b) Indicate operation by an ammeter

c) Record running hours with a local indicator and by computation in a central SCADA system where applicable.

d) Local annunciation on motor starter of each fault condition.

e) Record kilo-Watt.hour (kWh) of major drive equipment.

IV) Automatic System Control Facilities

a) Displays operator adjustable parameters, examples set point of top water level in a tank and the target dissolved oxygen level for a process.

b) Ability for the authorised operator to adjust the set point of operator adjustable parameters. A “default” value should always be provided.

c) Displays to advise operator of the set points of non-operator adjustable parameters. Examples would include the overflow level on a tank and the trip temperature for a bearing.

d) Displays measured values by all instruments, used to measure flow, level, DO, pH, temperature or applicable parameters.

e) The process control sequences must ensure system problems such as water hammer overtorque or overpressure the equipment of air compressors. Time delayed in starting and stopping of equipment where multiple duty units are installed, use a value with slower rate the final stage of closing, vary the speed of equipment during starting and stopping are some of the option for consideration in careful process automation.
4.5.11 **Supervisory Control and Data Acquisition Systems (SCADA)**

SCADA is the acronym for Supervisory Control and Data Acquisition. The term refers to a large-scale, distributed measurement (and control) system. SCADA systems are used to monitor or/and to control chemical, physical or transport processes. The following briefly describe the requirements of SCADA while the detail requirements of SCADA are listed in Appendix C.

The term SCADA usually refers to a central system that monitors and controls a complete site. The bulk of the site control is actually performed automatically by a Programmable Logic Controller (PLC). Host control functions are almost always restricted to basic site override or supervisory level capability. Provision of SCADA system shall be in accordance with Section 4.5.10.

I) **Control Systems**

a) All equipment shall be tagged in the SCADA system.
b) Develop sequential function diagrams to specify the control logic to suit the process operation for each system.
c) Check the process operation against the resulting sequential function diagram.
d) PLC programs to be written in modular form to aid fault finding and commissioning.
e) Design programs to be ‘fail to safety’. That is, PLC failure will cause plant to stop.
f) On restoration of supply, all controlled system shall be returned to the ready position before automatic restart takes place.
g) Bench test all application programs for PLC, before program installation on site.
h) Conduct functional control circuits tests for all items of equipment.
i) Ensure PLC programming software licences are delivered.
j) Provide paper copy listing of all PLC application programs and soft copies of application program (two copies of each required).
k) Despite the PE, all plants which requires automation and control shall be provided with human machine interface (HMI) at site.

II) **Supervisory Systems**

a) Where supervisory systems are used, schedule all graphic displays required to control plant using columns to define:

i) Graphic Name
ii) Information displayed

iii) Control features

b) Update times for screens to be not more than one second.

c) Nominate the alarm title to be used/displayed for each process-generated fault input or fault generated internally by the PLC program.

d) Nominate critical and non-critical alarms and the method of differentiation. Examples would be: nominating an alarm on a limit which has been reached as critical and an alarm on a limit which is being approached as non-critical; differentiated by, for example, red/amber lights or horn/bell).

e) At least eight variables to be displayed on a trend graph simultaneously for ease of monitoring and comparison. This is a measure of the level of software sophistication which should be expected.

f) Supervisory system to log running hours for all plant items.

g) Nominate the reports to be generated for plant operation, management and history. For example, reports to be daily, weekly and monthly and the list of parameters to be reported on in each.

h) Alarm analysis, that is, frequency of occurrence, similar plant faults, etc, to be provided as part of the supervising programs.

4.5.12 Early Warning System (EWS)

The EWS is used to monitor the status of the equipment operating inside the treatment plants such as pumps and aeration equipment. It shall act as the means to communicate information via Short Messaging Service (SMS), e-mail or via other telecommunication mean to technical staff for the fast recovery of the treatment system.

EWS system shall be able to transmit digital and analog values from the remote module to the operator through their inputs (equipment) via SMS and e-mail messages in text mode. The modules shall be able to interpret SMS message from the operator to activate or deactivate long distance machine (remote control).

4.5.13 Instrumentation

Provision for instrumentation shall be in accordance with the following Table 4.7. Instruments shall be installed in such a way that they can be removed for maintenance without interrupting the process.
Table 4.7 Required Process Instrumentation

<table>
<thead>
<tr>
<th>Treatment Unit</th>
<th>Instrumentation</th>
<th>STP Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inlet Pump Station</td>
<td>Level/ Pressure</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td>Flow Measurement</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td>Gas Detector (H₂S, CO₂, O₂ &amp; Combustible gases)</td>
<td>4</td>
</tr>
<tr>
<td>Aeration</td>
<td>DO/pH/ Turbidity</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Temperature</td>
<td>4</td>
</tr>
<tr>
<td>Blower</td>
<td>Air flow/ pressure/ temperature/ rpm</td>
<td>All</td>
</tr>
<tr>
<td>Decanter</td>
<td>Position Indicator /Speed</td>
<td>All</td>
</tr>
<tr>
<td>Effluent</td>
<td>Flow Measurement</td>
<td>All</td>
</tr>
<tr>
<td>Sludge (WAS/RAS)</td>
<td>Flow Measurement</td>
<td>4</td>
</tr>
<tr>
<td>Electrical Drive</td>
<td>Am/Volt/HR/kW/Power Factor meter</td>
<td>All</td>
</tr>
<tr>
<td>Disinfection</td>
<td>Dosage/Transmittance / Flowrate/outlet water level indicator</td>
<td>All</td>
</tr>
<tr>
<td>Polymer</td>
<td>Dosage/ Level Indicator/ Flowrate</td>
<td>All</td>
</tr>
<tr>
<td>Sludge Feed</td>
<td>Flowrate/ Pressure</td>
<td>All</td>
</tr>
</tbody>
</table>

For STP with PE 10 000 and above, a digital power meter is required to be installed at all individual panel of major equipment such as raw sewage pump, air blower, aerators, mechanical dewatering unit etc. The digital power meter shall be able to monitor the following:

<table>
<thead>
<tr>
<th>Real-Time Readings</th>
<th>Current, Voltage, Real Power, Reactive Power, Apparent Power, THD (V and I)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Readings</td>
<td>Accumulated Energy (Real kWh, Reactive kVarh, Apparent KVAh)</td>
</tr>
<tr>
<td>Demand and peak Readings</td>
<td>Current, Real Power, Reactive Power, Apparent Power</td>
</tr>
<tr>
<td>Other:</td>
<td>Power Factor, Load Operating Time</td>
</tr>
</tbody>
</table>

All parameters measured as mentioned must be retrievable at all time.
4.5.14 **Cables and Cabling Installation**

**I) General**

a) Segregate cables into the following categories:
   i) power (less than 1000 V phase to phase)
   ii) instrumentation/telemetry
   iii) control

b) Wherever possible, use a separate cable-support system for each cable category.

c) Separate such cable support systems by minimum clear distances of 300 mm.

d) When one cable support system has to be used, separate cable categories by minimum clear distances of 150 mm.

e) Secure cable at 900 mm intervals for horizontal runs and 300 mm for vertical runs.

f) Cable ties shall be made of non-corrosive material and if exposed to the environment, shall have UV protection.

g) All cables shall be at least of double PVC protection, and if exposed to the environment then armoured cable shall be provided.

**II) Instrumentation**

a) Use separate cables for digital and analog signals.

b) Marshal cables in a process or geographical area into junction boxes.

c) Use multipair cables between areas.

**III) Buried Cables**

a) Install cables without trees or through joints, unless approved.

b) All buried cables shall be laid in ducts.

**IV) Underground Ducts**

a) Construct road crossings from uPVC conduit of minimum 100 mm diameter with 900 mm cover and encased on all sides with 150 mm concrete.
b) All other ducts to be PVC conduit laid with a minimum cover of 600 mm. Ducts to be bedded in 75 mm sieved sand.

c) Provide draw strings in all ducts.

d) Provide cable pits to suit cabling layout and to allow drain-in of cables through the duct work. Cable pits shall be provided no greater than 100 m apart. They shall be fitted with trafficable cast iron covers and equipped with drainage.

e) Seal ducts into buildings with approved systems providing a fire rating of 30 minutes.

(V) **Conduits**

a) All cabling within buildings or structures where cable trays are not permitted, and in all external locations, shall be installed within conduits.

b) Conduits installed externally shall be arranged to minimise their length and exposure. PVC heavy duty conduit is permissible, where it is protected from physical damage and UV. Otherwise, metal or flexible conduits shall be used.

c) Use flexible steel reinforced conduit for connections, where relative movement and removal for maintenance has to be considered.

VI) **Cable Support Systems**

a) Ensure cable support systems in electrical switch rooms, equipment (for example, pump) rooms and service galleries.

b) When run in common service galleries, ensure cables are not adjacent to hot services.

4.5.15 **Earthing and Lightning Protection**

a) Provide earthing and lightning protection to meet local regulations.

b) Use a specialist inspector to verify the installation.

c) Earthing test results shall be submitted and results shall be below or equal to 1 Ohm.

d) Lightning arrestor test results shall be submitted and results shall not more than 5 Ohms.

e) Earthing and lightning arrestor chamber shall be of pre-cast material.
4.5.16 General Purpose Power

Provide general purpose power socket outlets as follows:

a) Single phase outlet rated at 10 A adjacent to, or inside each control cabinet and within 10 m of all equipment installations.
b) Three phase outlet rated at 50 A within 20 m of every screen, sludge scraper, clarifier rake, grit collector and conveyor.
c) Three (3) phase (with neutral) outlet rated at 50 Amp shall be provided at an interval of at least 20 m.
d) These outlets shall be water proofed industrial type switch socket outlets (SSO).

4.5.17 Manuals, Drawings and Labelling

a) Provide equipment manuals that are specific to the plant and instrumentation supplied.
b) System manuals describe the way each system manages the individual items of plant. Ensure these are available in draft form, before testing and commissioning commences.
c) Provide plant function diagrams, electrical system, electrical circuit, Process and Instrumentation Diagram (P&ID), instrument loop diagrams, electrical design calculations and single line diagrams with endorsement by qualified person, before the plant is pre-commissioned.
d) All plant and equipment are to be provided with inscriptions and labels to facilitate understanding and safe operation and to satisfy the requirements of any standards and regulations applying to the works. Labelling includes:
   i) inscriptions on equipment, cubicles, instruments, process controllers and on small equipment such as relays, control switches, indicating lights, etc
   ii) identification of cables at both ends and along their lengths
   iii) identification of terminations for cable cores and cubicle wiring in accordance with the circuit diagrams
e) Drawings submitted shall show all unit processes to be constructed, and equipment to be installed based on the ultimate capacity of the sewerage system, especially for phase development where the construction of unit processes and installation of equipment will be based on phasing.
f) For treatment plant with PLC/SCADA systems, ladder diagram, programme source codes and programming console unit shall be provided before pre-commissioning of the treatment plant.

4.5.18 Hazardous Areas

a) A plan setting out various hazardous areas and classes of electrical hazard is required. For example, flameproof area in the vicinity of anaerobic digesters/sludge gas compressors, chemical storages or laboratories.

b) Ensure the plant and methods of construction and installation conform to the requirements of each defined area, as this plan will be used by the Supply Authority to inspect the area for conformance.

4.6 Material Requirements for STP Structures and Installations

Materials permitted for structural fabrication in treatment plants are concrete, reinforced concrete, steel, fibreglass reinforced plastic and aluminium. The requirements for such materials shall be in accordance with information provided in the following sub-sections. Any others material used for STP structures and installations shall obtain special approval from the Commission.

Structural design of treatment plant structures shall be submitted by registered professional engineers. They shall be in accordance with the requirements and standards given in this section and any other relevant standards, as well as, sound engineering practices.

4.6.1 Concrete and Reinforcement

a) Concrete structures shall be designed in accordance with MS 1195, except that concrete structures for retaining sewage and other aqueous liquids shall be designed in accordance with BS 8007.

b) Concrete shall generally comply with the relevant requirements in MS 523.

c) Concrete for structures retaining sewage shall have a strength grade not less than grade C35A. Strength grades higher than C35A may be specified as required by the Commission.
d) Concrete for structures retaining sewage shall be designed for buoyancy due to ground condition.

e) Concrete for purposes other than structures retaining sewage shall have a strength grade not less than grade C20 where unreinforced, and not less than grade C30 where reinforced. Strength grades higher than the minimum may be specified as required by the Commission.

f) Concrete structures retaining sewage, shall be lined with high alumina cement mortar of 20 mm minimum thickness or other approved liners/lining materials.

g) Concrete and cement mortar exposed to soils or groundwater shall be made using a cement suitably resistant to sulphate attack, as specified in this section. Where part of a concrete structure is exposed to soils or groundwater, cement suitably resistant to sulphate attack shall be used for the entire structure.

h) Cement to be used to resist sulphate attack shall be one of the following:

i) sulphate-resisting portland cement complying with MS 1037.

ii) portland pulverised fuel ash cement complying with MS 1227.

iii) ground granulated blast furnace slag complying with MS 1387.

iv) high silica content portland cement

v) supersuphated cement complying with BS 4248.

i) Aggregates shall comply with MS 29 and shall be coarse aggregate of 20 mm nominal maximum size.

j) Approval for admixtures shall be obtained prior to inclusion in the concrete mix. All admixtures shall comply with MS 822.

k) Steel reinforcement shall comply with:

i) MS 144 for cold reduced mild steel wire.

ii) MS 145 for steel fabric.

iii) MS 146 for hot rolled steel bars.

l) Welding of steel reinforcement shall be in accordance with BS 7123.

m) Waterstops for sealing joints in concrete shall comply with MS 1292.
4.6.2 Steel

I) Structural steel

a) Structural steel sections shall comply with BS 4 or otherwise with:
   i) EN 10162 for cold rolled steel sections.
   ii) EN 10210 for hot rolled steel sections.
   iii) EN 10025 for weldable structural steel.
   iv) EN 10296, EN 10297 and EN 10305 for steel tube.

b) The use of structural steel in building shall be in accordance with MS 416.

c) Minor structural steelwork shall be Grade 43A complying with EN 10025. All other steelwork shall be of appropriate grade, as determined using MS 416 and other appropriate standards. These shall be determined by a qualified structural engineer.

II) Coating for steel

a) Steelwork that may be in contact with sewage through immersion, splash or spray, or that is over tanks containing sewage, shall be protected against corrosion using one of the following coating systems:
   i) high build tar epoxy system complying with AS 3750.2 and applied in two or more coats to give a total dry film thickness of not less than 200 µm.
   ii) high build micaceous iron oxide pigmented epoxy system complying with AS 3750.12 and applied in two or more coats to give a total dry film thickness of not less 200 µm.
   iii) hot dip galvanised coating of 140 µm nominal thickness in accordance with MS 740.
   iv) sealed sprayed zinc coating of 150 µm nominal thickness in accordance with EN ISO 2063.

b) Other coatings providing 10 to 20 years service, before first maintenance, as selected using Table 3 Part 8 of BS 5493 shall be considered for approval by the Commission. Steelwork that is exposed to the external atmosphere, except severe marine atmospheres, shall be protected against corrosion using one of the following coating systems:
i) a prime coat of a two pack polyamide cured epoxy zinc phosphate of dry film thickness 60 to 80 µm with a finishing coat of a high build micaceous iron oxide chlorinated rubber paint, spray applied to a dry film thickness of 60 to no more than 80 µm.

ii) hot dip galvanised coating of 85 µm nominal thickness, in accordance with MS 740.

iii) sealed sprayed zinc coating of 150 µm nominal thickness, in accordance with EN ISO 2063.

c) Steel substrates shall be prepared before application of coatings, in accordance with BS 7079.

d) Other corrosion protection coating systems for steelwork shall be determined using BS 5493 or AS 2312 for tropical atmospheres so as to provide 20 or more years to first maintenance.

e) Unprotected steelwork in contact with sewage shall be stainless steel grade 316S31 complying with EN 10088: Part 1 and 3 or EN 10029 and EN ISO 9445.

f) Successive coatings of the one component shall be tinted a different colour to facilitate overcoating and inspection.

g) All coatings shall be applied strictly in accordance with the coating manufacturer’s printed instructions.

h) Bolts, nuts, screws and other fasteners shall have either:
   i) hot dip galvanised, in accordance with MS 739
   ii) sherardized zinc coating, in accordance with BS 4921
   iii) electro plating
   j) Nuts, bolts, screws and washers in contact with sewage shall be stainless steel of Grade 316S31 steel complying with EN 10088: Part 1 and 3 or EN 10029 and EN ISO 9445.

k) Fasteners of incompatible material to the component being fastened shall have suitable isolating washers and sleeves.

III) Marine and Corrosive Environment

a) All areas within 5 km from the coast line or salt water bodies shall be classified as marine environment. Sewerage facilities in marine and corrosive environment e.g. where the atmosphere
or soil contains high levels of chloride, sulphates and corrosive chemical elements or compounds shall be adequately designed to withstand the corrosive actions of the chemicals prevalent in the environment. Necessary protections shall be provided against all corrosive actions of the environment.

b) Design requirement for facilities in marine and corrosive environment shall include:

i) Two coats of sodium silicate shall be applied to all external surfaces of concrete structures.

ii) Concrete shall be resistant to all chemical attacks and be designed in accordance with BS 8110 Part 1: 1997.

c) Exposed metal shall be of corrosion resistant and of marine grade. Proper smooth surface finishing shall be provided for the metal. Unprotected metals acceptable for use are as follows:

i) SS316L

ii) Aluminium alloy

iii) Materials suitable for use in corrosive environment acceptable by the Commission

d) All structural steelwork shall be thoroughly descaled to BS 7079 second quality and shall be painted with 2 coats of two pack epoxy based red lead primer before leaving the manufacturer’s works. In addition, all structural steelwork shall be provided with protective paint for chloride, sulphate or the prevailing chemicals in the site after installation.

e) Cathodic protection shall be provided for all load bearing steel structures in marine environment for a minimum life of 50 years.

4.6.3 **Fibre Reinforced Plastic (FRP)**

Only FRP products approved by the Commission shall be used and FRP products shall not be used for access purposes.

FRP tanks, vessels and appurtenances for sewage treatment processes shall be designed in accordance with BS 4994 and EN 13923. The thickness of the structural section of the FRP tank wall shall not be less than 5 mm and shall be at least of wall thickness as given in ASTM D 4097.

All other FRP products shall meet the requirements of ASTM C 582 for FRP laminates.
Notwithstanding any other requirements in standards, all FRP products, including FRP tanks and vessels for sewage treatment processes, shall conform to the following material requirements:

a) FRP properties shall be as determined by design to standards mentioned in this Section and other relevant standards, but shall not be less than the following values:

- Tensile strength - 80 MPa
- Tensile modulus - 7000 MPa
- Flexural strength - 140 MPa
- Flexural modulus - 6000 MPa
- Water absorption - ≤ 0.75 %
- Barcol hardness - 40
- Operating temperature - -40°C to +50°C
- Specific gravity - ≥ 1.5
- Fire rating – ASTM E84, < 25s or Class 1 BS476

b) Unsaturated polyester resins shall be used but shall only be isophthalic, bisphenol A fumurate or terephthalic polyester resins meeting the requirements of Type B or C of BS 3532.

c) All surfaces shall have a resin rich layer, gel coat. Surfaces in contact with sewage, water or any moisture shall comprise of a resin rich layer at least 1 mm thick. All other surfaces shall comprise of a resin rich layer at least 0.25 mm thick. Up to 10% by mass of corrosion resistant glass fibres, (that is, C-glass or E-CR glass), polyester fibres or acrylic fibres may be used in the surface layer.

d) A barrier layer shall be provided behind the surface layer and shall be at least 1.5 mm thick. The barrier layer shall comprise of 70 to 80 % by weight resin with the remainder by weight being E glass or E-CR glass.

e) The structural layer shall comprise resin impregnated layers of E glass or E-CR glass and shall comprise at least 25 % E glass or E-CR glass. Aggregate and filler may be included.

f) E glass and E-CR glass shall conform to the requirements of:

i) EN 14020 for glass rovings.
ii) EN 14118 for chopped strand mat.
iii) BS 3396 for woven fabric.
iv) BS 3749 for woven roving fabric.
g) Glass fibres shall have a surface treatment compatible with the manufacturing process to ensure bonding to the resin.

h) Aggregates shall only be used in FRP structural layers and external layers. Aggregates shall be clean, washed, high grade silica sand containing not less than 95% silica. Aggregates shall be of a size not greater than 20% of the thickness of the FRP structural layer with a particle size not less than 0.05 mm and not greater than 5 mm.

i) Fillers shall only be used as a resin extender and shall comprise of clean inert material, for example, silica, with particle size less than 0.05 mm.

j) Surfaces exposed to sunlight shall incorporate provisions to minimise ultraviolet degradation, such as, ultraviolet inhibitors, screening agents or pigment in the outer resin rich layer.

k) Pigments and dyes shall not normally be required, but where required by the Commission, shall be of a type and colour specified by the Commission.

l) FRP water tanks shall comply with the above requirements and requirements in:
   i) MS 1241: 1991 where not constructed of FRP panels.
   ii) MS 1390: 1995 where constructed of FRP panels.

m) All design of package plants using FRP materials shall take into account for the buoyancy effects. This effect is of concern during high ground water conditions and emptying of the tank content during desludging works.

n) Anchor strap shall be at least stainless steel grade 304.

4.6.4 Aluminium

a) Aluminium is found primarily as the ore bauxite and is remarkable for its resistance to corrosion (due to the phenomenon of passivation) and its light weight. Structural components made from aluminium and its alloys are very important in which light weight, durability, and strength are needed.

b) Wrought aluminium and aluminium alloys shall comply with:
   i) BS 1161 for structural purposes.
   ii) EN 485 for sheet plate and strip.
   iii) EN 754 for drawn tube.
   iv) EN 755 for bars, extruded round tubes and sections.
v) EN 1676 for ingots and castings.
vi) BS 4868 for profiled sheet.

c) Anodic oxidation coating on aluminium shall be in accordance with EN 12373.

d) Requirements for structural design, materials, workmanship and protection of aluminium shall be in accordance with BS 8118

4.6.5 HDPE (High Density Polyethylene)

High-density polyethylene (HDPE) is the high density version of PE plastic. Its molecules have an extremely long carbon backbone with no side groups. As a result, these molecules align into more compact arrangements, accounting for the higher density of HDPE. HDPE is stiffer, stronger, and less translucent than low-density polyethylene. HDPE is lighter than water, and can be moulded, machined and joined together using welding.

High-density polyethylene shall comply to the following physical properties:

- Tensile Strength: 0.20 – 0.40 N/mm²
- Notched Impact Strength: no break Kj/m²
- Thermal Coefficient of expansion: 100 – 220 x 10⁻⁶
- Max Cont Use Temp: 65°C
- Density: 0.944 – 0.965g/cm³
- Minimum Require Strength: 8.0 MPa