# OPERATION AND MANAGEMENT OF WASTEWATER TREATMENT PLANTS

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# Operation and Maintenance Manual

The purpose is to provide WWTPs' operators with the proper understanding of recommended operating techniques and procedures, and the references necessary to efficiently operate and maintain their facilities.

The O&M manual shall include:

a) Introduction
b) Permits and Standards
c) Description, Operation and Control of Wastewater Treatment Facilities
d) Description, Operation and Control of Sludge Handling Facilities
e) Personnel
f) Sampling and Laboratory Analysis
g) Records and Reporting
h) Maintenance
i) Emergency Operating and Response Program
j) Safety
k) Utilities

# Operation and Maintenance Manual

*Introduction*
General description: WWTP, location, sensitive areas, site map.

*Permits and Standards*
Type of permit, description of responsibilities of the owner, operator and consulting engineer.

*Description, Operation and Control of WWT Facilities*
Description of each WWTP component, their function and operating method, from the point of generation (including the conveyance system) through the treatment processes to final disposal.

*Description, Operation and Control of Sludge Handling Facilities*
Description of sludge handling and disposal requirements, including frequency and means of sludge removal from each unit process.

*Personnel*
Number and qualifications of the personnel, their duties and responsibilities. Weekly staff coverage and on-call and emergency operating personnel.

# Operation and Maintenance Manual

*Sampling and Laboratory Analysis*

List of all samplings and analyses required, appropriate protocols for proper sampling, storage, transportation, and analysis. Quality control/quality assurance plan.

*Records and Reporting*

List of all reporting requirements, location and method of record keeping (daily logs)

*Maintenance*

List of spare parts and supplies needed for maintenance and repair. Chart itemizing all equipments, their associated maintenance action and the frequency of such action.

*Emergency Operating and Response Program*

Program detailing procedures to be followed in the events of emergency situation: emergency conditions, actions to be taken, responsible authorities, corrective actions.

*Safety*

Itemized list of safety and first aid equipment instruction.

*Utilities*

List of names and notification requirements for water, electric, gas and telephone services.

# Screening

## Design Data

| | | Manually cleaned | Mechanically cleaned |
|---|---|---|---|
| Bar size: | | | |
| Width | [mm] | 5 – 15 | 5 – 15 |
| Depth | [mm] | 25 – 75 | 25 – 75 |
| Clear spacing between bars | [mm] | 20 – 60 | 10 – 30 |
| Slope from vertical | [°] | 45 – 60 | 70 – 90 |
| Approach velocity | [m $s^{-1}$] | 0.3 – 0.5 | 0.5 – 1 |
| Allowable headloss | [m] | 0.1 – 0.2 | 0.1 – 0.2 |

## Screened Material characteristics

| Clear spacing between bars [mm] | Volume of screenings [$m^3$ $PE^{-1}$ $y^{-1}$] | Suspended solids removal [%] | $BOD_5$ removal [%] |
|---|---|---|---|
| 15 | 2 $10^{-3}$ – 4 $10^{-3}$ | 1 – 3 | - |
| 10 | 3 $10^{-3}$ – 6 $10^{-3}$ | 2 - 5 | 1 – 3 |

A typical screen operation sheet should report details on routine inspections, lubrification and adjustment, performed by the operator.

# Screening

| ***Problem*** | Sand in the screen channel | Solid transport through the screen |
|---|---|---|
| ***Evidences*** | • Sand in the removed material<br>• Increased water level in the channel<br>• Less amount of sand removed by the sand- trap | • Regular clogging of the pipes downstream the screen<br>• Finding inappropriate materials in the pump impeller |
| ***Causes*** | • Low speed in the channel<br>• Obstacles in the channel | • Solids removal not effective<br>• Incorrect piping design or installation |
| ***Tests-Analysis*** | • Measure the amount of sand in the channel bottom<br>• Measure the speed for different flowrates<br>• Verify the design of the channel | • Check the presence of solids downstream the screen<br>• Check the pump water flow |
| ***Actions*** | • When < 0,5 m/s, the speed has to be increased by reducing the wet section in the channel | • Removal of all the blocked material<br>• Replacement of the damaged moving parts |

# Grit Removal

The goal is to separate gravel and sand and other mineral materials down to a diameter between 0.2 and 0.1 mm.
There are three general types of grit chamber: ***horizontal-flow*** – of either ***rectangular*** or ***square configuration*** – and ***aerated***.
The quantity of removed grit will vary depending on the type of sewer system, the caracheristics of the drainage area, etc.

Typical amounts of collected grit (combined sewer)

| Volume of grit [l $PE^{-1}$ $yr^{-1}$] | Volume of grit [l $m^{-3}$] | reference remark |
|---|---|---|
| 40 | 0.02 - 0.2 | ATV-Hanbuch, 1997 average: 0.06 l / $m^3$ |
| 2.4 – 58.8 | | Londong, 1990 |
| 2 | | Imhoff, 1993 high-density areas |
| 5 | | Imhoff, 1993 low-density areas |
| | 0.01 – 0.1 | Passino et al. (1999) |
| | 0.004 - 0.2 | Tchobanoglous, 2003 aerated grit chamber |

Collected grit moisture content ranges between 15 e 40%; volatile content, on dry basis, ranges between 20-50 %.

# Grit Removal

| | | |
|---|---|---|
| ***Problem*** | Sand in the effluent | Organic matter in the removed solids |
| ***Evidences*** | • Sand in the units process downstream the sand trap<br>• Reduced amount of sand removed | • Excess of removed solids<br>• Odours from the removed solids |
| ***Causes*** | • Low HRT (too high flow speed) | • High HRT (too low flow speed) |
| ***Tests-Analysis*** | • Measure inorganic SS in/out the sand trap at different flowrates<br>• Measure the flowrate speed in the sand trap<br>• If aerated, measure the air flowrate | • Measure the VSS in the removed solid fraction<br>• Measure the flow speed in the channel<br>• If aerated, measure the air flowrate |
| ***Actions*** | • Increase the wet section (water level) if possible<br>• If mechanical, reduce the rotating speed | • Reduce the number of parallel units<br>• Reduce the wet section (water level) if possible<br>• If mechanical, increase the rotating speed |

# Sedimentation

The goal is to remove readily settleable solids and floating materials thus reducing the suspended solids content; so quiet conditions are set up in the sedimentation basin.
The sedimentation process takes place in circular or rectangular basins made of concrete or iron, having the bottom lightly sloped towards a zone where the sludge is conveyed by appropriate withdrawal devices.

Typical operational data for different type of clarifier

| | HRT [h] | Overflow rate [$m^3$ $m^{-2}$ $h^{-1}$] |
|---|---|---|
| Primary Sedimentation | 1,5 – 2,0 | 0,8 - 1,2 |
| Primary Sedimentation upstream the Trickling filters | 3,0 – 4,0 | 0,5 - 0,8 |
| Secondary Sedimentation downstream the Trickling filters | 3,0 | 0,5 - 0,8 |
| Secondary sedimentation | 3,0 | 0,5 |

Basically, in a primary clarifiers, removal efficiency for BOD and TSS are mainly related to the HRT and the its influent concentration

# Sedimentation

| **_Problem_** | Sludge floating on water surface | Low efficiency in floating solids removal |
|---|---|---|
| **_Evidences_** | • Solids on water surface<br>• $H_2S$ odour | • Floating solids in the effluent from the settler |
| **_Causes_** | • Rising sludge due to high retention time in the settler (also in parts of the tanks) | • Floating solids (oils and scums) removal devices do not work properly |
| **_Tests-Analysis_** | • Measure SST in the extracted sludge<br>• Check the sludge extraction devices<br>• Check dead zones in the settler | • Measure the oil content in different WWTP sections<br>• Check the removal devices |
| **_Actions_** | • Increase the sludge extraction (duration, frequency, flowrate)<br>• Repair or replace the sludge extraction devices | • Install devices to avoid floating solids discharge<br>• Install efficient scum-skimmers<br>• Improve oils removal in primary treatments (floatation) |

# Sedimentation

| | | |
|---|---|---|
| ***Problem*** | Sludge in the effluent | Floating sludge in the settler |
| ***Evidences*** | • Too high SS in the effluent | • Too high SS in the effluent<br>• Evidence of floating sludge |
| ***Causes*** | • Not floc-structured sludge (bulking)<br>• Too high Hydraulic Load<br>• Failures in the sludge extraction devices | • Denitrification process in the settler |
| ***Tests-Analysis*** | • Measure turbidity and SS in the effluent<br>• Check the sludge extraction flowrate and the proper working<br>• Check the proper weirs design | • Measure nitrite and nitrate coming out from the activated sludge tank<br>• Calculate SRT<br>• Check the air flowrate |
| ***Actions*** | • Improve and modify the biological process avoiding<br>• Modify/Maintain weirs and extraction devices<br>• Increase sludge extraction flowrate | • Move the floated sludge<br>• Reduce the SRT<br>• Improve sludge extraction |

# Activated Sludge

Activated sludge treatment step takes place into **aeration tanks**, whose footprint shape has to be defined according to the aeration devices to be installed.

**Rectangular tanks** have to be realised when diffused aeration devices are installed. When mechanical aeration devices are installed, **circular shapes** can be choosen as well, especially in the case of small WWTPs.

- **Diffused aeration systems** consist of submerged diffusors, air pipes and blowers.
- **Mechanical aerators** can be with vertical axis or horizontal axis; both of them can be classified into submerged and superficial ones.

Basic parameters that characterize the activated sludge process are:

- HRT, Hydraulic Retention Time into the aeration tank
- TSS into the mixed liquor
- Organic Load referred to the biomass
- Volumetric Organic Load
- SRT, Sludge Retention Time
- Recycle Ratio
- Type of flow into the tank (completely stirred, plug flow)
- Aeration System

# Activated Sludge

## Typical operational data for different activated sludge process

| Process | Aeration system | Type of reactor | F/M $\frac{kgBOD}{kgMLVSS\ d}$ | Volumetric loading rate $\frac{kgBOD}{m^3\ d}$ | MLSS $\frac{kg}{m^3}$ | HRT [h] | Solid Retention Time [d] | Air requirement $\frac{Nm^3}{kg BOD_{removed}}$ | Recycle ratio [%] | $BOD_5$ removal efficiency [%] |
|---|---|---|---|---|---|---|---|---|---|---|
| Conventional (complete mix) | Air diffusion or Mechanical aerators | CSTR | 0.2 – 0.6 | 0.8 – 1.9 | 3 - 6 | 3 - 5 | 5 - 15 | 35 | 25 – 100 | 85 – 95 |
| Conventional (plug flow) | Air diffusion or Mechanical aerators | Plug flow | 0.2 – 0.4 | 0.3 – 0.6 | 1.5 - 3 | 4 - 8 | 5 - 15 | 50 - 60 | 25 – 50 | 85 – 95 |
| Extended Aeration | Air diffusion or Mechanical aerators | Plug flow or CSTR | 0.05 – 0.15 | 0.15 – 0.4 | 3 – 6 | 18 – 36 | 20 – 30 | 75 – 110 | 75 – 150 | 75 – 95 |
| Contact stabilization | Air diffusion or Mechanical aerators | Plug flow | 0.2 – 0.6 | 0.9 – 1.2 | 1. – 3<br>4 - 10 | 0.5 – 1<br>3 - 6 | 5 - 15 | 50 | 25 - 100 | 80 – 90 |
| High rate aeration | Mechanical aerators | Plug flow or CSTR | 0.4 – 1.5 | 1.2 – 2.4 | 4 – 10 | 1 - 3 | 5 - 10 | | 100 - 500 | 75 – 90 |
| Step feed | Air diffusion | Plug flow | 0.2 – 0.4 | 0.6 – 0.9 | 2 – 3.5 | 3 - 5 | 5 - 15 | 30 - 45 | 25 - 75 | 85 – 95 |
| High purity oxygen | Mechanical aerators | CSTR | 0.25 – 1 | 1.6 – 4 | 6 – 8 | 1 - 3 | 8 - 20 | | 25 – 50 | 85 – 95 |

# Activated Sludge

| ***Problem*** | Bulking Sludge | Foaming in the aeration tank |
|---|---|---|
| ***Evidences*** | • Solids in the treated effluent<br>• Filamentous bacteria in the activated sludge | • Foam on the tank surface |
| ***Causes*** | • Biological unit under-loading<br>• Toxic substances in the influent<br>• Insufficient aeration | • Oils, greases and detergents in the influent |
| ***Tests-Analysis*** | • Measure SVI<br>• Microscopic observations<br>• Check the BOD:N:P ratio<br>• Measure T, pH, $O_2$ in the tank<br>• Check the organic load | • Measure tensio-actives<br>• Measure SS and $O_2$ in the aeration tank<br>• Observe *Nocardia* in the sludges |
| ***Actions*** | • Chlorinate the sludge recycling (5-15 $gCl_2$ $kg^{-1}$ SS $d^{-1}$)<br>• Add chemicals<br>• Increase SRT<br>• Inoculate sludge<br>• Realise a selector | • Remove foams mechanically<br>• Use water to remove foams<br>• Add Chlorine in the aeration tank |

# Activated Sludge

| | | |
|---|---|---|
| ***Problem*** | Low oxygen in the tank | Variable organic load |
| ***Evidences*** | • Reduced treatment efficiency<br>• Low oxygen concentration<br>• Bulking and dark sludge | • SVI variability<br>• SRT variability |
| ***Causes*** | • Insufficient aeration<br>• Organic Load fluctuation | • Organic load fluctuations<br>• SSV fluctuation in the aeration tank |
| ***Tests-Analysis*** | • Measure $O_2$ in the tank<br>• Check influent characteristics | • Measure SVI<br>• Measure SSV in the aeration tank<br>• Measure all the flowrates |
| ***Actions*** | • Increase aeration<br>• Install oxygen-based control devices<br>• Increase the aeration tank volume | • Modify plant operation in order to stabilise control parameters (especially SRT) |

# Anaerobic Treatment

The most diffused types of anaerobic reactor are:

- ✓ Anaerobic contact process;
- ✓ UASB (Upflow Anaerobic Sludge Blanket)
- ✓ Upflow and Downflow attached growth processes
- ✓ Fluidized Bed Reactor

Basing on the OLR (Organic Loading Rate) the anaerobic processes can be classified in low rate (up to 5 kg COD $m^{-3}$ $d^{-1}$) and high rate reactors.

Wastewater load and temperature affect the feasibility of wastewater anaerobic treatment. Generally, COD concentration higher than 1550 – 2000 g $m^{-3}$ and reactor temperature in the range of 25-35°C are needed.

The main process control parameters are listed below:

- ➢ Chemical and biological wastewater characteristics
- ➢ Temperature
- ➢ Organic Loading Rate
- ➢ Hydraulic Retention Time
- ➢ Biogas production

# Lagoons

Suspended growth lagoons are shallow earthen basins varying in depth from 1 to 6m.

The **Aerated Lagoons** depth ranges usually between 1.8 and 6m, mixing and aeration is provided through the use of slow-speed surface aerators mounted on floats.
**Non Aerated Lagoons** can be classified in aerobic, facultative and anaerobic lagoons, depending on the main environmental conditions: biological conversion is carried out in aerobic and/or anaerobic conditions.
The aerobic lagoons depth usually ranges between 1 and 1.5m in order to guarantee sufficient oxygen concentration in the water. The anaerobic lagoons are deeper than the others and the main biological conversion is essentially anaerobic.

Typical operational data for different lagoons

| Lagoon | | Depth [m] | OLR [kg $BOD_5$ $ha^{-1}$ $d^{-1}$] | HRT [d] | $BOD_5$ removal [%] |
|---|---|---|---|---|---|
| Aerated | | 1.5 – 6 | | 3 – 10 | 80 – 95 |
| Non aerated | Aerobic | 1 –1.5 | 40 – 120 | 10 – 40 | 80 – 95 |
| | Facultative | 1 – 2 | 20 – 80 | 7 – 30 | 80 – 95 |
| | Anaerobic | 2.5 - 5 | | 20 - 50 | 50 - 85 |

# Lagoons

| | | |
|---|---|---|
| ***Problem*** | Foul smell emanation due to high organic load | Abnormal mosquitoes growth |
| ***Evidences*** | • Foul smell emanation from the lagoon<br>• pH and DO (Dissolved Oxygen) reduction trend | • Mosquitoes presence |
| ***Causes*** | • Biological oxygen demand higher than the available oxygen | • Presence of stagnant water and/or dead zones in the lagoon where a abnormal common weed growth is observed |
| ***Tests-Analysis*** | • Measure the pH and DO | • Observation of weed growth |
| ***Actions*** | • Reduce the organic loading rate<br>• Install suitable aerator, converting the lagoon in an aerated lagoon | • Remove common weed<br>• Use of insecticides (in this case the interruption of the incoming wastewater for 1 –2 days is needed) |