On-site Wastewater Management Training Course

Secondary Treatment

Aerated Wastewater Treatment Systems (AWTS and STS)

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

AS/NZS 1546.3:2017

Australian/New Zealand Standard AS/NZS 1546.3:2017 *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

Variety of Systems

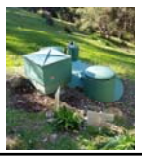
- Wide range of AWTS (AS/NZS 1546.3 2008) and STS (AS 1546.3 2017) designs and configurations (~100 models on AUS market)
- Large number of Australian and overseas manufacturers (~30 manufacturers)
- New brands and models entering market
- Some brands and models discontinued
- Others modified and/or are no longer accredited by the various State government agencies but still in operation

Variety of Systems

- Wide variety of configurations and processes
- Some key similarities due to compliance with the Standards AS/NZS1546:3 and AS1546.3 2017
- 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

AWTS/STS 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



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

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 (DLR/DIR) than Primary treated effluent
- Reduce impact on surface / ground waters
  - by removing pathogens and possibly some nutrients
- Provide reuse water for landscaping

Treatment Stages

Typically four treatment stages:

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

Anaerobic Digestion / Primary Treatment

- Can be in a separate septic tank or a chamber 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
  - Flotation (scum layer)
  - Clarification (partial)
  - Anaerobic degradation of organic material (BOD_5)

Anaerobic Digestion

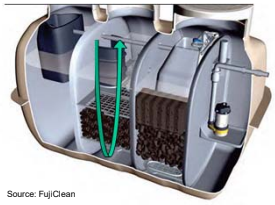
- Crust important to maintain anaerobic conditions and prevent the escape of gases and odours
- Can be disturbed by incorrect sludge return alignment

Sludge Accumulation and Removal

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

Anaerobic Upflow Filter

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



Source: FujiClean

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
- Avoid disturbing scum by returning to inlet tee

Aerobic Processes

- Occur in the presence of free (molecular) oxygen
- Primarily facilitated by bacterial metabolism
- Convert 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

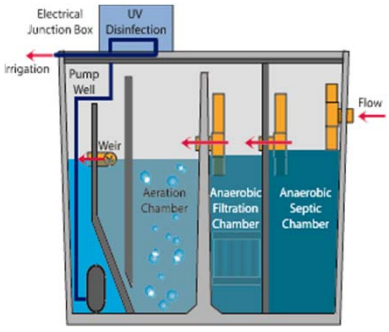
Aerobic Processes

- Two types of process designs:
  - Attached Growth Processes
  - Suspended Growth Processes
- Both can achieve a high level of BOD removal

Aerobic Treatment

- The addition of air to the aerobic chamber promotes oxidation and microbiological consumption of the organic matter and bacteria
- Oxygen supply by aeration (blowers and air diffuser assembly fixed to bottom portion of chamber)

Aeration



Source: AWTS Maintenance Services

Aeration

- Rising bubbles transfer oxygen to biomass and mix the wastewater to allow maximum contact with treatment surfaces
- Factors impacting on aerobic treatment are:
  - Volume of oxygen supplied (need to consider additional non-process requirements e.g. 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

Attached Growth Processes

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

- Typically requires 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)

Attached Growth Fixed Media

100-300 m^2/m^3

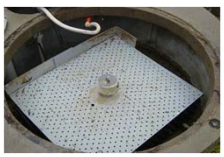
125-240 m^2/m^3

Attached Growth Floating Media

- Predominantly attached growth, but typically a hybrid of suspended / attached growth processes
- Consist of a chamber with fixed-submerged or free floating media
- Fixed media most common

Source: Onsite Consortium

Trickling Filter



Rotating Biological Contactor

Source: Kingspan

Attached Growth

- Wastewater contacts with the biofilm
- Food is brought to microbes
- Microorganisms consume or convert organic material as part of their metabolic processes
- Oxygen is provided to the system either passively (Trickling Filter and Rotating Biological Contactor) or mechanically by use of a blower
- Aerobic process requires oxygen concentration (DO>2mg/L)

Attached Growth

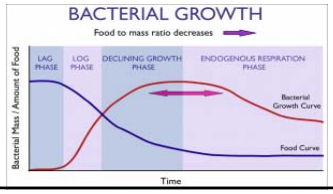
- Biofilm consists of aerobic and facultative bacteria, fungi, algae and protozoans
- Worms, larvae and snails may also be present in non-submerged systems
- Self cleansing – excess biological film sloughs off and settles and accumulates in the clarification chamber
- Must be periodically removed

Microbial Biofilm Growth

- Microorganisms attached to inert media
- Plastic tubes, plastic sheets, mesh with large surface area / volume ratio
- Attached or 'fixed-film' processes remove fine or dissolved organic matter from wastewater

Aerobic Treatment

- Aerobic 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
- Sludge may be proportionally returned to the treatment reactor in submerged and hybrid systems

Aerobic Treatment

- Aerobic treatment can be impacted by a variation in hydraulic or organic loads
- Factors impacting on 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

Design/Process Controls

- Often two baffled aeration chambers allowing managed oxygen control for nitrification and denitrification
- Few STS have defined nutrient reduction levels
- AS1546.3 2017 requires TN<15mg/L, TP<2mg/L
- NSW Health Accreditation for FujiClean ACE 1200 states 79.05% reduction in TN and 14.50% reduction in TP
- Generally no P reduction other than by sedimentation

FujiClean CE-1500EX

Source: FujiClean

Kingspan BioFicient

(Aerobic) Suspended Growth

- **Activated Sludge** is the principal aerobic suspended growth process used 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 positive dissolved oxygen (DO) concentration (DO>2mg/L)

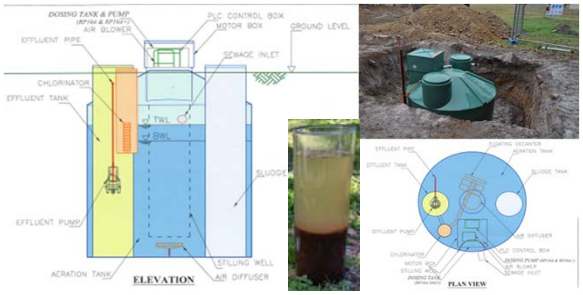
(Aerobic) Suspended Growth

- 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

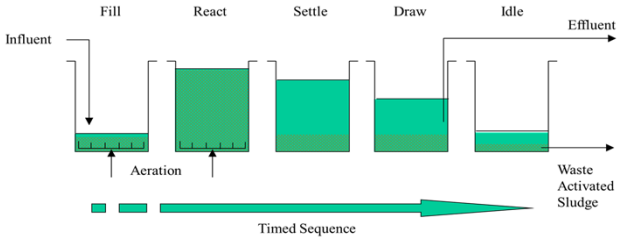
(Aerobic) Suspended Growth

- Process performance can be limited by multiple (environmental or 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

Ozzi Kleen Activated Sludge System

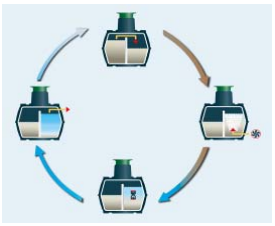


Sequencing Batch Reactor



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

Graf E-Pro SBR



Aerobic Treatment

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

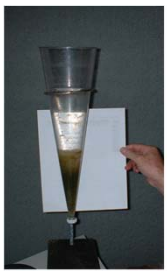
Clarification

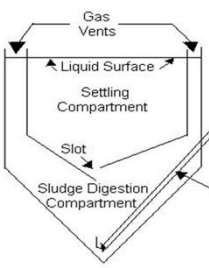
- Provides settling of aerobically treated effluent
- Facilitates solids settling by providing quiescent conditions
- May utilise a funnel (Imhoff) design to concentrate settled sludge and minimise re-suspension
- In smaller systems, WAS is typically directed to the Primary chamber by sludge return (return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

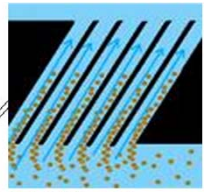
Clarification

- Eventually some sludge will need to be removed from the aerobic 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 aerobic chamber

Clarification

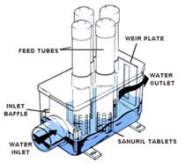




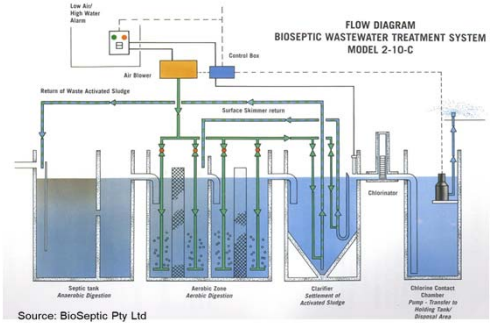


Disinfection

- Disinfection by either :
  - Chlorination (now used in all STS), or
  - Ultraviolet radiation (requires very high clarity)



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
  ≤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

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