TREATING PROCESS REJECT WATER USING THE AMTREAT PROCESS

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Abstract

The Amtreat process is a high-rate activated sludge plant for treating high-strength ammonia liquors with typical ammonia removal rates in excess of 97%. The original Amtreat process was developed in 1992, with the first full-scale plant installed at Cliff Quay STW in 1998 for Anglian Water. The plant was designed for complete ammonia removal. The second plant was installed at Ashford STW in 2008 for Southern Water. This plant was configured for complete ammonia removal and partial denitrification and alkalinity recovery.

ACWA are currently designing three new Amtreat plants for Anglian Water at three advanced digestion sites. The flexibility of the process has allowed two sites to re-use existing assets; including upgrading of the original plant at Cliff Quay. These third generation plants are designed to maximise nitrification, and are designed with glycerol and sodium hydroxide dosing to optimise denitrification and alkalinity recovery.

This paper discusses the development of the Amtreat process, and the design and operation of the Amtreat Plants at Cliff Quay and Ashford.

Keywords

Ammonia Removal, Amtreat, Liquor Treatment, Nitrification, Denitrification, Alkalinity Recovery.

Introduction

Conventional Mesophilic Anaerobic Digestion (MAD) produces a digestate that typically contains aqueous ammonia concentrations of 500 – 1,000 mg/l. If the digestate is dewatered to produce a caked product, the aqueous ammonia will be present in the dewatering process reject water or liquor. This reject liquor may represent 15 to 25% of the load.

As the number of municipal Advanced Anaerobic Digestion (AAD) and commercial Biowaste Anaerobic Digestion (BAD) plants have increased, there has been an associated increase in the ammonia concentrations contained in the process dewatering liquors. At AAD plants, the anticipated concentration of ammonia is in the range 1,500 – 3,500 mg/l, whereas at BAD plants ammonia concentrations in excess of 5,000 mg/l have been encountered.

At municipal Sewage Treatment Works (STW), the traditional treatment strategy for these liquors has been to pass them back to the existing treatment works. However, with the increasing implementation of tighter and total nitrogen limits, and the increasing ammonia concentrations, this practice may not be feasible because such plants often have insufficient nitrifying capacity. Commercial BAD plants tend to be stand-alone plants, so there is not a STW to return the liquors to. Therefore, in both applications there has been a move to treat reject liquors at a separate, dedicated plant.

The ACWA AMTREAT® Process

The Amtreat process was initially developed in 1992 with funding from a consortium of 3 Water Authorities looking for a solution to the problem of nitrifying high strength digested sludge liquors. There were initial pilot-plants located at Manor Farm and Wargrave STWs. In 1995 further research by a 4th Water Authority ratified the process as being a very stable and robust system for the reduction of ammonia in sludge liquors.

The Amtreat process is a high-rate activated sludge plant for treating high-strength ammonia liquors. The compact, high-rate ammonia treatment system has a relatively small footprint compared to conventional activated sludge treatment processes, and full nitrification of high-strength ammonia effluent can be achieved, with typical ammonia removal rates in excess of 97%.

Cliff Quay

The first full-scale plant was installed in 1998 at Cliff Quay STW, Anglian Water. Until 1995, Cliff Quay STW provided primary treatment to an average DWF of 32,500m^3/d from a population equivalent of 145,000. The daily raw sludge production including imported sludges was disposed of to sea. Between 1995 and 1996 the plant was extended to satisfy the requirements of the Urban Wastewater Treatment Directive, and to enable the cessation or marine sludge disposal. A high-rate non-nitrifying activated sludge plant was constructed to treat 3DWF to a consent standard of 175 mg/l BOD, 200 mg/l SS, and 50 mg/l ammoniacal nitrogen. A conventional MAD plant was provided for sludge treatment, followed by dewatering centrifuges. A decision was made to treat the sludge liquors in a dedicated side-stream Amtreat high-rate nitrification process, in order to reduce the concentration of ammonia in the final effluent.

The Amtreat process is a completely-mixed high-rate nitrifying activated sludge plant which is designed to create the optimum environment to ensure that autotrophic organisms dominate the bacterial population. This is achieved by controlling the C:NH_4^+ ratio using sodium hydroxide as a source of additional alkalinity and by controlling the temperature of the reactor. At Cliff Quay the temperature was controlled at the lower end of the mesophilic range (25°C).

Cliff Quay was designed to treat digested sludge dewatering liquors with an ammonia concentration of 1,400 mg/l. The plant achieves complete nitrification of this liquor, producing an effluent less than 5mg/l NH_3-N. Cliff Quay following construction is shown in Figure 1 below.

Figure 1: Cliff Quay ACWA Amtreat Plant

The average BOD and COD removal rates were 75% and 81% respectively, and the plant consistently achieved an ammonia removal in excess of 99% from a feed concentration of 1,200 – 1,400 mg/l, at a loading rate of 0.46 $NH_3/m^3/d$.

A simplified process flow diagram of the Cliff Quay Amtreat plant is shown in Figure 2 below, and the operating and performance data is shown in Table 1.

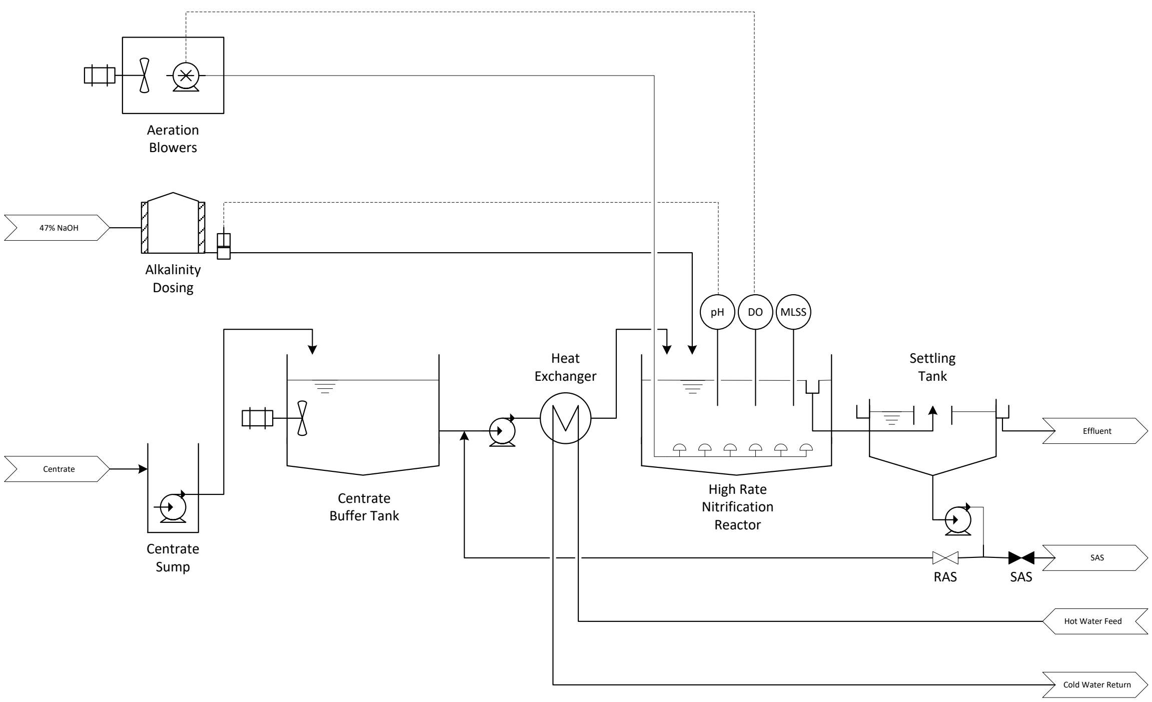

Figure 2: Cliff Quay Amtreat Plant - Schematic

The original plant at Cliff Quay is configured for complete nitrification, and comprises a centrate sump, centrate buffer tank, heat exchanger, Amtreat reactor, final settlement tank; and includes sodium hydroxide dosing as a source of alkalinity; and process heating to maintain the Amtreat reactor at 25°C. The main sewage treatment works at Cliff Quay is a high-rate activated sludge plant, and the Amtreat plant was designed to return a fully nitrified effluent back to the activated sludge plant to reduce the amount of aeration required.

Table 1: Cliff Quay Operating & Performance Data

Amm. N loading (kg $NH_3/m^3/d$)	0.46
Ammonia loading rate (kg NH_3/kg MLSS/d)	0.09
COD loading rate (kg COD/kg MLSS/d)	0.14
Amm. N removal (%)	99.4
Sludge age (d)	21
kg Amm. N removed/kg NaOH added	0.17

Ashford AMTREAT sludge Liquor Treatment Plant

The second Amtreat plant was installed in 2008 by Southern Water at their sludge treatment centre at Ashford. The plant replaced an existing SBR liquor treatment plant, and treats liquors arising from pre-digestion thickening, post-digestion dewatering, and condensate from a sludge dryer.

At Ashford, the SLTP comprises a balance tank with mixing system, hot and cold liquor blending system, and the Amtreat plant. The Amtreat plant is configured for nitrification, partial denitrification and alkalinity recovery; with a pre-anoxic tank for denitrification; the Amtreat reactor for nitrification; and final settlement tanks for solids removal. The plant includes an internal nitrate recycle and RAS recycle to optimise denitrification and alkalinity recovery, which in turn minimises the sodium hydroxide dosing.

The plant is designed to treat the sludge liquors arising from pre-digestion thickening, post-digestion dewatering, and sludge drying. Liquors are produced from the following sources:

- Dewatering centrate
- Condensate
- Centrifuge wash-down
- Cake storage area drainage and other drainage sources
- Gravity belt thickener (GBT) liquors and washwater

The dewatering centrate and condensate liquors are classified as 'hot liquors'. The remaining liquors are classified as 'cold liquors'. The liquors to be treated can vary significantly in volume, strength, and temperature. The production of the liquors can be broadly categorised into the operating scenarios detailed in Table 2 below.

Table 2: Ashford SLTP Design Scenarios

Scenario	Description
1	Maximum dryer rate post maintenance plus liquors from the gravity belt thickeners
1A	Expected dryer performance after maintenance
2	Normal dryer operation
4	Dryer maintenance plus liquors from gravity belt thickeners including centrate
5	Dryer maintenance plus liquors from gravity belt thickeners, no centrate or condensate

The base design of the Amtreat plant was for Scenario 2, which is the normal operating scenario. However, in reality the plant has to treat all the site-wide liquors irrespective of the operating scenario. Therefore, although Scenario 2 formed the basis of design, the final design incorporated the other operating scenarios, with some pragmatic design limits to ensure a robust, yet cost-effective design.

The SLTP is a twin stream system operating at 50% per stream. Each stream is capable of hydraulically treating 100% of the flow for Scenarios 2, 4, and 5. However, for Scenarios 1 and 1A flow conditions, it is not possible to treat the maximum flow through a single stream whilst still maintaining self-cleansing velocities through both streams under normal operating conditions (Scenario 2). Ideally, when Scenario 1 or 1A is the operational scenario, both streams must be in use.

A simplified process flow diagram of the liquor treatment plant is shown in Figure 3 below.

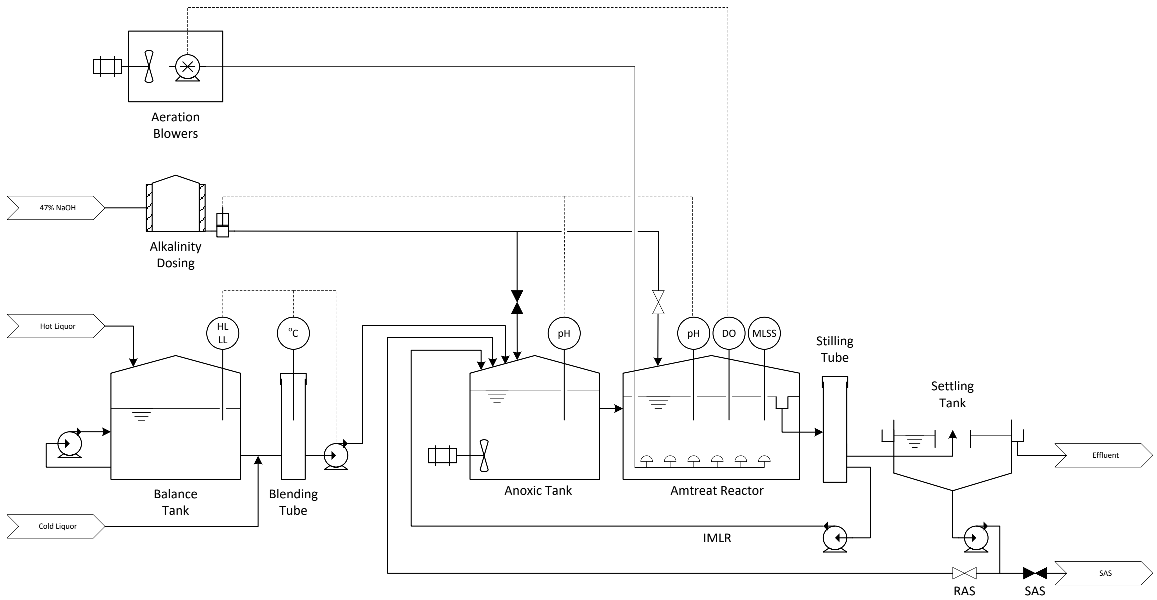

Figure 3: Ashford Amtreat Plant - Schematic

The plant at Ashford is a twin-stream plant configured for complete nitrification, partial denitrification and alkalinity recovery and comprises a hot liquor balance tank, a hot and cold liquor blending tube, 2no. pre-anoxic tanks, 2 no. Amtreat® reactors, 2 no. stilling tubes, an Internal Mixed Liquor Recycle (IMLR), 2 no. settlement tanks, and includes sodium hydroxide dosing as a source of alkalinity.

Ashford Design Flow and Load

The SLTP design flow and loads are detailed in Tables 3 and 4 below.

Table 3: Ashford Design Flows

Scenario	Hot Feed m^3/day	Cold Feed m^3/day	Total LTP feed m^3/day	Total LTP Feed m^3/hr (post balancing)
1	1,779	313	2,092	87.2
1A	1,207	236	1,443	60.1
2	890	313	1,203	50.2
3	650	313	963	40.2
4	---	501	501	20.9

Table 4: Ashford Design Loads

	Unit	Scenario 1	Scenario 1A	Scenario 2	Scenario 4	Scenario 5
Suspended Solids	kg/day	3,624	2,098	2,105	2,081	936
BOD	kg/day	1,118	753	769	731	770
Ammonia	kg/day	1,895	1,064	1,022	927	180
Alkalinity	kg/day	433	2,567	2,331	2,331	327
Phosphorous	kg/day	13	10	8	8	6
pH	pH	7.5	7.5	7.5	7.5	7.5

The hot and cold liquors are blended after the liquor balance tank to control the temperature of the liquor fed to the SLTP. The flow to the SLTP is controlled via two control loops; the first loop is based on the level in the hot liquor balance tank; and the second is based on the temperature in the blending tube. Based on the temperature and flows of the hot and cold liquor, process heating or cooling is not required. The design range was based on a temperature variation of approximately 5 to 36^{o}C, with the pre-construction anticipated temperatures shown in Table 5 below.

Table 5: Temperature of the Blended Liquors

	Scenario 1	Scenario 1A	Scenario 2	Scenario 4	Scenario 5
Minimum	30.22	28.43	23.49	18.25	5
Maximum	32.84	32.38	31.14	26.15	20

The SLTP was designed to meet effluent quality standards of 200 mg/l Suspended Solids, 200 mg/l BOD and 50mg/l Ammonia (95%ile.)

Ashford Process Description

The SLTP comprises of a covered hot liquor balance tank, blending tube, 2 no. covered anoxic tanks; 2 no. covered Amtreat reactors; 2 no. stilling tubes; 2 no. final settlement tanks; and associated pumps, blowers, and instrumentation. The plant is an above ground installation using glass coated steel process tanks. The tanks are accessed via stairs and associated walkways. The access gantry is shown in Figure 4 below.

Figure 4: Ashford SLTP – Tank Access

Balancing and Transfer of Hot and Cold Liquors

The hot liquors are transferred to a hot liquor balance tank (HLBT). The hot balancing system consists of a HLBT complete with jet mixing, blending tube, and forward feed transfer pumps. The HLBT has a working volume 2,800m^3 to balance the average flows produced by the sludge treatment centre over an operating period of 3.5 days per week to feed the SLTP at a constant rate over a 7 day operating week.

Hot liquors from the HLBT are transferred to the blending tube. Cold liquors are introduced to the line feeding the blending tube from the HLBT. Flow meters monitor the flow to the HLBT and hot and cold liquors pumped to the blending tube. Within the blending tube the hot and cold liquors are mixed in the correct proportions to give the optimum flow, load and temperature to feed the SLTP. The blended liquors from the blending tube are transferred by duty / duty / common standby forward feed pumps to the two anoxic tanks.

Anoxic Tanks

Flows from the balancing system are pumped to the anoxic tanks (working volume 150m^3 each) via flow meters in each line. MLSS recycle flows, direct from the stilling tube, and RAS flows, from the final settlement tanks are returned to the anoxic tanks via flow meters in each individual return line.

Sodium hydroxide can be dosed to either the anoxic tanks, or the Amtreat reactors. Selection of the destination tank is made locally by an operator. The addition of sodium hydroxide is controlled on a PID loop, utilizing a pH probe installed in the destination tank. The initial design dosed sodium hydroxide into the anoxic tank. However, post commissioning, the dosing system was modified to include the facility to dose direct to the Amtreat reactors as it allowed better control of pH in the Amtreat reactor. Currently the pH is controlled at pH 6.1 in the Amtreat reactors.

Amtreat Reactors

Liquors from the anoxic tanks gravitate to the two Amtreat reactors. They have a working volume of 1,275 m^3 each, and are each equipped with a fine bubble diffused air system, dissolved oxygen meters, level instrumentation (float switch) and pH / temperature measurement. Air is supplied to the Amtreat reactors via a fine bubble diffused aeration grid consisting of membrane plate diffusers and controlled using dissolved oxygen monitors to a set-point residual dissolved oxygen concentration. The treated liquors from the Amtreat reactors gravitate to two stilling tubes. An internal mixed liquor recycle is taken directly from the stilling tubes and returned to the anoxic tanks for blending with the incoming raw liquors.

Final Settlement Tanks

The treated liquors from the stilling tubes gravitate to the final settlement tanks (FST). The FSTs are equipped with half bridge scrapers and rotation sensors. Treated supernatant (final effluent) from the FSTs gravitates to the main wastewater treatment works. Settled solids from each FST are drawn from the tanks on a regular basis. The return activated sludge (RAS) is returned back to the anoxic tanks. Surplus activated sludge is directed to the sewage treatment works using the same set of pumps.

Chemical Storage

Sodium hydroxide at 47% concentration is stored within a 40m^3 storage tank located in a concrete bund. The storage tank is equipped with an ultrasonic level measurement and thermostatic heater. Dosing pumps transfer the sodium hydroxide solution to either the anoxic tank or Amtreat reactor based on operator selection. Each dosing line is trace heated and lagged and equipped with a flow switch.

The Amtreat plant at Ashford is shown on Figures 5 and 6 below.

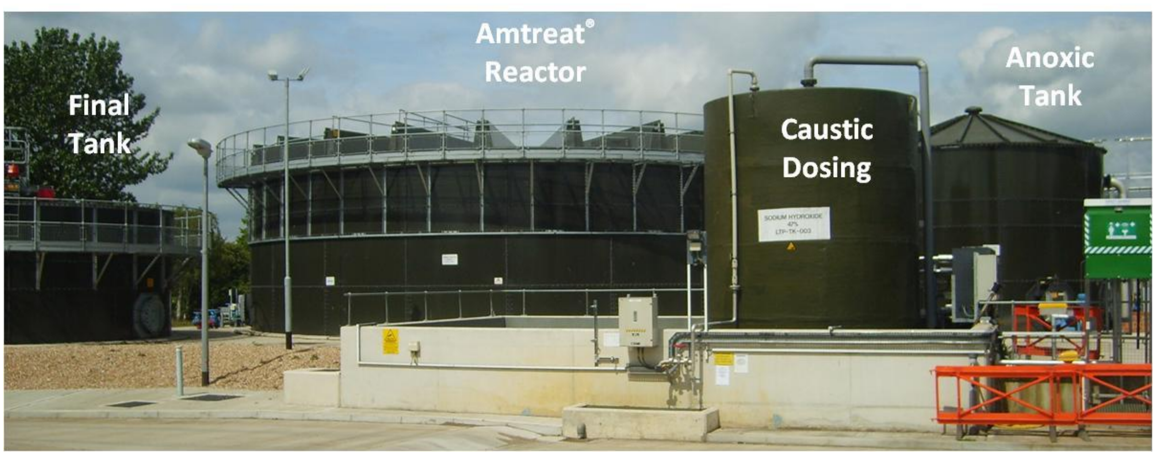

Figure 5: Ashford Amtreat Plant

Figure 6: Ashford Amtreat Plant

The Amtreat process has an optimum operating temperature of approximately 30°C, but is capable of operating across a very wide temperature range. The original plant at Cliff Quay was designed to operate at 25°C, which was a balance between the optimum growth rates of nitrifying bacteria, and the cost of maintaining the process close to that temperature.

Nitrification is an exothermic process, therefore, it generates heat. Therefore, dependant on the influent ammonia concentration and liquor temperature, the process can be self sustaining in heat. At Ashford, given the ammonia concentration and mixture of hot and cold liquors; and unlike Cliff Quay where there was process heating to 25°C, process heating was not required. As the ammonia concentration increases the resultant heat of formation increases, so without the cold liquor, process cooling would have been necessary. The plant at Ashford has been designed with a maximum operating temperature of 36°C.

The plant is configured for nitrification, partial denitrification and alkalinity recovery; with a pre-anoxic tank for denitrification; the Amtreat reactor for nitrification; and final settlement tanks for solids removal. The plant includes an internal nitrate recycle and RAS recycle to optimise denitrification and alkalinity recovery, which in turn minimises the sodium hydroxide dosing. A key design feature of the Amtreat plant is that it is a high-rate activated sludge plant which is simple and robust to operate.

In operating with a conventional nitrifying biomass, it is tolerant of wide variations of flow and load, and it is not dependent on a critical operational balance between the solids retention time (SRT) and hydraulic retention time (HRT); influent ammonia concentration; dissolved oxygen concentration; and reactor temperature.

The robustness and flexibility of the Amtreat process outweigh the stoichiometric benefits short-circuiting nitrification & denitrification practised by other liquor treatment technologies.

Nitrification and Denitrification

The original Amtreat plant was developed in 1992, and designed for complete nitrification; whereas at Ashford, the plant was designed for nitrification, partial denitrification and alkalinity recovery. It includes a pre-anoxic tank for denitrification; the Amtreat reactor for nitrification;

an internal nitrate recycle; a conventional RAS recycle; and sodium hydroxide dosing to supplement the alkalinity.

Recently, a number of alternative high strength ammonia treatment processes have emerged which short-circuit nitrification & denitrification, and claim to be more efficient than conventional nitrification and denitrification processes. However, where the flow, load, and temperature are highly variable, the stoichiometric benefits of short-circuiting nitrification & denitrification are limited in comparison with the requirement for a robust and flexible process. The process of nitrification and denitrification is discussed below.

Nitrification

Nitrification is the term used to describe the two-step biological process in which ammonium (NH_4-N) is oxidised to nitrite (NO_2-N) and nitrite is oxidised to nitrate (NO_3-N).

Nitrification Step 1 – Nitritation

The process of converting ammonium to nitrite:

$$2NH_4^+ + 3O_2 \Rightarrow 2NO_2^- + 4H^+ + 2H_2O \quad (1)$$

Nitrification Step 2 – Nitratation

The process of converting nitrite to nitrate:

$$2NO_2^- + O2 \Rightarrow 2NO_3^- \quad (2)$$

Total Nitrification Reaction

$$2NH_4^+ + 4O_2 \Rightarrow 2NO_3^- + 4H^+ + 2H_2O \quad (3)$$

From equations 1 & 2, it can be seen that three molecules of oxygen per two molecules of ammonium are required during nitritation, and one molecule of oxygen per two molecules of nitrite is required during nitratation.

Denitrification

Denitrification is the term used to describe the biological reduction of nitrate to nitric oxide, nitrous oxide, and nitrogen gas. Biological denitrification is an integral part of biological nitrogen removal, which involves both nitrification and denitrification.

In biological nitrogen removal processes, the electron donor is typically one of three sources: (1) the biodegradable soluble COD in the influent wastewater, (2) the bsCOD produced endogenous decay, and (3) an exogenous source such as methanol (CH_3OH), acetate (CH_3COOH), or glycerol ($C_3H_5(OH)_3$).

Denitrification Step 1 - Denitratation

The process of converting nitrate to nitrite:

$$CH_3OH + 3NO_3^- \Rightarrow 3NO_2^- + CO_2 + 2H_2O \quad (4)$$

or

$$2CH_3OH + 6NO_3^- \Rightarrow 6NO_2^- + 2CO_2 + 4H_2O \quad (5)$$

Denitrification Step 2 – Denitritation

The process of converting nitrite to dinitrogen (nitrogen gas)

$$CH_3OH + 2NO_2^- \Rightarrow N_2 + CO_2 + 2OH^- + H_2O \quad (6)$$

or

$$3CH_3OH + 6NO_2^- \Rightarrow 3N_2 + 3CO_2 + 6OH^- + 3H^2O \quad (7)$$

Overall Denitrification Reaction

The overall process of converting nitrate to nitrogen gas

$$5/6CH_3OH + NO_3^- \Rightarrow 1/2N_2 + 5/6CO_2 + OH^- + 7/6H_2O \quad (8)$$

or

$$5CH_3OH + 6NO_3 \Rightarrow 3N_2 + 5CO_2 + 6OH^- + 7H_2O \quad (9)$$

In comparing the denitrification steps, from equations 5 & 7, it can be seen that two molecules of methanol per six molecules of nitrate are required during denitratation, and three molecules of oxygen per six molecules of nitrite are required during denitritation. The overall denitrification process stoichiometrically requires five molecules of methanol per six molecules of nitrate.

During conventional biological nitrogen removal; ammonium is oxidised to nitrite, nitrite oxidised to nitrate, nitrate is then reduced back to nitrite, and finally nitrite reduced to nitrogen. Therefore, theoretically, from the above equations, processes that short-circuit nitrification-denitrification reduce the oxygen requirement by 25% and carbon requirement by 40%. However, in practice, to take advantage of this reduction in oxygen and carbon it is essential to control the SRT; the HRT; the influent ammonia concentration; the dissolved oxygen concentration; and reactor temperature.

Also where the environment is regularly switching between anoxic and oxic conditions, there is an oxygen removal requirement that is not covered in the above equations, as described below.

Oxygen Removal

$$CH_3OH + 1.5O_2 \rightarrow CO_2 + 2H_2O \quad (10)$$

In an anoxic zone, the available oxygen must first be consumed to a dissolved oxygen concentration of <0.3mg/l so that the bacteria are forced to substitute the nitrite as the electron acceptor and reduce the nitrite to nitrogen gas (Equation 6). Therefore, in order to minimise the external carbon dosing, the initial treatment step should be in the absence of free oxygen.

One of the purposes of the stilling tube is to reduce this dissolved oxygen concentration prior to the flow entering the anoxic zone, in comparison with processes that transfer flows direct from an oxic zone to an anoxic zone.

At Ashford, the flow, ammonia concentration, and liquor temperature are very variable. The design scenarios yield a potential range in ammonia load of 180 to 1,896 kg per day. The design temperature varies from 5 to 33^{o}C, and the design flow varies between 501 and 2,093 m^3/d. Given this wide operational requirement, process robustness, and process flexibility are essential. Under these conditions the robustness and flexibility are more important than theoretical reductions in the process oxygen requirement short-circuiting nitrification and denitrification.

The Amtreat plant has been operating at Ashford since September 2008. The plant was commissioned a stream at a time, with seed sludge being taken from a now redundant liquor treatment SBR. SAS from the SBR was used to seed the first stream. Once the process was stable, mixed liquor was equalised across the two Amtreat reactors, and the feed split between the two streams. Since the initial commissioning of the plant, the performance has been such that Southern Water does not have to monitor the process closely, and the plant operates with minimal operator intervention. Results to date are shown below.

Results

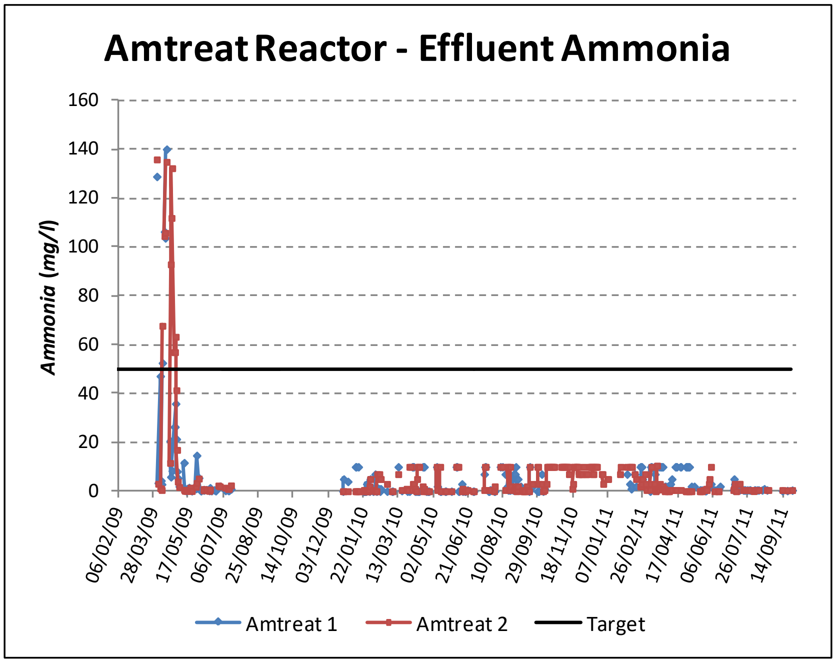

Figure 7: **Amtreat SLTP Effluent Ammonia**

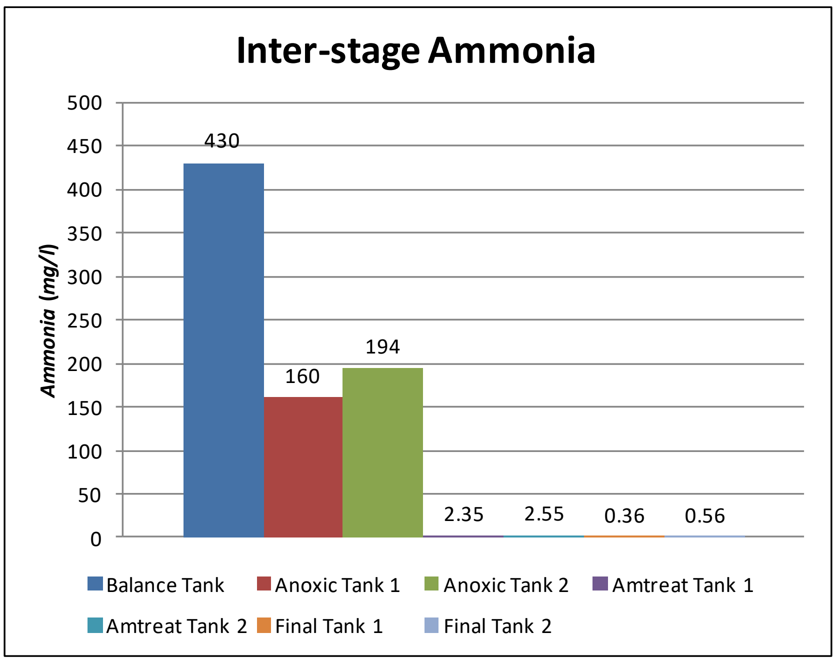

Figure 8: **Inter-stage Ammonia**

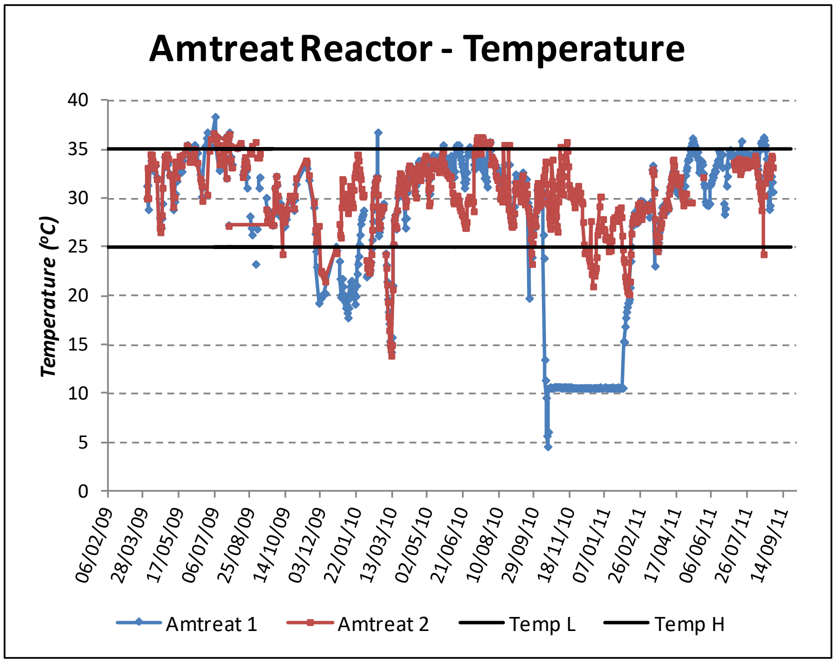

Figure 9: **Amtreat Reactor Temperature**

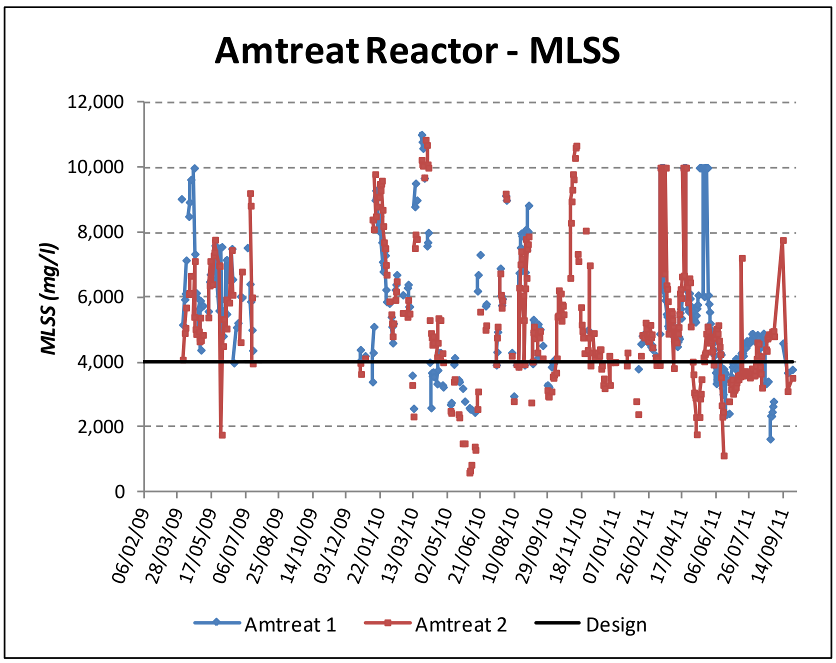

Figure 10: **Amtreat Reactor MLSS**

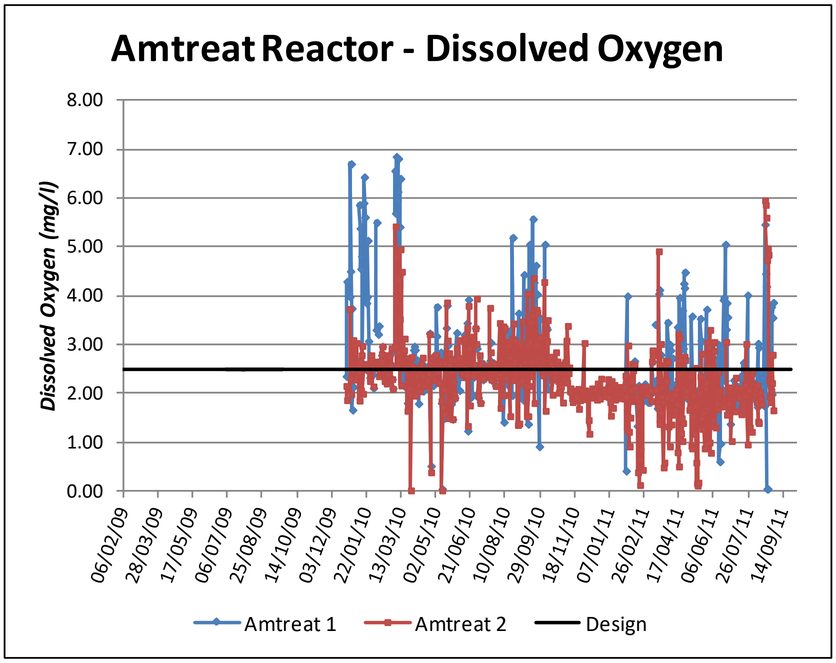

Figure 11: Amtreat Reactor Dissolved Oxygen

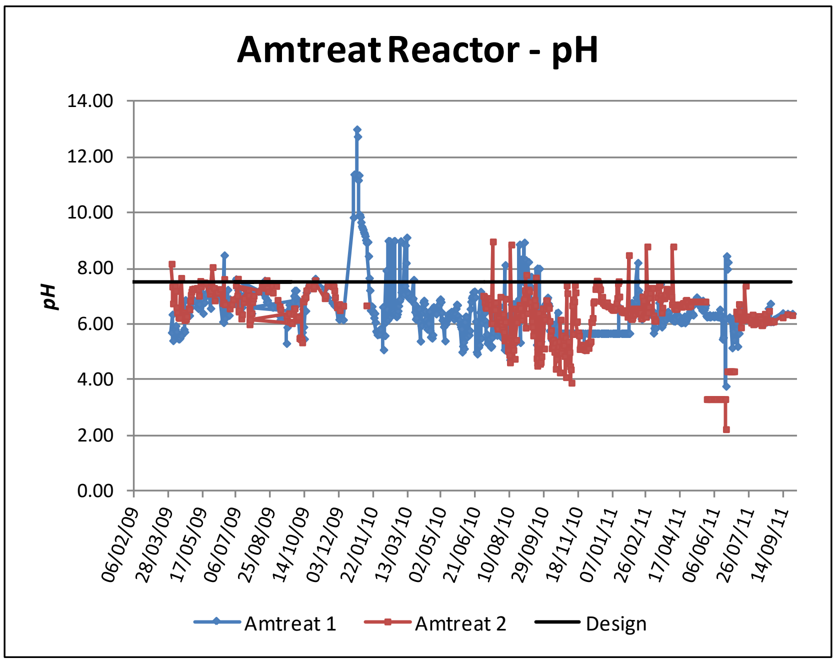

Figure 12: Amtreat Reactor pH

Southern Water monitors the performance of the plant using a combination of spot samples for laboratory analysis, field tests, and continuous instrumentation. Routinely, the effluent quality is monitored using field tests for ammonium, with a range of 0 to 10mg/l NH_4; and the operation of the plant is monitored using fixed instrumentation for flow, pH, temperature, dissolved oxygen, and MLSS.

The normal operation of the plant is not monitored using laboratory analysed samples. There was an intensive period of sampling for laboratory analysis during the performance and reliability tests, and there have been a number of inter-stage sampling campaigns. Other-than-that, the field kits, and continuous data have been sufficient to monitor the operation of the plant.

Effluent Ammonia

Following initial commissioning the SLTP very quickly produced a highly nitrified effluent which was low in ammonia. The design standard for ammonia is 50mg/l. The long-term average (inclusive of all results), are shown in Table 6 below. The long-term feed ammonia concentration is 603mg/l NH_3-N, with a recorded combined effluent average of 3.52mg/l; in excess of 99% ammonia removal.

Inter-stage Ammonia

Southern Water has undertaken a number of inter-stage samples to assess the ammonia removal across the process. The graphical results are shown in Figure 7 above. The average for the sampling campaigns is 430mg/l in the feed liquor, and 0.36mg/l and 0.56mg/l being discharged from FST 1 and FST 2 respectively. Again, like the long-term ammonia removal described above; from the inter-stage sampling campaigns, the ammonia removal efficiency is in excess of 99%.

Temperature

The temperature is controlled by simply blending hot and cold liquors prior to feeding the SLTP. The original design assumed that the action of blending hot and cold liquors would produce blended liquor with a temperature as described in Table 5 above. Within this temperature band the SLTP would be capable of operating without any supplemental heating or cooling. The control philosophy is such that the SLTP feed pumps are inhibited if blended liquor temperature exceeds 35°C.

The hot liquor is already partially cooled before entering the HLBT. However, from the graphical results detailed in Figure 8 above, it is shown that although the liquid temperature in the SLTP is generally within the original design range, it does exceed the design high temperature limit. As a consequence, Southern Water had to make some operational alterations to ensure continuous treatment could be maintained at all times. In the short-term, Southern Water installed a temporary cooling unit to ensure the liquor fed to the SLTP was always below 35°C. As the long-term solution, Southern Water modified the control of the SLTP feed pumps and installed a bypass facility around the SLTP.

The speed of the SLTP feed pumps is proportional to the level in the HLBT. Problems would arise if the discharge from the HLBT was too hot, as the volume of cold liquor required to cool the flow would exceed the hydraulic capacity of the SLTP. To overcome this, Southern Water installed an automated bypass facility around the SLTP, which bypasses a proportion of the liquor flow around the SLTP.

Mixed Liquor Suspended Solids (MLSS)

The MLSS concentration in the Amtreat reactor is highly variable. The long-term average MLSS is 5,498mg/l and 5,257mg/l for Reactors 1 and 2 respectively. The standard deviation for both reactors is 2,000mg/l, indicating the extent of the variation. However, this variation has not caused any operational problems or deterioration in the effluent ammonia concentration. In conjunction with the other results, it does suggest that although the overall performance is very good, there is potential to further optimise the process.

Southern Water is already in the process of optimising the MLSS control. Online MLSS instrumentation was installed at the beginning of 2011. Since then the control of the MLSS has improved significantly.

SAS is wasted from the underflow of the FSTs. The volume of SAS wasted is controlled by setting the run time of the SAS pumps. The run time is set at the HMI, so it is a semi-automated process. The MLSS meters are not used to control the run time, but the operators manually change the run : dwell time of the SAS pumps based on the MLSS reading displayed on the MLSS meters. So although the MLSS control is not fully automated, it has improved significantly since Southern Water installed the MLSS instrumentation. Excessive spikes in the results following the installation of the MLSS meters have been due to instrument failure, and not lack of control of the MLSS level.

Dissolved Oxygen

The long-term average dissolved oxygen concentration in reactor 1 is 2.62mg/l O_2, and in reactor 2 it is 2.31mg/l O_2, which is normal for a nitrifying activated sludge plant. Southern Water has slowly reduced the control set-point without any loss in performance. The initial set-point was 2.5mg/l, but this has been reduced to 2mg/l O_2.

Table 6: Long Term Average (inclusive of commissioning results)

	BOD (mg/l)	COD (mg/l)	NH_3-N (mg/l)	Alkalinity (mg/l)
Feed	547	1,456	603	2,689
FST 1	10.45	154	5.93	52
FST 2	9.03	169	7.2	40
Combined Effluent	19.80	142	3.52	-

pH

From the results graph, it can be seen that the pH is relatively well controlled. Over time, a number of adjustments to the configuration of the sodium hydroxide dosing have been completed which has improved the pH control.

AMTREAT Operation

The ACWA Amtreat® plant in essence is a standard activated sludge plant. There is no specialist or propriety equipment. Therefore, the operation is similar to a standard activated sludge plant. The day-to-day operations normally take about an hour including a daily walk-around to check and record flows, dissolved oxygen concentrations, temperature, pH, and MLSS. Every two-weeks the operator input increases to two-hours for the cleaning and calibration of instruments.

Conclusions

The STW at Cliff Quay treats a population equivalent of 145,000, and the STW at Ashford treats a population equivalent of approximately 97,600. The process reject liquors generated at Cliff Quay have been successfully treated in an Amtreat® Plant since 1998, and at Ashford since 2008.

- The Amtreat Plants treat a variety of high-strength process reject liquors arising from pre-digestion thickening, post-digestion dewatering, and condensate from a sludge drying plant. The liquors fed to the Amtreat Plants are highly variable, with this variance including but not exclusively, the flow, the ammonia concentration, and the temperature.

- Irrespective of the quality and quantity of the liquor fed to the Amtreat plants, the performance has been excellent, with a high-quality treated effluent being reliably produced.

Cliff Quay Amtreat® Plant

- The ammonia removal in the Amtreat Plant exceeds 99%.
- The BOD removal in the Amtreat Plant is 76%.
- The COD removal in the Amtreat Plant is 81%.

Ashford Amtreat® Plant

- The ammonia removal in the Amtreat Plant exceeds 99%.
- The BOD removal in the Amtreat Plant exceeds 96%.

- The COD removal in the Amtreat Plant exceeds 88%.

ACWA are currently designing three new Amtreat plants for Anglian Water at three Advanced Anaerobic Digestion (AAD) sites. The flexibility of the process has allowed two sites to re-use existing assets; including upgrading of the original plant at Cliff Quay. These third generation plants are designed to maximise nitrification, and are designed with glycerol and sodium hydroxide dosing to optimise denitrification and alkalinity recovery.

Acknowledgements

The opinions expressed in this report are those of the author(s), and do not necessarily reflect the views of the organisations involved.

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