On-site Wastewater Management Training Course

## Secondary Treatment Systems

## Aerated Wastewater Treatment Units (ATUs)



## Alternative Terminology

ATUs are alternatively known as:

- Aerated wastewater treatment systems Aerated septic tanks
- Home aeration plants
- Household package plants, or
- Treatment plants
- Sometimes the word “aerobic” is used in place of the word “aerated”



## Aerated Wastewater Treatment Units

- Adopt treatment process utilised in larger wastewater treatment plants
- Design attempts to replicate these
- Larger wastewater treatment plants more frequently monitored and adjusted
- ATUs infrequently serviced (quarterly)
- ATUs performance commonly variable
- Challenging to operate



## AS/NZS 1546.3:2008

Australian/New Zealand Standard AS/NZS 1546.3:2008 *On-site domestic wastewater treatment units, Part 3: Aerated wastewater treatment systems* (Standards Australia 2008) covers:

- Performance criteria
- Design requirements
- Minimum marking requirements



## Variety of Systems

- Wide range of commercial ATU designs and configurations
- Large number of Australian and overseas manufacturers
- Some brands and models discontinued, others modified and/or are no longer accredited by the various State government agencies



## Variety of Systems

- Wide variety of configurations and processes
- Understanding of basic processes is important
- Some key similarities due to compliance with the Standard AS/NZS1546:3
- Most systems are 1 or 2 tank attached growth systems, with some exceptions

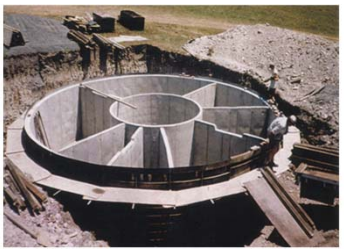
## ATU Configurations

- Typical ATUs may comprise between 3 and 6 separate treatment process chambers
- The chambers may be contained within either a single (integral) or multiple (modular) vessel design
- Typically the vessels are constructed from either concrete, fibreglass or polypropylene



## AWU Configurations

Modular design



Integral design



## Design Load

AS/NZS 1546.3: 2008 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 and apply at higher loading rates (DLR/DIR) when compared to primary treated effluent
- Reduce impact on surface / ground waters
  - Remove/reduce nutrients and pathogens
- Provide reuse water for landscaping or other purposes



## Secondary Treatment Processes

**Physical**

Gravity Separation
Clarification
Flotation

Filtration
Packed Bed filters
Membranes

Adsorption
Amended materials

**Biological**

Aerobic
Suspended growth
Attached growth

Combined
BNR

Lagoons
Facultative

Natural Systems
Wetlands and Aquatic systems

**Disinfection**

Chlorine
Ultraviolet
Ozone

**Solids Management**

Sludge Management
Solids Handling



## Treatment Stages

Four stages:

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

## Biological Treatment Processes

Anaerobic Processes:
- Digestion
- Contact

Aerobic Processes:
- Suspended Growth
- Attached Growth



## Primary Treatment

- Can be in a separate septic tank or a chamber within a single tank system
- Minimum of 24 hours detention time to maximise settling and moderate peak flows
- Physical, chemical and biological processes:
  - Sedimentation of solids
  - Flotation (scum layer)
  - Clarification
  - Anaerobic degradation of organic material ($BOD_5$)



## Sedimentation / Flotation

- Achieved by density settling in quiescent tank
- Surge flows should be avoided
- Aided by flocculation
- Sludge accumulates at base of tank or chamber
- Periodically requires pumpout
- Scum layer or crust forms at surface
- Forms air tight seal, creates anaerobic conditions
- Prevents escape of gases, reduces odours



## Solids (Sludge) Management

- Processes described previously all produce waste solids (grit, screenings, scum, solids and biological material) commonly referred as sludge
- The quantity of sludge produced depends on the load and treatment processes
- Sludge generally removed from domestic ATUs by suction tanker and disposed of to licensed facility (STP)



## Anaerobic Degradation

- Anaerobic processes occur in the absence of free (molecular) oxygen
- Scum provides seal to reduce oxygen (air) transfer
- Organic material retained at the base of the tank undergoes facultative and anaerobic decomposition (microbiologically facilitated)
- Three steps – hydrolysis, acidogenesis and methanogenesis

## Anaerobic Degradation

- Organic material is converted to stable compounds and gases (carbon dioxide, methane and hydrogen sulphide) and water
- Retained sludge is mainly ligneous material that is difficult to decompose and will continue to accumulate and gradually reduce the effective capacity of the system
- Requires pH and temperature control to aid methanogenesis (methane production)



## Anaerobic Upflow Filter

Up-flow sludge blanket / fixed-bed process
e.g. FujiClean CE1500



## Sludge Return

- Sludge may be returned from the aeration and/or clarification chamber to the primary chamber
- Useful for addressing high-strength wastes or toxic loads
- Also assists with de-nitrification
- Avoid disturbing scum by returning to inlet tee



## Aerobic Processes

- Aerobic treatment processes occur in the presence of free (molecular) oxygen
- Primarily facilitated by bacterial metabolism and 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 & P), and for
- Waste (sludge) stabilisation



## Aerobic Treatment

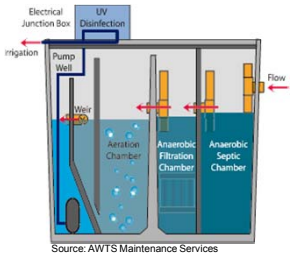
- The addition of air to the aerobic chamber promotes oxidation and microbiological consumption of the organic matter and bacteria
- Two types of process designs:
  - Attached Growth Processes
  - Suspended Growth Processes
- Both achieve a high level of BOD removal



## Aerobic Treatment

- Oxygen is supplied by:
  - Pump (blower) with an air diffuser in the tank
  - Mechanical mixing/ agitation of the effluent
  - Trickling effluent over a porous media (passive)
- Organic matter in the effluent provides food for the aerobic microbes which are suspended or attached to the media
- Oxygen facilitates the conversion of bioavailable organic material to inorganic compounds through microbial respiration

## Aerobic Chamber



Source: AWTS Maintenance Services


Source: Onsite Consortium



## 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
- Most systems rely on continuous flows and have limited ability to buffer flows
- Aerobic treatment can be impacted by a variation in hydraulic or organic loads



## Air Supply

- Oxygen supply by aeration (blowers or air diffuser assembly fixed to bottom portion of chamber)
- Rising bubbles transfer oxygen to biomass and mix the wastewater to allow maximum contact with treatment surfaces

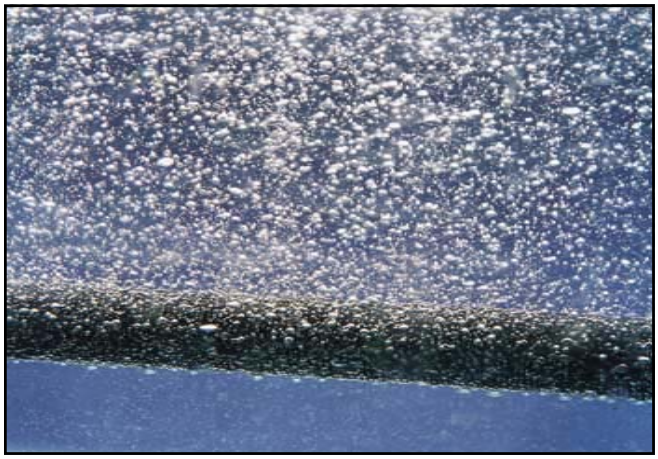


## Aeration

Factors impacting on aerobic treatment are:

- Volume of oxygen supplied
  - Need to consider non-process requirements (air lifts)
- Rate/timing of oxygen supply (variable demand)
- Oxygen efficiency is highly dependent upon diffuser type and air bubble size (surface area)
- Larger air bubbles transfer minimal oxygen to the water….fine bubbles transfer up to 80% of the available oxygen to the water column





## Design/Process Controls

- The air supply and sludge return systems require regular monitoring and adjustment to ensure optimal system performance
- 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)
- ATUs experience constant variations in the above factors and can rarely be left as installed

## Attached Growth Processes

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

- Systems typically utilise a high surface area media (mineral or synthetic) or discs or drum to support the growth of a biological film (biofilm)

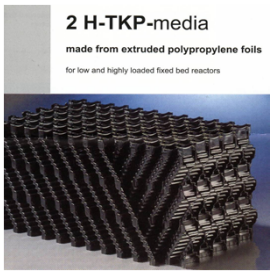


## (Aerobic) Attached Growth

- Attached or 'fixed-film' treatment processes used to remove fine or dissolved organic matter from wastewater
- Facilitated growth of a microbiological film (biofilm) on a fixed or mobile substrate that is either actively or passively aerated
- Commonly encountered process configurations include:
  - Submerged attached-growth
  - Non (or partially) submerged attached-growth
  - Hybrid suspended and attached-growth



## Attached Growth Fixed Media




*125-240 $m^2/m^3$*

*100-300 $m^2/m^3$*



## Microbial 'Biofilm' Growth

- Microorganisms attached to inert media
- Plastic tubes, plastic sheets
- Plastic cells (large surface area / unit volume)



## (Aerobic) Attached Growth

- Wastewater in the treatment reactor contacts with the biofilm
- Biofilm microorganisms consume or convert organic material and other constituents as part of their metabolic processes
- Aerobic process requires a positive dissolved or atmospheric oxygen concentration
- Biofilm consists of aerobic and facultative bacteria, fungi, algae and protozoans
- Worms, larvae and snails may also be present in non-submerged systems



## (Aerobic) Attached Growth

- Systems require careful consideration of media hydraulics (including biofilm) and organic loading rates
- Process typically requires primary sedimentation to remove coarse solids and avoid clogging
- Treated mixture requires secondary settlement (clarification) to remove sloughed biofilms and residual solids from the waste stream
- Sludge may be proportionally returned (RAS) to the treatment reactor in submerged and hybrid systems

## Attached Growth

- Often two baffled aeration chambers allowing managed oxygen control for nitrification and denitrification
- Excessive attached growth will slough off and settle at the bottom of the tank. Must be periodically removed
- Fixed media systems most common design in Australia but do incorporate suspended growth principles ('coupled-contact aeration')



## Trickling Filter / RBC



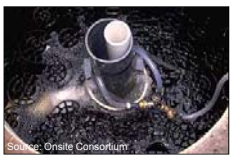
## Attached Growth

- Oxygen provided to the system either passively (Trickling Filter and Rotating Biological Contactor) or mechanically by use of a blower
- Self cleansing – excess biological film sloughs off and settles and accumulates in the clarification chamber
- Food is brought to microbes



## Attached Growth Floating Media

- Typically a hybrid of suspended / attached growth processes
- Consist of a chamber with a fixed-submerged or free floating media



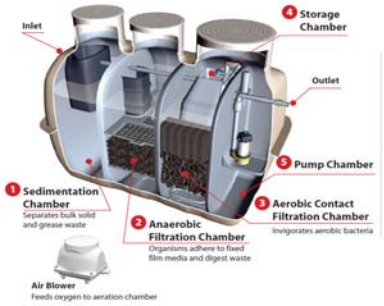



## Attached Growth Systems

| Attached Growth | Media Type |
|---|---|
| Bioseptic Performa | Fixed |
| Earthsafe ES10PC | Fixed |
| Envirocycle 10NR | Fixed |
| Aqua-nova 10EP | Fixed |
| Aqua-nova NR | Fixed |
| Fuji clean model CE1200 | Floating and Fixed |
| Fuji clean model CRX1500 | Floating and Fixed |
| Fuji clean model CE 1500 EX | Floating and Fixed |
| Ultra clear model Ultra10 | Fixed |
| Ultra clear model ST8 | Fixed |
| Ultra clear model ST10 | Fixed |
| Turbojet 2000 | Fixed |
| Krystel Kleer Model ADV5000 | Fixed |
| Biocycle model BIO7000 | Fixed |
| Gardenmaster GM7100 | Fixed |
| Econocycle ENC 10-1 | Fixed |
| Econocycle ENC 10-2 | Fixed |
| Econocycle ENP 10-2 | Fixed |
| Supertreat SE 10 | Fixed |
| Supertreat SB 10 | Fixed |
| Taylex compact | Fixed |
| Taylex ABS | Fixed |



## Floating and Fixed Media




source: www.fujiclean.com.au

## (Aerobic) Suspended Growth

- **Activated Sludge** is the principal aerobic suspended growth process used in ATUs
- Involves blending raw or primary treated wastewater with a retained population of wastewater-consuming microorganisms in suspension within a treatment reactor (Mixed Liquor)
- Wastewater is fed into the reactor and biological populations consume or convert organic material and other constituents as part of their metabolic processes
- Process requires a positive dissolved oxygen (DO) concentration



## (Aerobic) Suspended Growth

- Treated mixture requires secondary settlement (clarification) to remove flocculent microorganisms from the waste stream
- A proportion is returned to the aerobic reactor (Return Activated Sludge)
- There have been a large number of adaptations to the basic process to address issues such as:
  - Nutrient Removal
  - Small flows
  - Intermittent or low-strength flows
  - Operational simplicity



Mirrors processes in large scale STP

## Suspended Growth Performance

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)
- Alkalinity – for nitrification (min 50-100 mg/L as $CaCO_3$)
- Available oxygen (DO) – 2mg/L to 3mg/L + mixing
- Essential nutrients – CNP ratio (100:10:1)
- Inhibiting substances

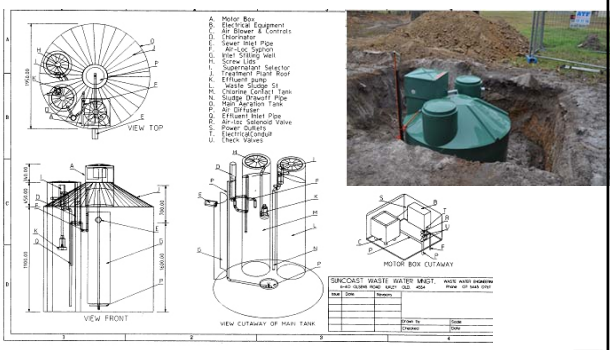


## Suspended Growth 'Activated Sludge'

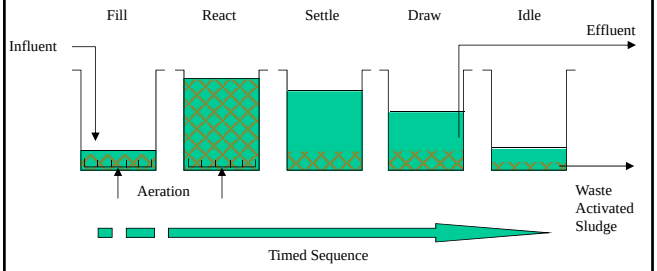
- Blends raw or primary treated wastewater with a retained population of microbes within suspension in an aerobic reactor (Mixed Liquor)
- Food mixed with microbes
- Microorganisms retained in suspension by mechanical mixing or aeration (blowers)
- Sludge return from clarification chamber maintains high microorganism population in aeration chamber
- SBR / IDEA: Proportion of activated sludge retained in tank after decanting



## Ozzi Kleen Activated Sludge

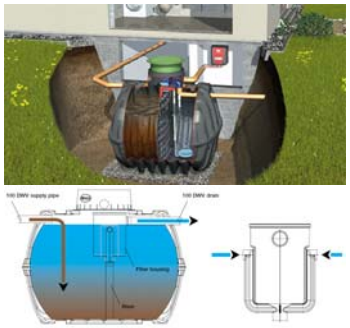


## Sequencing Batch Reactor






## Klaro SBR








## Aerobic Treatment

- Aerobic processes also convert organic nitrogen and ammonia to nitrate (nitrification)
- Some ATUs 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



## 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
- Skimmer for floatable flocs and debris

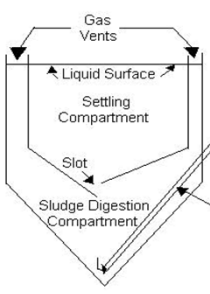


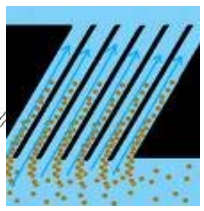
## Clarification

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



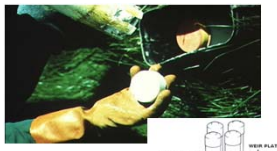
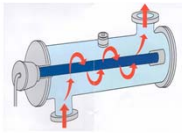
## Clarification

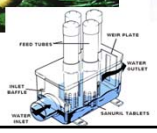


## Disinfection

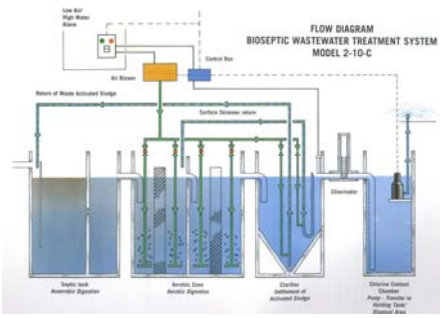
- Disinfection by either :
  - Chlorination (most common)
  - Ultraviolet radiation (gaining acceptance)



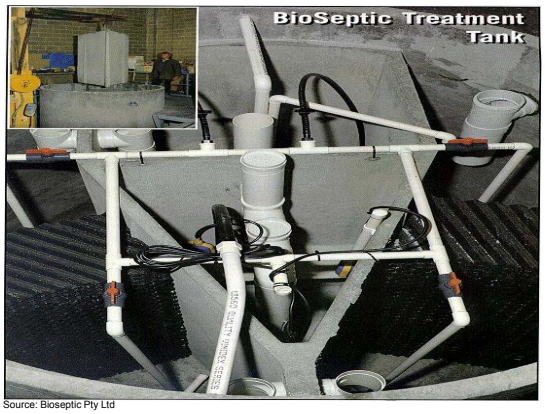



## ATU System Configuration




Source: BioSeptic Pty Ltd






Source: Bioseptic Pty Ltd



## ATU 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)
- ATUs are sensitive to biocides (e.g. bleaches, disinfectants, antibiotics)
- ATUs can remove up to 90% $BOD_5$ and TSS but less effective at removal of thermotolerant coliforms
- ATUs do not significantly reduce N or P without careful management and design modifications



## Performance objectives

***(90th percentile)***

- Biochemical oxygen demand
  - 20 mg/L
- Total suspended solids (TSS)
  - 30 mg/L
- Chlorination (if applied)
  - thermotolerant bacteria - median <10 cfu/100 mL
  - total chlorine > 0.2 – 2.0 mg/L



## ATU New Zealand Trials

Photo: Brent Fletcher