

Secondary treatment – liquid

Biological nutrient removal (BNR)

Wastewater information sheet 4

After primary treatment the waste stream is separated into two components – liquid and solid waste. The liquid stream is conveyed to the reactor/clarifiers for secondary treatment.

Nine reactor/clarifiers make up the secondary treatment system. The circular, doughnut-shaped units comprise an outer reactor section concentrically arranged around an inner clarifier. Each unit is 77 metres in diameter and nearly nine metres high, is able to hold 31.3 million litres of effluent, and is capable of managing the wastewater treatment requirements of a small provincial city or the equivalent of 200,000 people.

As most of the structure is recessed below ground level, the units are much less visually intrusive than the old technology fixed-growth reactors.

The secondary treatment process known as BNR (biological nutrient removal), using activated sludge, is carried out within the reactor/clarifiers. The activated sludge treatment system was first developed

in the UK and is the most widely used sewage treatment process in the world. It relies on the controlled growth of populations of micro-organisms, predominantly bacteria, to biologically strip out organic pollutants and help transform sewage into environmentally acceptable end products. Incoming primary treated effluent is fed into the reactor where it is mixed with activated sludge (sludge that is high in bacteria) which is recycled from the clarifier.

Together this forms what is called a ‘mixed liquor’. The reactor is made up of a series of eight compartments or zones – four aerobic and four anoxic. Each compartment is slightly lower than the preceding one allowing the wastewater to flow from zone to zone. Oxygen levels in the different zones are raised and lowered to select populations of specific bacteria which break down organic pollutants and remove nitrogen. In recent decades, major efforts have been directed towards the control of nutrients using the BNR process.

The heart of the secondary treatment process – three of the nine reactor/clarifiers – showing the outer anoxic and aerobic compartments arranged around a central clarifier



The reactor

Anoxic zones

Primary treated effluent is fed proportionately into the four anoxic zones or compartments (see diagram). Recycled activated sludge is fed into the first anoxic compartment only. The anoxic compartments are not aerated. The low oxygen environment encourages heterotrophic bacteria to use nitrate (NO₃) rather than oxygen (O₂) as the oxygen source for respiration. This process, termed denitrification, results in the conversion of nitrate to nitrites then to nitrogen gas. It also converts the organic (carbonaceous) material in the wastewater to carbon dioxide (CO₂) and cell material for the growing populations of bacteria.

Aerobic zones

Compressed air is injected into the aerobic compartments to raise oxygen levels. The aerobic conditions encourage high levels of autotrophic bacteria which remove organic nitrogen and ammonia from the effluent by converting it to nitrate and water. Heterotrophic bacteria are also present and these convert the organic matter present in the effluent to carbon dioxide and water and to cell material for bacteria. About five percent of the incoming effluent is discharged from the last aerobic compartment as waste activated sludge (WAS). The waste sludge is passed through dissolved air flotation (DAF) thickeners, and proceeds to the gravity belt thickeners to be combined with primary thickened sludge from the gravity thickeners. This blended sludge is then further thickened in the gravity belt thickeners before proceeding to the digesters for treatment.

The clarifier

After it has passed through the anoxic and aerobic compartments in the reactor, the processed effluent flows into the clarifier sedimentation tank where the heavier sludge, including the bacteria and other micro-organisms, settles to the bottom. The settled material, including some residual nitrates, is collected by rotating sweep arms and recycled back to the reactor as returned activated sludge (RAS). This enables the bacteria to go to work again.

Once it has been processed in the clarifier, the clarified wastewater is then allowed to cascade over a notched weir positioned concentrically within the clarifier walls. It then proceeds to the filtration facility where it is passed through anthracite filters and then to the UV disinfection plant where it is treated with ultraviolet light. This eliminates the bulk of remaining bacteria and viruses before it is ultimately discharged into the sea.

Nitrogen in the form of ammonia and nitrate is a pollutant of the coastal marine environment. The discharge of such nutrient material can lead to eutrophication which can stimulate the growth of algae and seaweed. This in turn causes the depletion of oxygen levels which degrades the health and life-supporting capacity of harbour waters. In order to remove biological nitrogen from effluent it is not possible to go directly from harmful ammonia to harmless nitrogen gas. However, under aerobic conditions (in the presence of oxygen) nitrifying bacteria convert ammonia to nitrate and water. In anoxic conditions, bacteria convert the nitrate into harmless nitrites and nitrogen gas. The new treatment process has significantly reduced nitrogen discharges to the Manukau Harbour.

How the reactor/clarifier works.

