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NITROGEN REMOVAL USING TERTIARY FILTRATION

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BACKGROUND

In 2002 both West Hornsby and Hornsby Heights Sewerage Treatment Plants (STP) completed a Biological Nutrient Reduction (BNR) upgrade. Prior to the upgrade the plants were achieving Total Nitrogen (TN) of approximately 25mg/l. The aim of the upgrade was for both plants to achieve a TN of 5mg/l as a 90 percentile in the effluent. Realistically that means the plants have to target a TN of 3mg/l to achieve compliance. Included in the BNR upgrade was the installation of a methanol dosing facility providing an external carbon food source for more removal of TN.

Due to the nature of BNR, process designers were unsure how to combine and quantify the internal organic carbon food source from the fermenter with the methanol in order to achieve desired TN levels. It was up to the production team to test various quantities and dosing points of the Methanol to optimise the best results for nitrogen removal from the wastewater. Both plants were commissioned in June 2002 and after 18 months of process changes the plants were still only achieving approximately 7mg/l of TN in the plant effluent. We were a long way from reaching the goal of the upgrade.

At a similar time a pilot project of dosing methanol to the filters was being carried out at Quakers Hill STP. Although the trail showed some promising results for TN reduction, it had to be abandoned due to the nature of their shallow bed sand filters, which were unable to cope with the added solid production. It was then recommended that further testing be carried out at the Hornsby Plants to see what affects this dosing would have on Dual Media Filters.

In November 2003 both Hornsby plants conducted trials of dosing Methanol to the tertiary filters to determine the ability of the filters to further reduce Nitrogen prior to disinfection.

1.0 PROCESS DESCRIPTION - HORNSBY TREATMENT PLANTS

The Hornsby Treatment plants both operate under a 5 stage modified Bardenpho process which is illustrated in the diagram below.

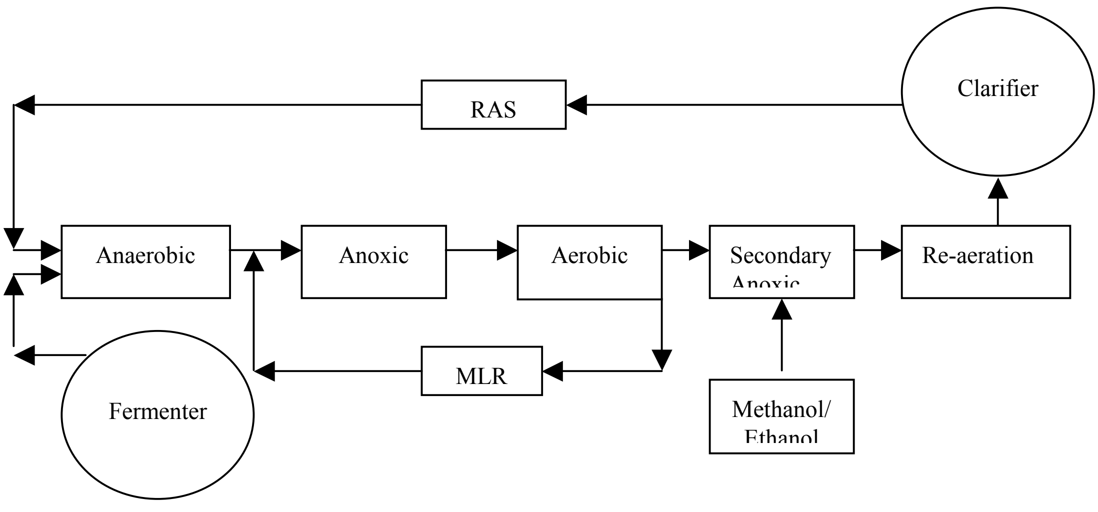

Figure 1: ***5 Stage Bardenpho Biological Nutrient Removal Process- Hornsby Heights STP & West Hornsby STP.***

Primary effluent, fermented sludge and Return Activated Sludge (RAS) mix in the **Anaerobic Zone** which provides an environment free of dissolved oxygen where much of the biological phosphorus release occurs. The flow then enters a three way splitter where Mixed Liquor Recycle (MLR) is returned to the process and flows into the **Anoxic Zone**. This zone provides an environment free of dissolved oxygen where denitrification occurs. Flow then enters the **Aerobic Zone** where the presence of dissolved free oxygen, ammonia and carbonaceous components are biologically oxidised and phosphorous uptake occurs. Within the **Secondary Anoxic Zone** methanol or ethanol is added to provide an external carbon source for denitrification. Flow then enters the **Re-aeration Zone** which provides a small amount of additional nitrification and phosphorus uptake before the secondary clarifiers.

1.1 Tertiary Filters at the Hornsby Treatment Plants

Both Hornsby Heights & West Hornsby have Dual Media filters containing a top layer of Anthracite and lower layers of sand and fine gravels. Figure 2 below illustrates the design process of a Dual Media Filter.

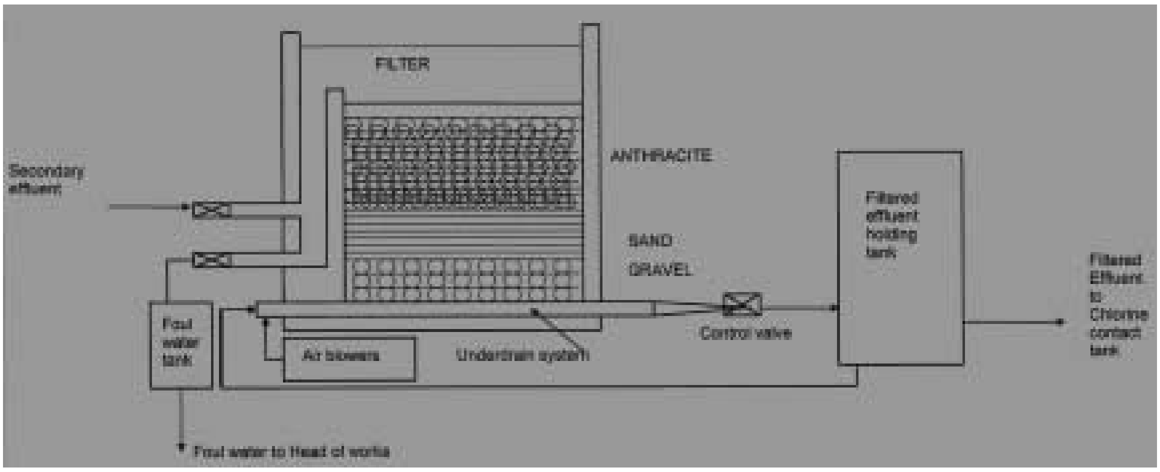

Figure 2: ***Dual Media Tertiary Filtration Process Diagram (West Hornsby UPG).***

The secondary effluent flows from the filter inlet chamber through the filter media. Suspended solids in the secondary effluent are trapped in the filter bed. Effluent then flows through the underdrain to the holding tank then flows to UV disinfection prior to discharge. The filters are regularly backwashed to remove any trapped suspended solids. The suspended solids then drain to the foul water tank and are pumped back to the head of the plant for treatment.

1.2 What is Nitrogen Removal?

Nitrogen removal within wastewater treatment can best be described as a combination of two biological reactions notably nitrification and denitrification. This two step process is achieved by a variety of bacteria that function under different environmental conditions in separate zones within the wastewater treatment facility.

► **NITRIFICATION:**

$NH_3 + O_2 + \text{alkalinity} \longrightarrow NO_3 + \text{newcells} + H_2O$

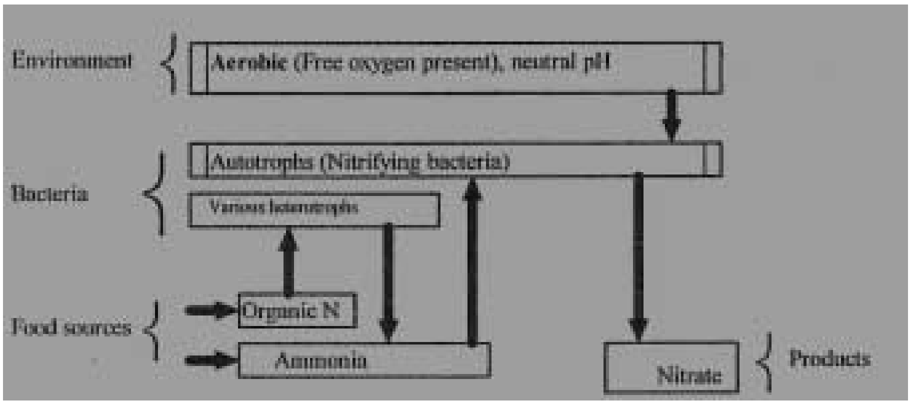

Figure 3: ***Schematic diagram of the nitrification process. (Hornsby Heights BNR UPG).***

Nitrification occurs within the aerobic zone (environment where free oxygen is present). Micro-organisms in activated sludge known as autotrophs (nitrifying bacteria) require this oxygen and alkalinity within the aerobic zone to convert the ammonia into nitrites and then nitrates.

► **DENITRIFICATION:**

$NO_3 + \text{Organic matters} \longrightarrow N_2 + CO_2 + H_2O$

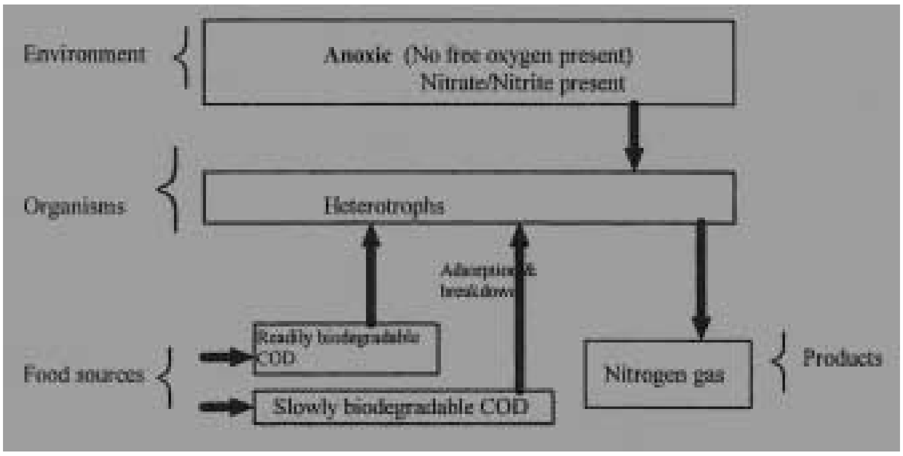

Figure 4: ***Schematic diagram of the Denitrification process. (Hornsby Heights BNR UPG).***

Denitrification occurs in the zone were no free oxygen is available – the anoxic zone. Another group of bacteria known as heterotrophs convert the nitrite/nitrate produced during nitrification to nitrogen gas. As can be seen from figure 4, these bacteria also require a carbon source (food) for this reaction to occur. This carbon food source required for denitrification can be classified as organic carbon i.e. - occurring naturally in sewage or fermented sludge. The other is an external carbon source. At the Hornsby treatment plants this external source of carbon is methanol or ethanol.

The main reason why Methanol or ethanol is a good carbon source is the nature of their chemical makeup. To quote from the US Methanol Institute, "Methanol serves as a carbon source for bacterial bugs. Accelerated by the addition of methanol, anaerobic bacteria convert the nitrate to harmless nitrogen gas, which is vented into the atmosphere".

2.0 HORNSBY HEIGHTS STP

2.1 Procedure

1. To facilitate the trial minor changes were required to the Methanol dosing system
2. Baseline results were determined by analysing the filter effluent for nitrate (NOX) and ammonia over a period of 7 days with no changes to the system. The plant lab is not able to analyse for TN so nitrate level's were used.
3. Commenced with a dose rate of 5 mg/L of methanol to filters flow paced to the primary effluent flow, increasing to 10 mg/L overtime.
4. The time between backwashes of the filters for most of the trial was 18 hours. As the filters were starting to fail the time between backwashes was decreased to 16 hours and then again to 12 hours before ceasing the methanol dose.
5. The parameters kept constant to avoid results being inconclusive were;
    - 30 mg/L of methanol dosed to the secondary anoxic
    - Fermenter sludge age
    - dissolved oxygen levels
    - Alum, SPL and lime dosage rates
    - Mixed liquor recycle rate
    - % availability of equipment
    - Samplers set up to take 4 hourly samples from clarifier effluent and plant effluent (pre and post the filters)

2.2 Results

1. At a dose rate of 5mg/L of Methanol to the filters the NOX results varied showing some decrease but nothing substantial.
2. When the dose rate was increased to 10mg/L an average decrease across the filters was 1.3mg/L
3. Due to the solids increase in the filters the trial had to be abandoned. We were alerted to the problem as the filters were continually backwashing on head loss. We realised that two out of the four filters had not been upgraded for ten years and required sand and media replacement.

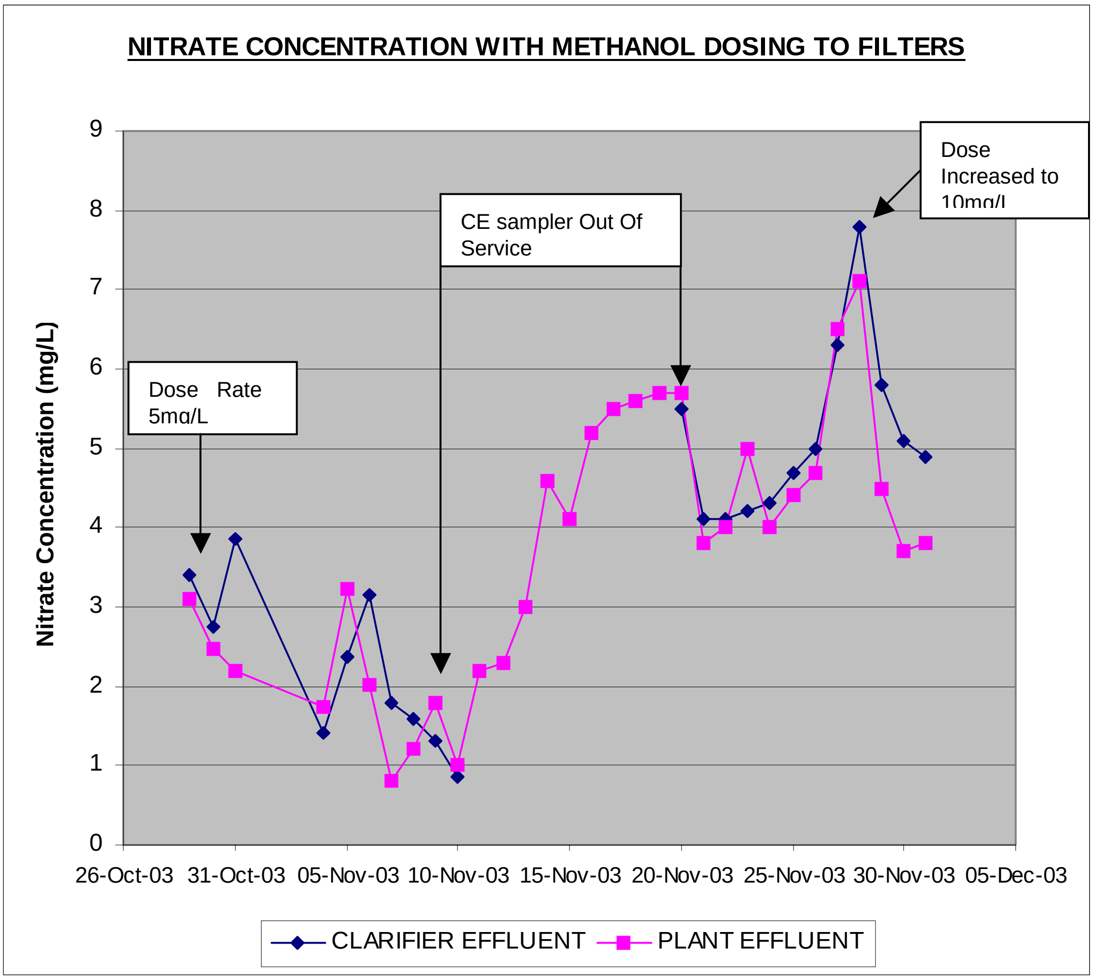

Figure 5: ***Nitrate results for the CE & FE during the Methanol trial at Hornsby Heights STP. (Note: period from 10/11/03 to 19/11/03 problems with CE sampler)***

3.0 WEST HORNSBY STP.

3.1 Procedure

1. Baseline results were determined by analysing the filter effluent for nitrate (NOX) and ammonia over a period of 7 days with no changes to the system. The plant lab is not able to analyse for TN so nitrate level's were used.
2. **All dosing to other points was stopped.**
3. On the 8th of November 2003 the dosing of methanol to the Tertiary Filters began at 5mg/L flow paced to the primary effluent flow.
4. After 7 days the dose rate was increased to 10mg/L for a further 4 weeks.
5. On the 4th of December 2003 the dosing rate was further increased to 15mg/L.
6. On the 17th of December West Hornsby STP received a delivery of ethanol; therefore, the product was a mixture of both methanol and ethanol.
7. **22nd of December dosing restarted to the Secondary Anoxic at 15 mg/L.**
8. During the dosing of Methanol / Ethanol to the Tertiary Filters at West Hornsby STP the backwash time remained at 24 Hours. This was to allow as much biomass growth on the filter bed increasing biological activity thus gaining as much nitrogen removal as possible from the filters within the backwash run time.

9. It must be noted that as well as testing of Nitrates other analysis on Ammonia and COD were carried out. There was no significant variation in these results over the period in which the trial was carried out.
10. Early March 04, dosing to the filters was stopped as the filters became blocked and continually backwashing on head loss.

3.2 Results

1. It was not until the dose rate was increased to 15mg/L that the trial began to show a clear difference between the amount of nitrate recorded in the Clarifier Effluent (CE) compared to the Final Effluent (FE).
2. Approximately one week after dosing was restarted to the secondary anoxic there was a significant reduction in the overall nitrate levels in the plant effluent.
3. The average difference between the nitrate present in CE and that in FE for the period from the 08/12/03 to the 19/01/04 was 2.52mg/L.

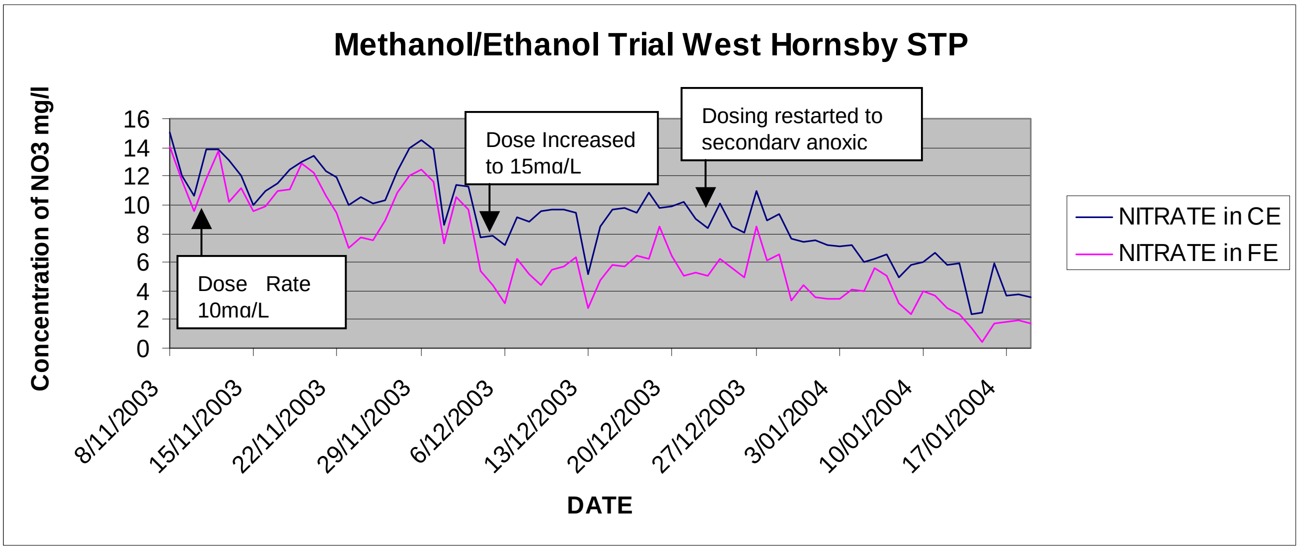

Figure 6: ***Nitrate results for the CE & FE during the Methanol/Ethanol trial at West Hornsby STP.***

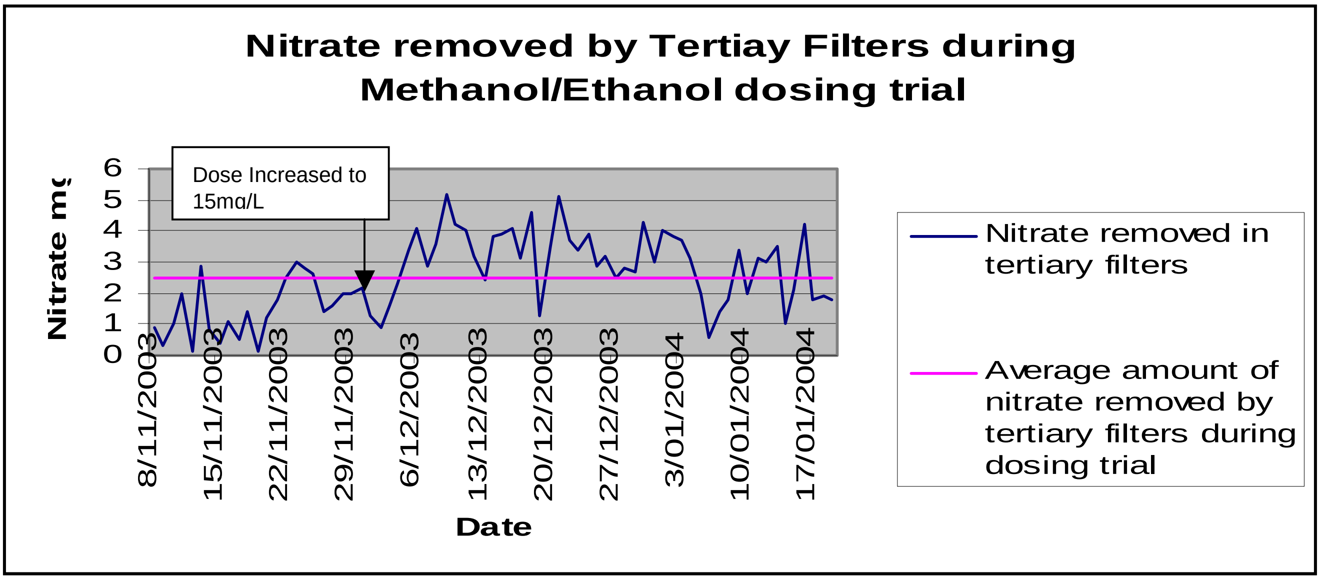

Figure 7: ***Difference between Nitrate present in CE and FE during the methanol/ethanol trial.***

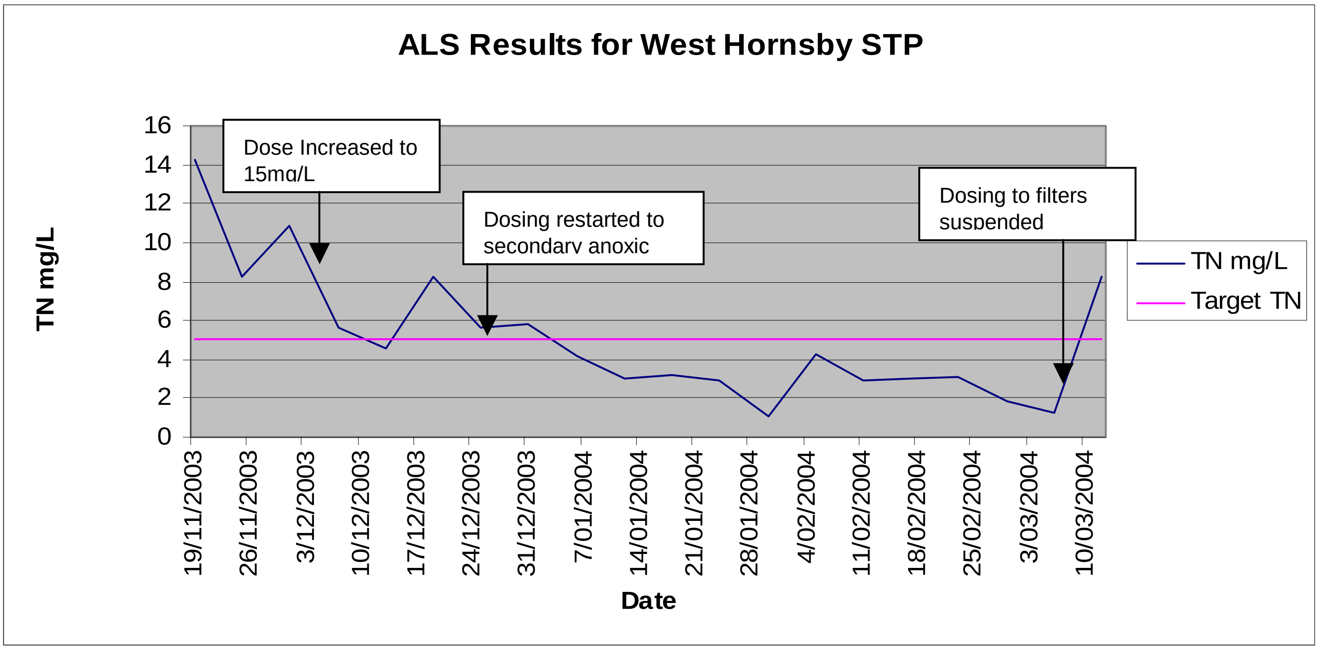

Figure 8: ***EPA Licence results (TN) from the 19/11/03 to the 30/03/04, when methanol/ethanol was being dosed to the Tertiary filters at West Hornsby STP.***

4.0 CONCLUSION

As can be seen from the results at the Hornsby treatment plants the ability to dose methanol or ethanol to the tertiary filters can reduce the nitrogen levels in plant effluent. However, the degree of nitrogen removal is vulnerable to many factors specific to each individual treatment plant or process condition.

Probably the most significant factor that impacts on the nitrogen removal process in the tertiary filters is the capacity and backwash period of the filters.

A problem highlighted at Hornsby Heights STP was that two of its four filters operated poorly and blocked up very quickly with the addition of methanol. Further analysis of these two filters showed that they had approximately 40% less media than the other two filters, consequently these two filters are to be refurbished.

West Hornsby STP with eight slightly larger filters running on a 24-hour backwash time proved that it could remove further nitrogen from the process. However, after a period of time the filters here started to block up and could not function properly. It is widely accepted that perhaps the best way to alleviate the issue of filters blocking up due to biomass growth and increased levels of nitrogen gas accumulation is what is termed a 'bumping procedure' at the filters. This involves aerating the filter media occasionally between backwashes so as to relieve nitrogen gas accumulation and extend the filter run time, thus maximising the filters ability to remove more nitrogen from the process.

This bumping procedure was not carried out at either of the Hornsby treatment Plants as it was uncertain what, if any long-term detrimental effects this may have on a dual media filter. Researching the Internet it was found that several treatment plants in Europe and the US have installed filters (BIOSTYR & BIOFOR) that are specifically configured for nitrogen removal. Methanol addition to the unaerated sections of these filters is suitable for denitrification.

This trial has proven that it is possible to remove nitrogen using tertiary filters. At West Hornsby STP this rate of removal was on average 2.52mg/L between the 8th of December 03 and the 19th of January 04. However, it is recommended further studies be carried out to assess if the additional costs involved in dosing methanol/ethanol to the filters and higher energy consumption with increased backwashing or bumping of the filters is economically viable in terms of process results and plant operations in the long-term.

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6. *West Hornsby/Hornsby Heights- Unit Process Guideline (UPG), Filtration Process.*