

## Keldgate WTW

### innovative ACWA NITREAT™ plant future proofs water treatment works against anticipated increase in nitrate levels

**K**eldgate WTW lies north west of Kingston upon Hull and draws groundwater from natural borehole supplies, within a rural agricultural area identified by Defra as a Nitrate Vulnerable Zone. Recent tests have indicated that the level of nitrate in the water supply for this particular area have been increasing steadily for some time. Whilst nitrate levels are currently acceptable, non-intervention could only result in the levels rising to an un-acceptable 63mg/litre by 2025 - a much higher level than the Prescribed Concentration Value (PCV) of 50mg/litre and a major factor in **Yorkshire Water's** decision to take positive, pre-emptive action.



3-dimensional drawing of new plant

Courtesy of ACWA Services Ltd

The nitrate removal new plant at Keldgate WTW will be the largest of its kind in the UK and forms part of a contract, in excess of £4M, awarded by Yorkshire Water to the civil engineering company, **MMB (Mott MacDonald Bentley) Ltd.** **ACWA Services Ltd** will design and build the NITREAT™ Nitrate Removal Plant, which is scheduled for commissioning towards the end of 2009.

When compared with other more conventional nitrate removal systems, the system makes more effective use of resin, provides lower levels of waste and eliminates process downtime for regeneration, whilst maintaining consistent effluent characteristics. During early off-site performance tests, the effectiveness of the system to produce waste volumes of less than 0.5% of total works output was seen as a significant advantage of the process design.

The NITREAT™ counter-current ion exchange system is an improvement on conventional 'batch' systems, as exhausted ion resin is continuously taken off-line, backwashed, regenerated, rinsed and returned to absorption, with all phases of the cycle occurring concurrently.

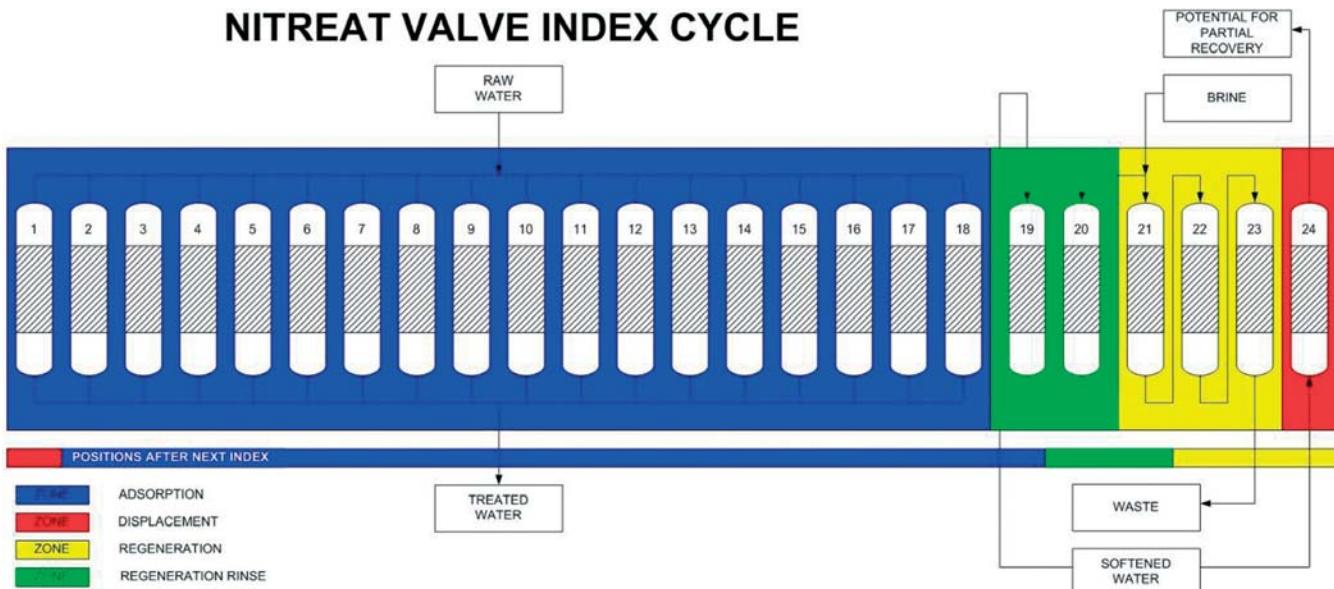
The WTW capacity at the Keldgate site is 90 million litres per day, of which the plant design allows for up to 33 million litres to pass through the nitrate removal system. After reducing nitrate levels to fewer than five parts per million, the treated water will be blended back into the main flow to produce water for public consumption at 42mg/litre. This is well within the limits for drinking water quality and will future proof the system against any anticipated increase in nitrate levels.

#### The NITREAT™ Process

Historically, most conventional nitrate removal systems in the UK have utilised fixed resin beds through which raw water is allowed to pass for defined periods of time - depending on the level of nitrate - before they are taken off-line for regeneration.

In contrast, the new ACWA NITREAT™ system uses a number of smaller vessels in parallel in which conventional DWI approved nitrate selective resin adsorbs the nitrates from the raw water sources. The vessels are in turn taken off line, backwashed, regenerated and rinsed and returned to service as described below, without interruption to the main process.

## NITREAT VALVE INDEX CYCLE



The NITREAT™ process flow diagram

Courtesy of ACWA Services Ltd

Instead of the more conventional method of packing a single bed with resin (which can often lead to ineffective utilisation of the resin), the system uses a series of smaller resin-filled pressure vessels (columns) in which raw water is more effectively distributed.

This unique system reduces the potential for ineffective distribution, caused by channeling within the vessel, ensuring more complete utilisation of the resin. The depth and volume of each bed is determined by the contact time necessary to kinetically adsorb nitrates and also to provide complete regeneration of the resin.

The system design ensures that pressure drops across the bed remain appropriately low enough to provide the resin with adequate protection. Exhausted resin is continuously taken off-line, backwashed, regenerated, rinsed and returned to adsorption - all of the processes occurring concurrently. The regeneration process itself provides a progressive increase in brine strength as the regeneration proceeds.

### Operation and Control

In each stream, the patented multi-port distributor valve connects to (and from) the twenty-four resin vessels. A rotating process disc within the valve moves (indexes) at regular intervals to change the 'process position' of each vessel (NB – the physical position remains unchanged).

A complete 360 degree rotation of the valve disc equates to a process cycle (which may well exceed 24 hours). The actual duration is re-calculated by a PLC after each 'index' of the valve according to the nitrate level in the raw feed water and the main works flowrate. As the process progresses, each of the vessels remain in position for the calculated period of after which the valve disc rotates 15° to re-distribute the flow. The valve movement takes 10-15 seconds and is known as a 'step'.

### Zones

The four zones of the NITREAT™ process are termed Adsorption, Displacement, Regeneration and Regeneration Rinse. The vessels are arranged equidistant around the multi-port valve, allowing the system to be installed in a relatively small footprint. Within the system, resin regeneration is carried out as part of the complete cycle, providing significant cost-savings by eliminating operator intervention, standby vessels and process downtime.

### The four zones operate as follows:

#### *Adsorption Zone (Process positions No 1 ~18)*

In this zone the resin is loaded with nitrates and other anions (sulphate, bicarbonate) with all eighteen the vessels being operated in parallel.

The main feed ports on top of the multiport valve are connected to the process disc feed channel which is at any time connected to 18 consecutive valve exit ports (18 x vessel feeds). The raw water passes into the valve and out to the top of these 18 vessels and down through the resin.

The Low-Nitrate treated water exits the bottom of the 18 vessels and passes back to the valve through 18 mating inlet ports. These are all connected to the treated water channel within the process disc which directs the flow out through 8" treated water ports on the underside of the valve.

Depending on the works flow and Nitrate loading of the raw water the valve 'Indexes' periodically bringing a new vessel into the zone and moving one out of the zone. An index consists of a precise 15-degree rotation of the process disc within the valve body. No movement is evident externally.

If (for example) the prevailing conditions determine that the valve would index once per 60 minutes and an index is about to occur then it is evident that one of the 18 vessels would have been in the zone for an hour, one for two hours, one for 3 hours,.....and one for 18 hours.

The 'freshest' vessel (most recently moved into the zone) would be producing almost nitrate free water, whilst at the other end of the zone the vessel which has been in the zone longest would be exhausted of nitrate removal capacity and would be producing water with in excess of 10mg/l NO<sub>3</sub>. However as an average over the whole zone the treated water would be <5mg/l NO<sub>3</sub>.

Upon the next multi-port valve index, the 'exhausted' vessel (process position No.1 in the diagram above), saturated with nitrates is moved out of the adsorption zone and into the displacement zone.

#### *Displacement Zone (Position No 24)*

This zone only has one vessel in it at any time and contains resin



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This approach has led to MMB being able to demonstrate capability, expertise and success in a number of substantial infrastructure and non-infrastructure water and wastewater projects for Yorkshire Water.

We're delighted to have been appointed as contractors for the Keldgate Nitrate Removal Scheme.

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saturated with nitrates. The vessel would have been treating raw water for a total of 18 indexes and may have accumulated some debris on the top of the resin during this period. As it passes into the zone the vessel contains raw water, which in the case of Keldgate is relatively high in Hardness salts.

Softened water enters through a port on the underside of the multiport valve. This zone is the only one where the flow from the multiport valve is directed to the bottom of the vessel and has three purposes –

- The upflow configuration partially fluidises the resin bed ensuring that compaction and channeling within the resin bed is minimised ensuring a uniform bed for the next cycle of adsorption.
- The fact that the bed is fluidised ensures that any accumulated debris is backwashed out of the vessels to waste. This contributes to maximising resin life.
- The hard water present in the vessel is displaced by soft water ensuring that in the next zone hardness salts are not precipitated on contact with the brine regenerant. This avoids maintenance downtime for cleaning scaled equipment.

Upon the next multi-port valve index, the ‘backwashed’ vessel, full of clean, soft water is moved out of the displacement zone and into the regeneration zone.

#### **Regeneration & Regeneration Rinse Zones (Position 19~23)**

The remaining 5 vessels are operated in series but are split into two zones. The resin vessels move ‘right to left’ through the 5 available positions, whilst the liquids flow ‘left to right’. This gives the advantage of true counter-current operation improving the utilisation of the brine and allowing for higher resin capacities.

#### **Liquid flow (From 19 through 20, 21, 22, 23 and to waste)**

The soft water rinse flow passes into the top of the multiport valve; through the ‘regeneration rinse’ channel in the process disc; out to the top of the vessel in process position number 19; down through the resin; out of the base of the vessel; back to the multiport valve; back out to the top of the vessel in process position number 20; down through the resin; out of the base of the vessel.

The soft water rinse flow again passes back to the multiport valve at which point it is mixed with a 26% brine stream entering through the top of the multiport valve. The brine flowrate is only half the rinse flowrate and is therefore diluted to 8.66%.

The diluted brine is directed from the valve to the top of the vessel in process position number 21; down through the resin, out through the base of the vessel; back to the multiport valve; back out to the top of the vessel in process position number 22; down through the resin, out through the base of the vessel; back to the multiport valve; back out to the top of the vessel in process position number 23; down through the resin, out through the base of the vessel; back finally to the multiport

valve and passes out to waste via a port on the underside of the valve.

#### **Resin flow (From 23 through 22, 21, 20, 19 and then into position 18 of the adsorption zone)**

The direction of ‘flow’ of the resin is ‘counter’ (ie opposite) to that of the liquids through these two zones.

The exhausted resin moves from the displacement/backwash zone (process position 24) into the regeneration zone passing through process positions 23, 22, 21 and contacting with progressively more concentrated brine solution as it does so. The nitrates, sulphates and other anions present on the resin are replaced with chloride ions.

The waste produced in this zone is predominantly sodium nitrates and sulphates and excess brine. A portion of this effluent (equivalent to the first 15% of the waste flow immediately following each valve index) may be recycled back to the bulk brine tank thereby reducing the amount of brine consumed and the amount of waste produced.

Upon the next multi-port valve index, the ‘fully regenerated’ vessel in process position 21, full of clean brine is moved out of the regeneration zone and into the regeneration rinse zone.

This zone consists of the remaining two process positions and is included to prevent brine from entering the treated water stream. The bulk of the brine is flushed out whilst in process position 20 and whilst in process position 19 the resin is polished to the highest possible quality before moving back into the adsorption zone, minimizing the traditional conductivity ‘spike’ in the treated water.

#### **Waste**

Waste flow from the NITREAT™ process is relatively small due to the recovery and reuse of process streams and is a significant factor in the reduction of disposal costs. As a large proportion of the displacement flow may be recovered, waste effluent mainly comprises the rinse/brine flow, with instrument, self-cleaning filter waste and water softener waste adding a very small fraction to the overall volume. Up to 15% of waste brine may be recovered - the actual fraction being site specific.

The process design is extremely effective with regards to the efficient removal of nitrates, low waste production, low salt usage and low power consumption, requiring low operator intervention on mainly unmanned sites.

A number (>10) of ACWA NITREAT™ Nitrate Removal Systems are already operating successfully in other water companies, including Thames Water and Anglian Water, where in addition to removing nitrates, they are also providing a number of significant cost-effective operational advantages.

**Note:** The editor and publishers wish to thank ACWA Services Ltd for providing the above article for publication. ■



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