On-site Wastewater Management Training Course

Secondary Treatment

Aerated Wastewater Treatment Systems (AWTS and STS)

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- Mechanical secondary treatment option incorporating aeration
- Replicates treatment processes of larger municipal wastewater treatment plants in small tank(s) suited to domestic setting
- Aerated Wastewater Treatment Systems (AWTS) aka Secondary Treatment Systems (STS) (AS1546.3 2017), are alternatively known as Aerated Treatment Units (ATUs) or Household Package Plants

AS1546.3:2017

Australian Standard AS1546.3:2017 *On-site domestic wastewater treatment units, Part 3: Secondary treatment systems* (Standards Australia 2017) covers:

- Performance criteria / design requirements
- Minimum marking requirements
- Information to be provided with the system
- Product conformity evaluation for type testing

Design Load

AS/NZS 1546.3: 2017 stipulates the following design load characteristics:

- Minimum daily flow of 150 litres per person
- Average daily BOD_5 – 70 grams per person
- Average daily TSS – 70 grams per person
- Average daily total nitrogen – 15 grams per person
- Average daily total phosphorus – 2.5 grams per person

Variety of Systems

- Wide range of older AWTS (AS/NZS1546.3 2008) and newer STS (AS1546.3 2017) designs and configurations (~100 models on AUS market)
- Large number of Australian and overseas manufacturers (~30 manufacturers)
- Some brands and models discontinued
- New brands and models entering market
- Many older systems no longer accredited, but still in operation
- Older systems often modified

Variety of Systems

- Wide variety of systems and processes, but some similarities due to compliance with the Standards
- Some differences between systems accredited under 2008 and 2017 Standards
- Understanding of basic processes is important
- Performance commonly variable
- Many AWTS prove challenging to operate well
- Evidence is that, at any time, >50% of systems may be operating poorly or failing

Configurations

- Most systems comprise 1 or 2 tanks, with between 3 and 6 separate chambers
- The tanks are constructed from either concrete, polypropylene or fibreglass

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The Aims of Secondary Treatment

- Improve effluent quality:
  - To reduce impact on receiving environment
  - To reduce land area required for safe disposal by applying at higher loading rates than Primary treated effluent
- Reduce impact on surface / ground waters
  - By removing pathogens and possibly some nutrients
- Provide reuse water for landscaping

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Treatment Stages

Typically four treatment stages:

- Anaerobic digestion (Primary treatment)
- Aerobic digestion (Secondary treatment)
- Clarification (settling)
- Disinfection

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Anaerobic Digestion / Primary Treatment

- Can be in a separate septic tank or chamber(s) within a segmented single tank system
- Minimum of 24 hours detention required to maximise settling and moderate peak flows
- STS Primary chambers ~2,300L - ~3,500L
- Physical, chemical and biological processes:
  - Sedimentation of solids (sludge layer)
  - Flotation (scum layer)
  - Clarification (partial)
  - Anaerobic degradation of organic material (BOD_5)

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Anaerobic Digestion

- Crust important to maintain anaerobic conditions and prevent the escape of gases and odours
- Avoid damaging crust by directing sludge return to inlet tee

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Sludge Accumulation and Removal

- Sludge accumulates at base of tank
- Progressively reduces the effective capacity of system and will require periodic removal

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Anaerobic Upflow Filter

- Accelerates anaerobic breakdown and methane generation, improves solids stabilisation (e.g. FujiClean ACE1200)

Source: FujiClean

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Sludge Return

- Sludge may be returned from the aeration and/or clarification chamber to the Primary chamber
- Adds to sludge accumulation in Primary
- Assists with de-nitrification
- Return to inlet tee to avoid disturbing crust

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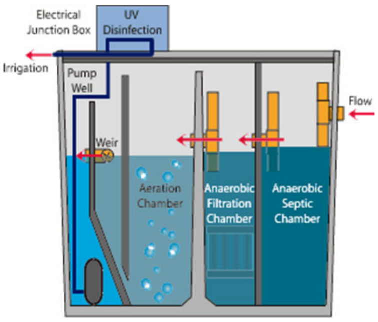
Aeration



Source: AWTS Maintenance Services

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Introduction of Air

- Oxygen supplied by air pump (blower) through air diffuser fixed to bottom portion of chamber
- Introduction of air to the aeration chamber promotes oxidation and microbiological consumption of the organic matter

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Aeration

- Rising bubbles transfer oxygen to the biomass and mix the wastewater to allow maximum contact with treatment surfaces
- Factors impacting aerobic treatment are:
  - Volume of oxygen supplied (need to consider additional non-process requirements such as air lifts)
  - Rate/timing of oxygen supply (variable demand)
- Oxygen transfer efficiency is highly dependent upon diffuser type and bubble size (bubble surface area)
  - Larger bubbles transfer minimal oxygen to the water
  - Fine bubbles transfer up to 80% of the available oxygen to the water column

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Aerobic Processes

- Aeration facilitates the conversion of suspended and dissolved organic materials to energy, biomass and wastes
- Efficient process for the removal of:
  - Carbonaceous organic matter (BOD and TOC)
  - Nutrients (N and P), and for
  - Waste (sludge) stabilisation

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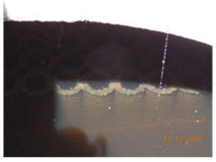
Aerobic Processes

- Can be by way of:
  - Attached Growth Processes
  - Suspended Growth Processes
- Both can achieve a high level of BOD removal

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Attached Growth Processes

- Fixed or Floating Media (FM) systems
- Trickling Filter (TF) systems
- Rotating Biological Contactor (RBC) systems

- Typically require Primary sedimentation to remove coarse solids and avoid clogging
- Systems typically utilise a high surface area media (mineral or synthetic) or discs or drums to support the growth of a biological film (biofilm)

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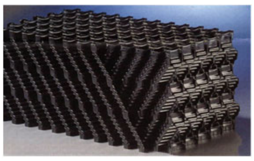
Attached Growth Fixed Media

100-300 m²/m³



125-240 m²/m³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Attached Growth Floating Media

- Predominantly attached growth, but typically a hybrid of suspended / attached growth processes
- Chamber may contain fixed-submerged or free floating media
- Fixed media most common



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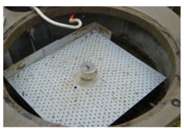
Trickling Filter





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Rotating Biological Contactor



Source: Kingspan

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Attached Growth

- Inert media comprise plastic tubes, sheets or mesh with large surface area / volume ratio
- Microorganisms attach to media to form biofilm
- Wastewater contacts biofilm
- Food is brought to microbes
- Microorganisms consume or convert organic material as part of their metabolic processes
- Attached or 'fixed-film' processes remove fine or dissolved organic matter from wastewater

Attached Growth

- Biofilm consists of aerobic and facultative bacteria, fungi, algae and protozoans
- Worms, larvae and snails may also be present in non-submerged systems

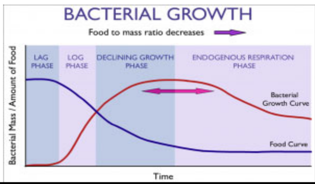


Attached Growth

- Oxygen is provided to the system either passively (Trickling Filter and Rotating Biological Contactor) or mechanically by use of a air pump/blower
- Aerobic process requires a dissolved oxygen concentration (DO) >2mg/L
- Media are self cleansing – excess biological film sloughs off and is transferred to the clarification chamber where it and settles and accumulates

Aerobic Treatment

- Aeration chambers are sized to ensure endogenous respiration occurs
- Over time dead cell mass and residuals will accumulate in the chamber and will eventually need to be removed



Aerobic Treatment

- Most systems rely on continuous flows and have limited ability to buffer flows
- Systems require careful consideration of hydraulic and organic loading rates
- Treated effluent requires clarification to remove sloughed biofilms and residual solids
- Some sludge may be returned to the treatment reactor to assist with denitrification

Aerobic Treatment

- Aerobic treatment can be impacted by a variation in hydraulic or organic loads
- Factors impacting aerobic treatment are:
  - Volume/rate/timing of oxygen supply
  - Food/microorganism ratio (F/M)
  - Temperature and pH
  - Sludge return ratios and wasting (sludge age)
- AWTS experience constant variations in the above factors and can rarely be left as installed

Design/Process Controls

- The air supply and sludge return systems require regular monitoring and adjustment to ensure optimal system performance
- Air-lift transfer at controlled rates is a more common feature of STS, but requires larger air supply
- Higher rate sludge return may be used to “dilute” influent

Nitrogen Removal

- Aerobic processes also convert organic nitrogen and ammonia to nitrate (nitrification)
- Some AWTS are designed to provide denitrification of this nitrate to nitrogen gas
- Denitrification requires high organic content (BOD_5) and anaerobic conditions
- For this to occur the aeration pump must be shut off for extended periods, which can adversely impact on BOD reduction

Design/Process Controls

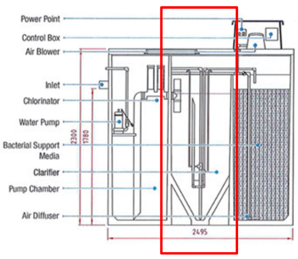
- Two baffled aeration chambers allow managed oxygen control for nitrification and denitrification
- Few STS have defined nutrient reduction levels
- AS1546.3 2017 requires TN<15mg/L, TP<2mg/L
- Certification may state % nutrient reduction (e.g. FujiClean ACE 1200: 79.05% reduction in TN and 14.50% reduction in TP), but removal depends on nutrient concentrations in influent
- Generally no P reduction other than by sedimentation

Clarification

- Provides settling of aerobically treated effluent
- Facilitates solids settling by providing quiescent conditions
- May utilise a funnel (Imhoff) design to concentrate settled sludge and minimise re-suspension
- In smaller systems, WAS is typically directed to the Primary chamber by sludge return (return to inlet tee)
- Skimmer may remove floatable flocs and debris (sometimes to the aeration chamber)

Clarification

- Uses funnel (Imhoff) design to concentrate settled sludge and minimise re-suspension

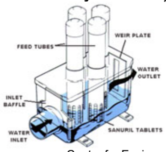


Clarification

- Eventually some sludge will need to be removed from the aeration chamber
- High F/M ratio - more food than microbes - will result in poorer BOD reduction and poorer final effluent quality
- However, some additional food (sludge return) is needed in the aeration chamber to assist with denitrification

Disinfection

- Requires highly clarified effluent
- Disinfection by either:
  - Chlorination (now used in all STS), (requires turbidity <5NTU), or
  - Ultraviolet radiation (requires turbidity <1NTU)



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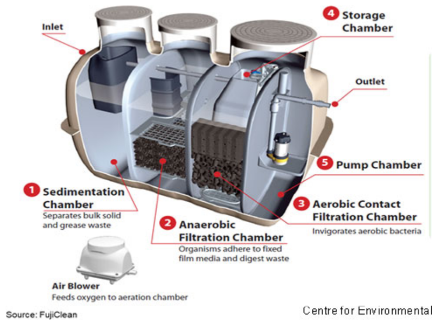
FujiClean CE-1500EX



Source: FujiClean

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Kingspan BioFicient

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Activated Sludge Systems (Aerobic) Suspended Growth

- **Activated Sludge** is the principal aerobic suspended growth process in AWTS
- Blends raw or Primary treated wastewater with a retained population of microbes in suspension in an aerobic reactor (Mixed Liquor)
- Microbes consume or convert organic material as part of their metabolic processes
- Process requires a dissolved oxygen (DO) concentration >2mg/L

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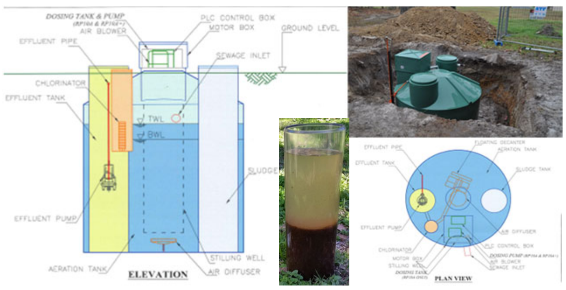
Ozzi Kleen Activated Sludge System



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(Aerobic) Suspended Growth

- Treated mixture requires clarification to remove flocculent microorganisms from the waste stream
- A proportion is returned to the aerobic reactor (Return Activated Sludge)
- Various adaptations to the basic process address issues such as:
  - Nutrient removal
  - Small flows
  - Intermittent or low-strength flows
  - Operational simplicity

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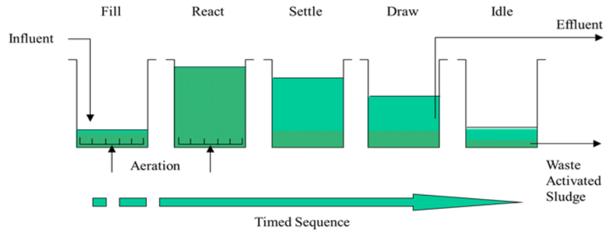
(Aerobic) Suspended Growth

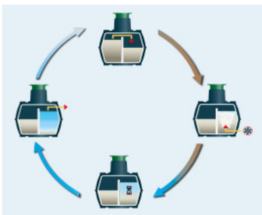
- Process performance can be limited by various environmental and chemical factors:
  - Temperature – cold (slow), warm (fast) metabolism
  - pH – 6.0-9.0, prefer limited variation (6.5-7.5)
  - Available oxygen (DO) – 2mg/L to 3mg/L + mixing
  - Alkalinity – for nitrification (min 50-100mg/L as $CaCO_3$)
  - Essential nutrients – CNP ratio (100:10:1)
  - Inhibiting substances
- Above are rarely managed in domestic AWTS

Sequencing Batch Reactor

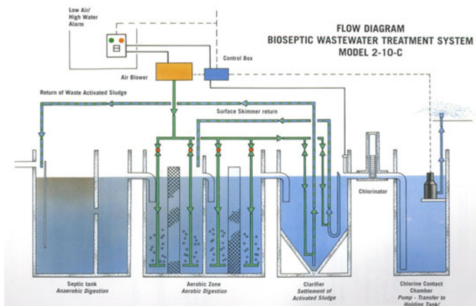


- In a Sequencing Batch Reactor (SBR) a proportion of activated sludge is retained in the tank after decanting

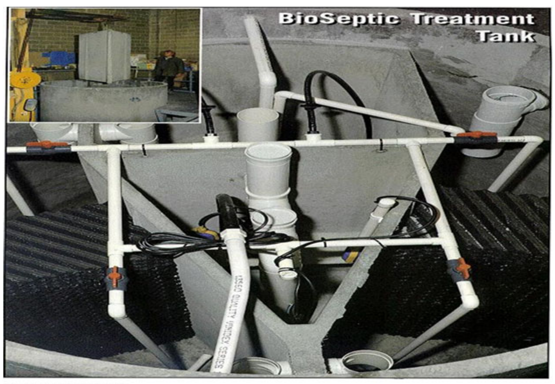
Graf E-Pro SBR



AWTS System Configuration



Source: BioSeptic Pty Ltd



Source: Bioseptic Pty Ltd

AWTS Treatment Summary

- Treatment efficiency is highly dependent on even and constant hydraulic and organic loads
- Domestic wastewater is highly variable in quantity and quality (short and long term)
- AWTS are sensitive to biocides (e.g. bleaches, disinfectants, antibiotics)
- AWTS can remove up to 90% BOD_5 and TSS, but less effective at removal of thermotolerant coliforms
- AWTS do not significantly reduce N or P without careful management and design modifications

Performance Objectives

(90th percentile)

- Biochemical oxygen demand (BOD_5) ≤20mg/L
- Total suspended solids (TSS) ≤30mg/L
- Chlorination (if applied)
  - Thermotolerant bacteria - median ≤10 cfu/100 mL
  - Total chlorine 0.5 – 2.0mg/L

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References

- Standards Australia/Standards New Zealand (2008) AS1546.3:2008 On-site domestic wastewater treatment units. Part 3: Aerated wastewater treatment systems
- Standards Australia (2017) AS1546.3:2017 On-site domestic wastewater treatment units. Part 3: Secondary treatment systems

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