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Analysis of Ecocatalyst® Dosing on the Industrial System at GWF

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Executive Summary

A significant layer of fat rich floating debris has formed under the anaerobic reactor covers. This crust layer was being moved 'glacial style' in the direction of the AR flow causing damage to the covers. Ecocatalyst is an enzyme based product which targets fats and has been used to try to remove the crust. Other claimed benefits are increased biogas volume, nutrient liberation and reduced final sludge volume. This report aims to evaluate the effect of this dosing.

Crust

Automated Crust Dosing started on the 9/8/16. This has provided consistent targeting of the crust without the time constraints and OH&S risks of dosing manually. Dosing at the domestic inlet to target fats in the domestic system before they get to the anaerobic reactors appears to be an effective tactic. A distinct thinning of the crust upstream of the first set of hatches has been observed. However, it is possible that the AP Booster pump upgrade has also contributed to this. Dosing directly onto the crust is currently being undertake at hatches 1, 2, and 5/6 (see Figure 2). The crust in this region of the AR's has thinned. It is recommended that the hoses be lengthened to allow for dosing further down the anaerobic reactors.

Measurements of crust depth taken on the 12th April 2016 were markedly worse than previous measurements. This corresponded to the dumping of several ML of Domestic Foam into the AR's. It is observed that the cost of treating this floating foam using Ecocatalyst once it becomes a part of the anaerobic crust is far greater than removal via other methods. It is recommended that domestic foam not be pumped into the anaerobic reactors but rather directed to dewatering if possible. If this is not possible, it is recommended that a sucker truck be used to remove it.

Measurements of the crust is an inexact science, and therefore the measurements are not high confidence. Efforts are continuing to find technologies which will provide a more accurate estimate. Attempts to solubilise the crust using Ecocatalyst only are quite expensive, it is suggested that some system of physical movement (ie water blasting) would assist in reducing the cost of keeping the crust under control.

Biogas

Biogas production has been excellent during the period since continuous dosing commenced. Methane volumes have averaged 1973m^3, compared with 1206m^3 before. Conversion of TOC rates increased to an average of 0.197 m^3/kgC. from 0.132m^3/kgC.

Nutrient Balance

The mean dissolved total nitrogen exiting the AR's before continuous Ecocatalyst dosing was 83.4kg/day. Since continuous dosing it was 138.3kg/day. The amounts of aqua ammonia and phosphoric acid dosed into the MBR have been reduced significantly. On average the volume used before continuous Ecocatalyst dosing was 490L/day of aqua ammonia and 76L/day of phosphoric. In the period since continuous dosing a mean average of 24L/d of aqua ammonia and 2.1L/day of phosphoric acid. This represents a saving o[redacted]per week.

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Abbreviations

AR's	Anaerobic Reactors
APST	Advanced Primary Sedimentation Tank
RLPS	Return Liquor Pump Station
IWAS	Industrial Waste Activated Sludge
FOG	Fats Oils and Grease.

Background

After approximately 3 years of operation of the GWF anaerobic reactors, it became evident that a significant layer of floating debris had formed under the covers. This crust layer was found to have a high Fats, Oils and Grease (FOG) content and to originate from a mixture of sludges. This crust layer was being moved 'glacial style' in the direction of the AR flow.

The destructive potential of this accumulated floating crust layer was demonstrated by significant tension in the north AR cover, with the studs pulling holes in the cover material. In the south reactor, the movement has caught the underside of the hatch flanges (now four) ripping them out. Aside from removing access points to the AR's this presented a OH&S risk.

The thickness of the crust (>3m thick in some spots) resulted in reduced hydraulic volume of the AR's and thus decreased the hydraulic retention time available to process influent.

Crust reduction methods were investigated. This resulted in 'crust busters' being designed and installed at one location in each reactor (see CB in Figure 2 below). However, the use of these was minimal due to the flow limitations the placed upon GWF. Due to the design of the units they placed extra stress on the covers and eventually caused a leak and have been removed from AR2. AR1 crust buster remains in place.

As the crust buster failed to alleviate the problem, alternative approaches were investigated. A product Ecocatalyst, which enzymatically dissolves the FOG was thought to be appropriate to trail. The product claims to target FOG, simultaneously breaking down crust and increasing solubilisation of substrates biogas production.

Ecocatalyst was trialled during May – July 2015. This constituted continuous dosing at the Industrial Inlet, RLPS and manually into the AR hatches on a roughly weekly basis. This period is referred to as the Phase 1 trial. The crust thickness results have been reported informally prior, but are summarised in this report for completeness. Dosing after the cessation of this trial was via the RLPS only and was somewhat sporadic in nature.

Subsequent to hatch dosing ceasing, and the dumping of several ML of domestic foam into the anaerobic reactors a significant crust depth was again detected. A second major effort to was started on 12/4/2015. Dosing into the RLPS commenced and weekly manual covers dosing was targeted. Soon after this an evaluation of time restraints and OH&S risks associated with manual dosing resulted in the recommendation that automated dosing be investigated.

An upgrade to the dosing rig was made to automate the process and it was commissioned on the 9/8/16. Phase 2 crust removal trial commenced with this automated crust dosing and dosing at the domestic inlet (not RLPS). The dosing at the domestic inlet is set at 18L per day (costing $306). The dosing into the crust functions for 5 days a week and uses 36L/day ($3060/week). A total cost per week for Ecocatalyst is $5202.

This report aims to evaluate the outcomes of this Phase 2 period. Data on the crust and anaerobic performance has been collated for the 2014-2017 period.

Appearance of Crust

Figure 1: Appearance of Crust before and after commencement of dosing

When manual dosing of the hatches was first started, the crust was observed to be quite dense and difficult to push a hose into. It also had a very noticeable smell which would normally be associated with putrescent fats. The consistency of the crust is now observed to be significantly more liquid. Very few of the hatches monitored have dense crust. An increasing number contain a well homogenised liquefied crust or sections comprised of seeds and other non-readily degradable substances.

Evaluation of Crust

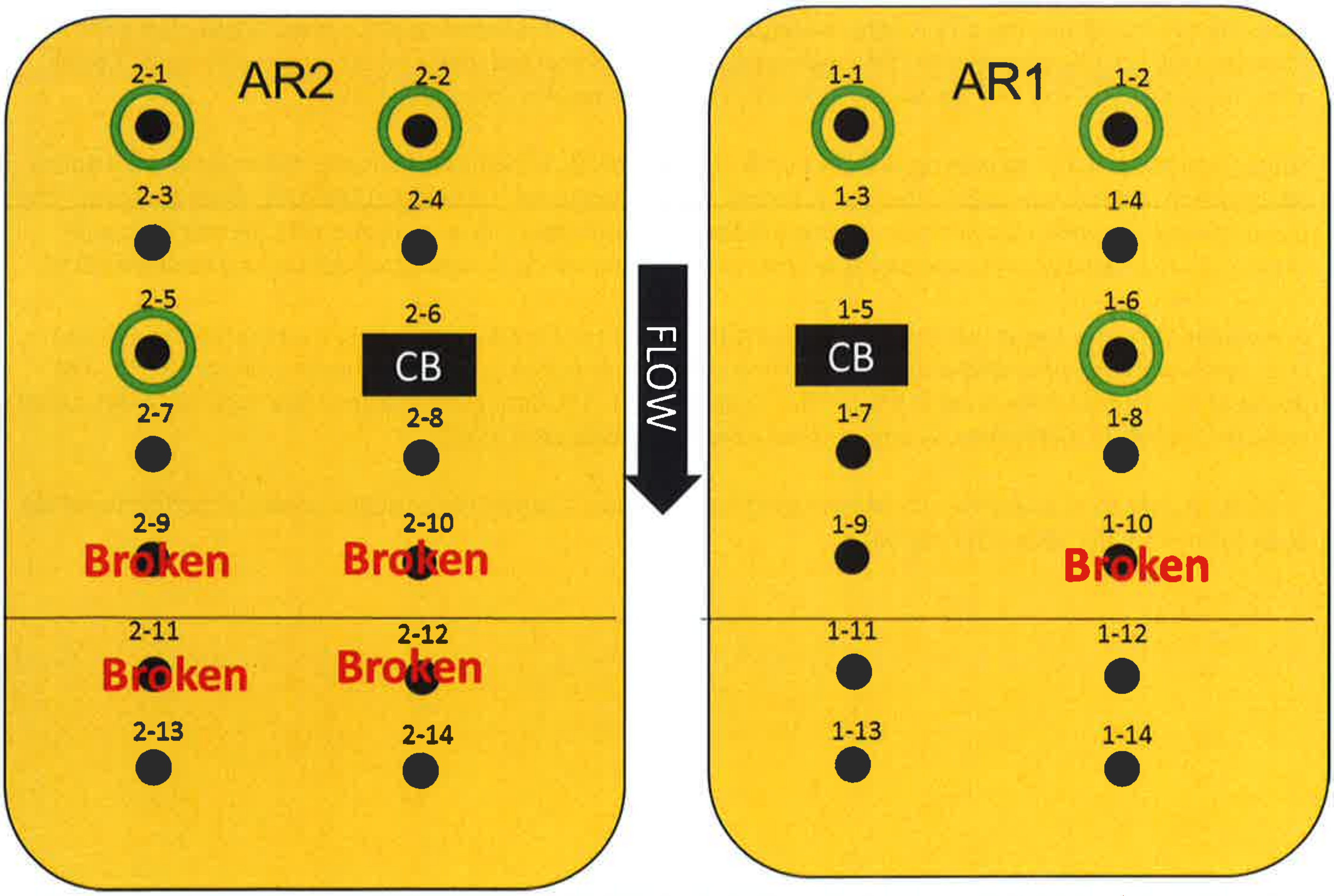

Figure 2: Location of Hatches on AR's, CB denotes location of Crust Buster (no dosing possible). Broken indicates hatches destroyed by crust (current January 2017). Green indicates location of current dosing points.

Phase 1 Crust Reduction

In Phase 1 the crust was measured using a method formulated by Transfield staff. This involved the use of a dumpy level. The thickness of the crust was calculated by the difference between the highest level on the covers and the lowest level. As the end of Phase 1 it was decided that this method was not accurately reflecting crust depth. The explanatory analogy was that this method was equivalent to measuring the portion of the iceberg that extended out of the water.

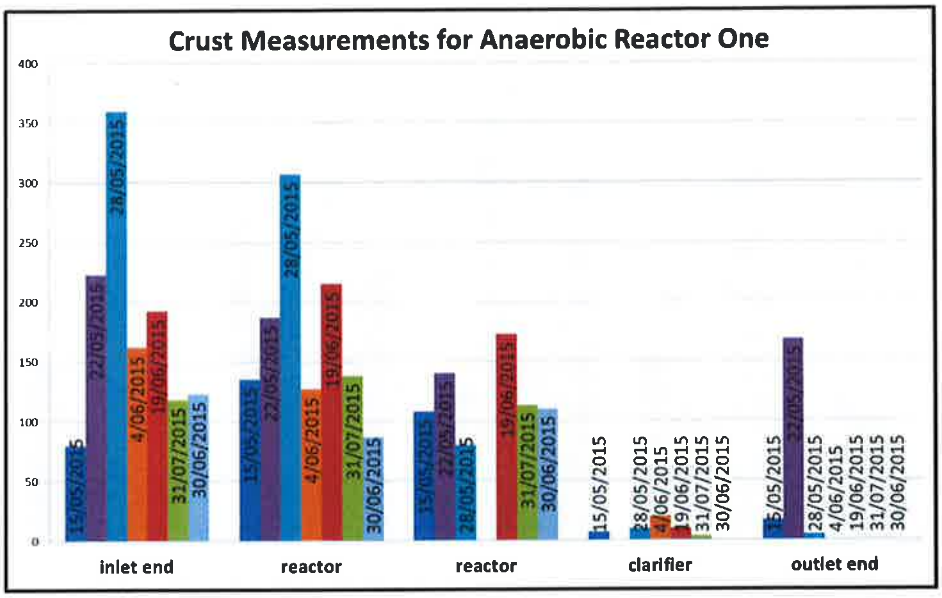

Figure 3: Phase 1 Crust measurements for AR1

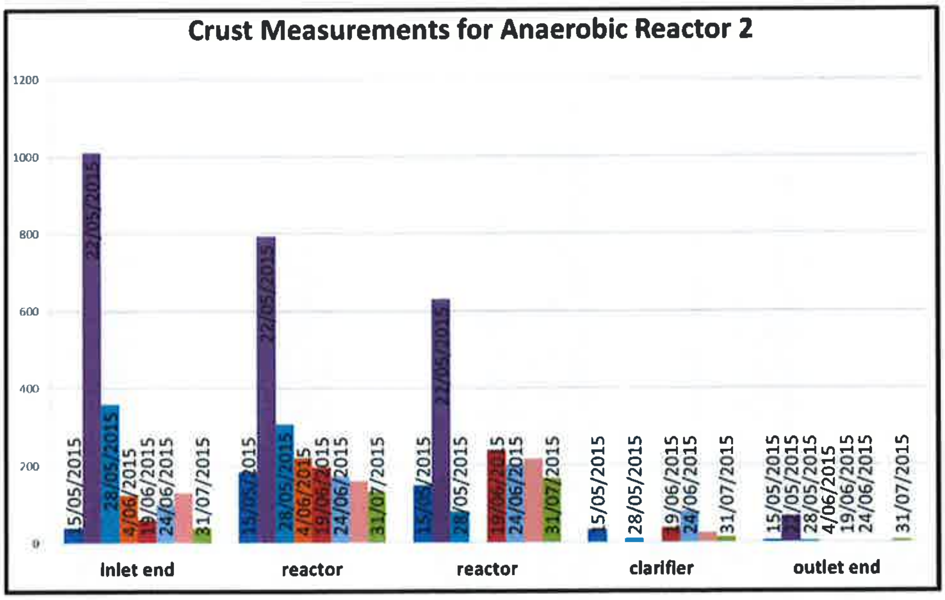

Figure 4: Phase 1 Crust measurements for AR2

Despite the limitations of this method, some reduction in the 'above water line' portion of the crust can be seen.

Phase 2 Crust Reduction

A second method of crust measurement was implemented in December 2015. This involves inserting a pole into the crust slowly to feel for the point where resistance is lessened. This is limited to around 1.25m as sensitivity is lost beyond this point. Therefore, points in figure 5 and 6 below that show 1.25 actually indicate 1.25+. Even with the newer method, the measurement of the crust is an inexact science, and involves subjective measurements. It should be noted that the measurement of crust is an estimation of depth, and does not record the relative density or liquidity of the material. It is also clear that the layer of crust below the covers is capable of movement, therefore crust material that is below one hatch may have moved by the next time measurements occur. This liquidity adds to the difficulty in analysis of the crust. Efforts are continuing to find technologies which will provide higher confidence data.

Phase 2, Crust Reduction Trial commenced 9/8/2016 with the continuous automated dosing directly into the crust. In addition, dosing into the Domestic Inlet at 19.2L/day was commenced at the same time.

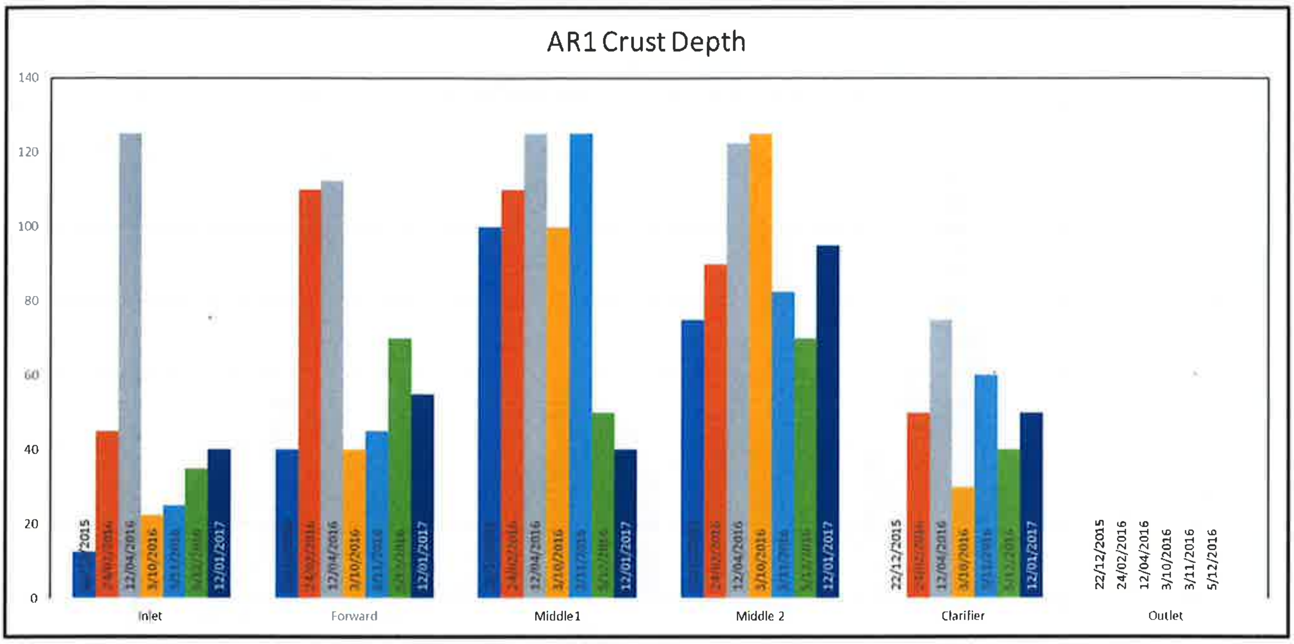

Figure 5: AR1 Crust measurements from 22/12/2015 (New measurement method). Note large spike on 12/4/16

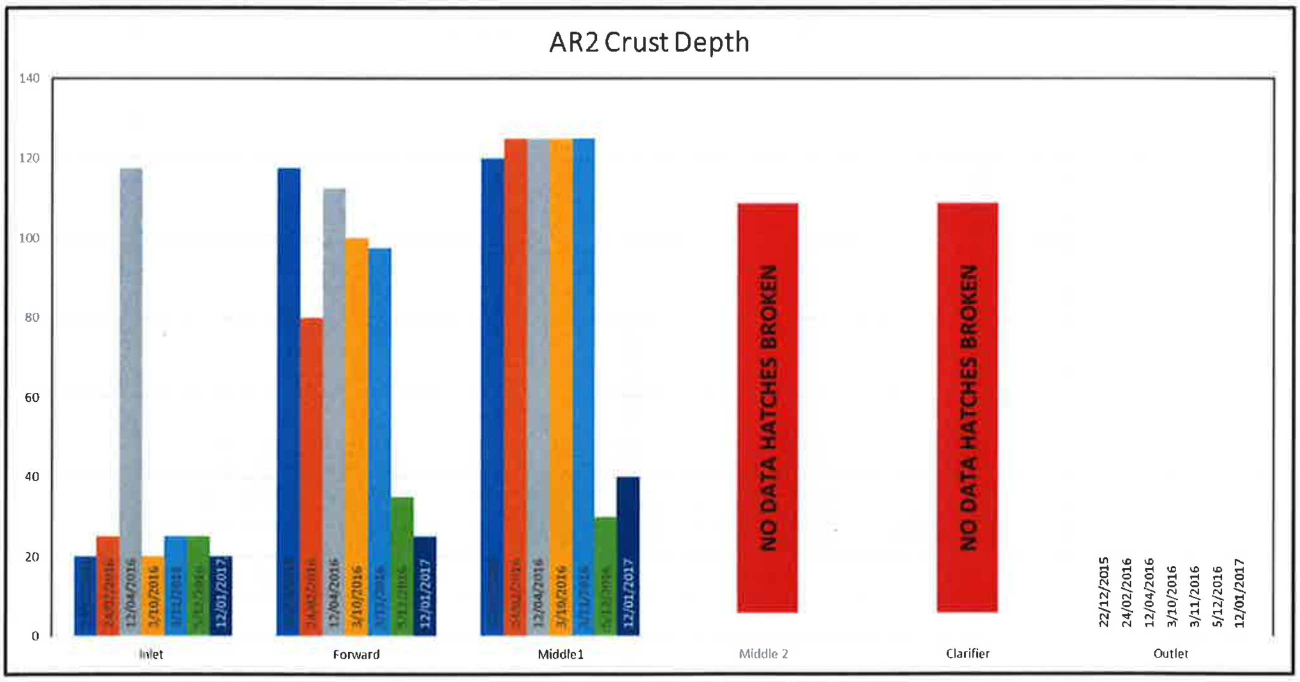

Figure 5: AR2 Crust measurements from 22/12/2015 (New measurement method). Note large spike on 12/4/16

The grey series (12th April 2016) is a standout as it showed a rapid increase in crust depth. It is believed that this was related to the pumping of several ML of floating domestic MBR foam into the anaerobic reactors in the week before measuring. **It is recommended that Domestic Foam not be pumped into the anaerobic reactors** but rather directed to dewatering if possible. If this is not possible it is recommended that a sucker truck be used to remove it. **The cost of treating this floating foam using Ecocatalyst once it becomes a part of the anaerobic crust is far greater than removal via other methods.**

As of 12/1/17 the crust level has reduced markedly from the high levels experienced in April 2016. Measurement of crust has taken place roughly monthly since October 2015 and will continue to be done into the future with assistance from Ecocatalyst staff.

Also of note is the considerable softening of the covers in the area of the AR's prior to any hatches. It is likely that there are two factors contributing to this. Firstly, dosing of Ecocatalyst into the domestic inlet is intended to target fats which enter the AR's via the primary sludge. This prevents crust building up in this zone. Secondly an increase in flow rates to the AR's enabled by the AP booster pump upgrade. Although the overall volume of influent to GWF has not increased significantly, it is noted that GWF can now match AP's discharge with very little overflow into the AP60. Previously any high flows had to be stored in the AP60 brought to GWF during times when AP had low discharges. This has resulted in higher peak flows and possibly pushed the crust further down the reactors.

At the current time AR1 being dosed in AR at hatches 1,2 and 6. AR2 is currently being dosed at hatches 1, 2, and 5 (see figure 2). As the crust problem at the influent end of the reactor appears to have lessened, it is **recommended that the dosing hoses be lengthened so that the middle of the rectors can be targeted.**

Overall it is noted that attempts to solubilise the crust using Ecocatalyst only is quite expensive, **it is suggested that some system of physical movement (ie water blasting) would assist in reducing the cost of supressing the crust.** Physical movement would help homogenisation and spread the Ecocatalyst more effectively. The current crust buster arrangement was unsuccessful due to it limiting the flow that could be brought into the plant. Its size meant that changing the direction of crust buster flow was physically difficult and time consuming. The distance that the inlet pipe extended into the air also meant that wind and gravity eventually caused the part of the cover that joined to the crust buster to break. A smaller but higher pressure device which is moveable may be more readily used.

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Biogas Production

Biogas production is difficult to evaluate as it can be influenced by temperature, hydraulic volume / contact time, carbon available for conversion and carbon to sulfate ratios. None of these factors have been constant over the 2014-2017 period. Despite this, Figure 7 below, clearly shows an increase in the amount of methane produced per kg of carbon entering the AR's.

Phase 1

During Phase 1 (Purple Arrow) weekly covers dosing and continual dosing into the Return Liquor Pump Station and the Industrial Influent was undertaken. Whilst this reduced the crust layer, it occurred during a period of sporadic flow from AP and cold conditions. Therefore, no significant judgement about the impact upon the biogas could be made.

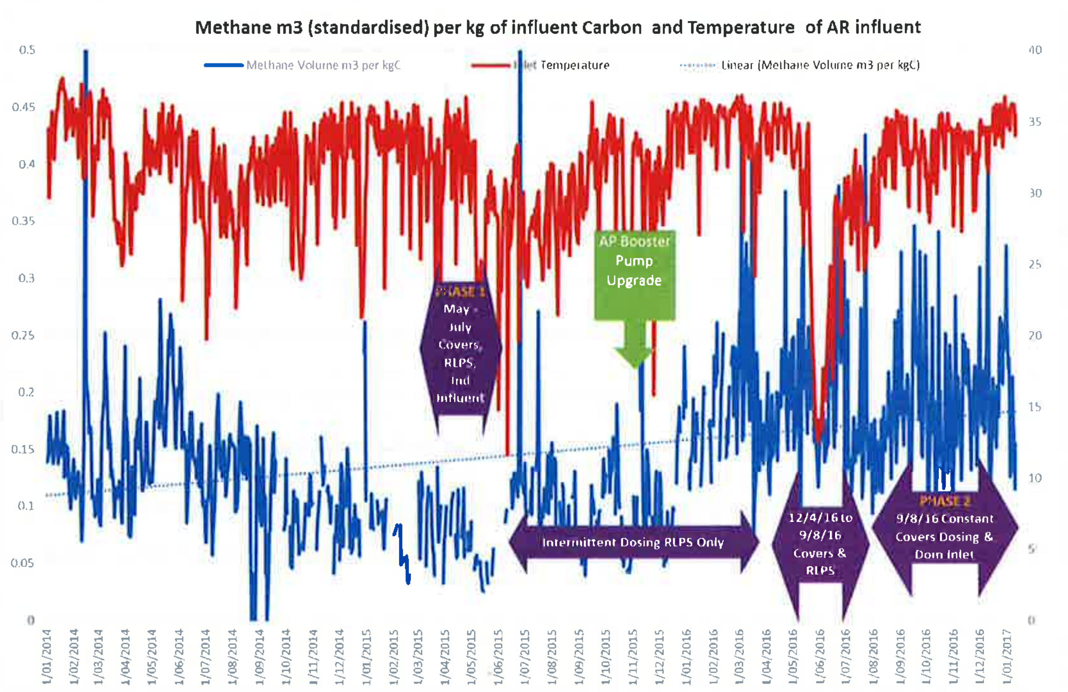

Figure 7: Methane m3 per kg of Influent Carbon (Blue), Influent Temperature (Red)

After Phase 1 trial was completed (July 2015) dosing occurred intermittently at the RLPS only. It is difficult to evaluate the effect of the sporadic dosing however it has been marked on figure 7 above. Between April 2016 and August 2016 continuous dosing into the RLPS and regular manual dosing into the hatches was undertaken. The conversion of carbon to methane appears to have been increased during this second period.

Phase 2

Phase 2 (August 2016 – Present) is a period where much higher confidence analysis can be performed. Excluding ~2 weeks in late September, dosing in this period dosing has been constant at both the Domestic Inlet and directly into the covers. We can see that during this time methane conversion per kg of carbon has been excellent. To assist in evaluating if this increase is due to fluctuations in temperature or flow four annualised graphs have been produced (Figure 8 below).

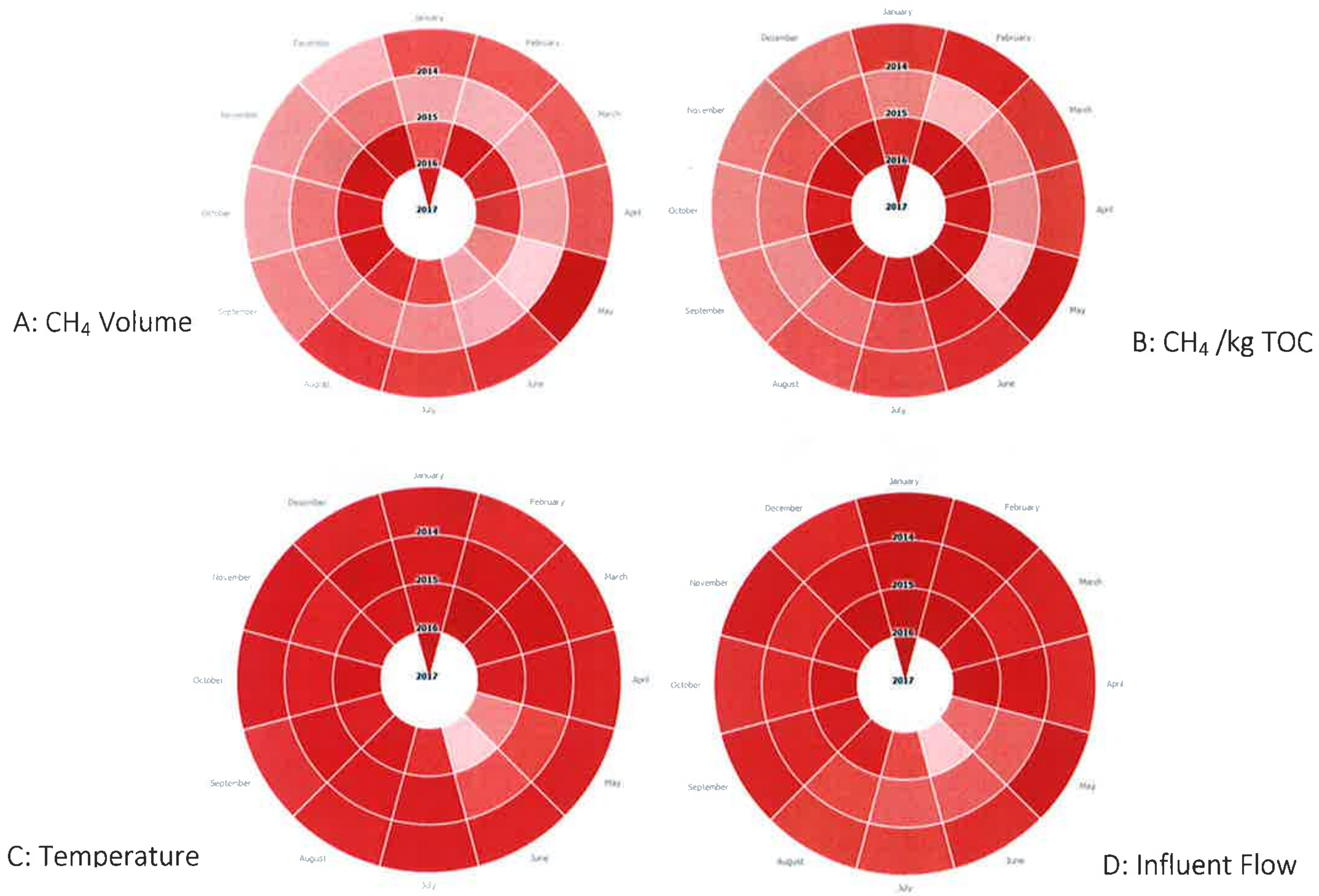

Figure 8: Annualised Spiralograms A: Methane Volume (std 25°C), B: Methane Volume (std 25°C) per kg of Influent Organic Carbon, C: AR Inlet Temperature, D: AR Influent Volume

Figure 8A shows that the volume of methane has been noticeably higher in the Phase 2 continuous dosing period (September 2016-Present). Figure 8B shows that in general 2016-2017 has been very good for carbon conversion to methane with higher methane to influent TOC ratios. This ratio is takes into account the TOC in Influent from AP, Primary Sludge, Industrial WAS and Domestic WAS. Methane would also be expected to be created from the solubilisation of the crust which is not in the equation. This source may be partly responsible for the elevated methane to carbon ratio. Figures 9A and 9B show the biogas data split into two groups (before and after the start of continuous dosing). Very significant differences are evident. This reveals biogas volumes of 1206m^3 (before) vs 1973m^3 (after) and conversion rates 0.132m^3/kgC vs 0.197 m^3/kgC.

Figure 8C shows the relative temperatures of AR influent during the 2014-2017 period. A seasonal trend can be observed. At this stage, it is difficult to evaluate Phase 2 (156 days) vs the remainder of the dataset (951 days) as the continual dosing has not occurred over a winter period. Therefore, a difference in the mean temperatures of these periods of 31.1°C (Before phase 2) vs 33.5°C (During Phase 2), have to be interpreted with some caution. The rough rule is that methane production is expected to double for every 10°C in temperature increase. Therefore, roughly a 4% increase in biogas production could be expected from this mean temperature increase. A 63% increase in methane was observed.

Figure 8D showing flows to the AR's do not appear to be abnormal when compared to the same time in previous years. However statistical analysis of the periods before and during the Phase 2 continuous dosing, suggest otherwise (see figure 9D). Again, due to the uneven sampling depth it is difficult to comprehensively evaluate. Mean flow before the Phase 2 period was 14.71MLD (951 days including Reactor 3 shut) vs 16.24MLD (156 days).

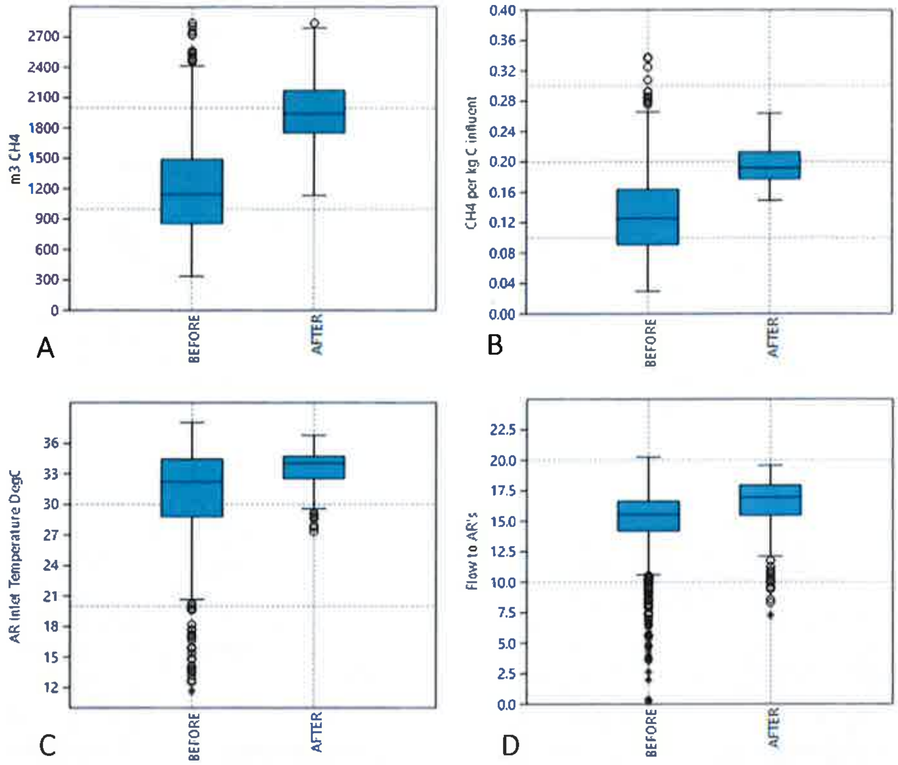

Figure 9: Before and After the start of Phase 2. Methane m3 per day (A) Methane per kg of influent Carbon (B), AR Inlet Temperature (C) and Flow to the AR's (D).

The effect of the Booster Pump Upgrade on the Biogas.

It was also hypothesised that the pump upgrade could have been responsible for an increase in temperature in the influent (due to no storage in the AP60) and thus increase the biogas production. The period before and after the booster pump upgrade (1st November 2015) is 665 days and 447 days. This provides a much representitive sample with which to draw conclusions. Naturally the last 156 days of this is shared with the Phase 2 continuous dosing.

There was a minimal temperature difference before and after the pump upgrade (mean 31.2°C before vs 31.9°C after) which was nevertheless statistically significant ($p = 0.006$). This should be expected to result in around a 7% increase in biogas. The methane volume in the two periods was very different at 1141m^3 /day Before vs 1579m^3/day after. This represents a 38% increase.

The flows through the AR's of 14.98MLD vs 14.94MLD were not statistically different. However, an overall increase in flow after the upgrade could be masked by the considerable flow decrease experienced during the reactor 3 shut (also included in this part of the dataset).

The effect of 19A Tankers on Biogas

Evaluation of the effect of acceptance of tankers of waste from Lion Nathan Morwell (19A or "Yoghurt") is complicated by the low confidence of earlier data. The number and frequency of tankers was poorly recorded prior to 2017. In instances where there are a number of tankers recorded in the Chain of Custody then this number is included as the number of tankers. Where there is analytical lab data (TSS/VSS, COD or TOC) but no record in the Chain of Custody then the number of tankers on that day is assumed to be 1 (but may have been more). There has been a greater frequency of tankers during the past 6 months (how many more is debatable).

There does indeed appear to be an increase in methane correlated to the number of 19A tankers. However, the correlation is strongest when longer term averages are used. Table 1 below shows that the best indicator of methane volume on any given day is the number of 19A tankers over the last 90 days.

Period of Correlation	r value	R^2	p value
Same day	0.14159	0.0200	1.77E-06
Average of 2 days prior	0.21656	0.0469	1.90E-13
Average of 3 days prior	0.24515	0.0601	6.69E-17
Average of 4 days prior	0.2649	0.0702	1.49E-19
Average of 5 days prior	0.28517	0.0813	1.64E-22
Average of 6 days prior	0.30422	0.0925	1.61E-25
Average of 7 days prior	0.3148	0.0991	2.82E-27
Average of 10 days prior	0.32821	0.1077	1.46E-29
Average of 14 days prior	0.34036	0.1158	1.08E-31
Average of 21 days prior	0.34448	0.1187	2.80E-32
Average of 28 days prior	0.36305	0.1318	1.06E-35
Average of 90 days prior	**0.41505**	**0.1723**	**1.19E-44**
Average of 120 days prior	0.33806	0.1143	1.78E-28

Table 1: Tanker Numbers averaged over various periods and the level of correlation with methane volume from the anaerobic reactors. Note averaged periods includes the day of correlation (ie 7 days is and average of the day on which the data is compared and the previous 6 days).

The correlations indicated in Table 1 do have large correlation coefficients (R^2 max 0.1723) however they are sufficient to say that 19A tankers do have an important effect on the biogas volume produced. The scatter plot below shows the methane volume produced on any given day and the average number of 19A tankers in the previous 90days.

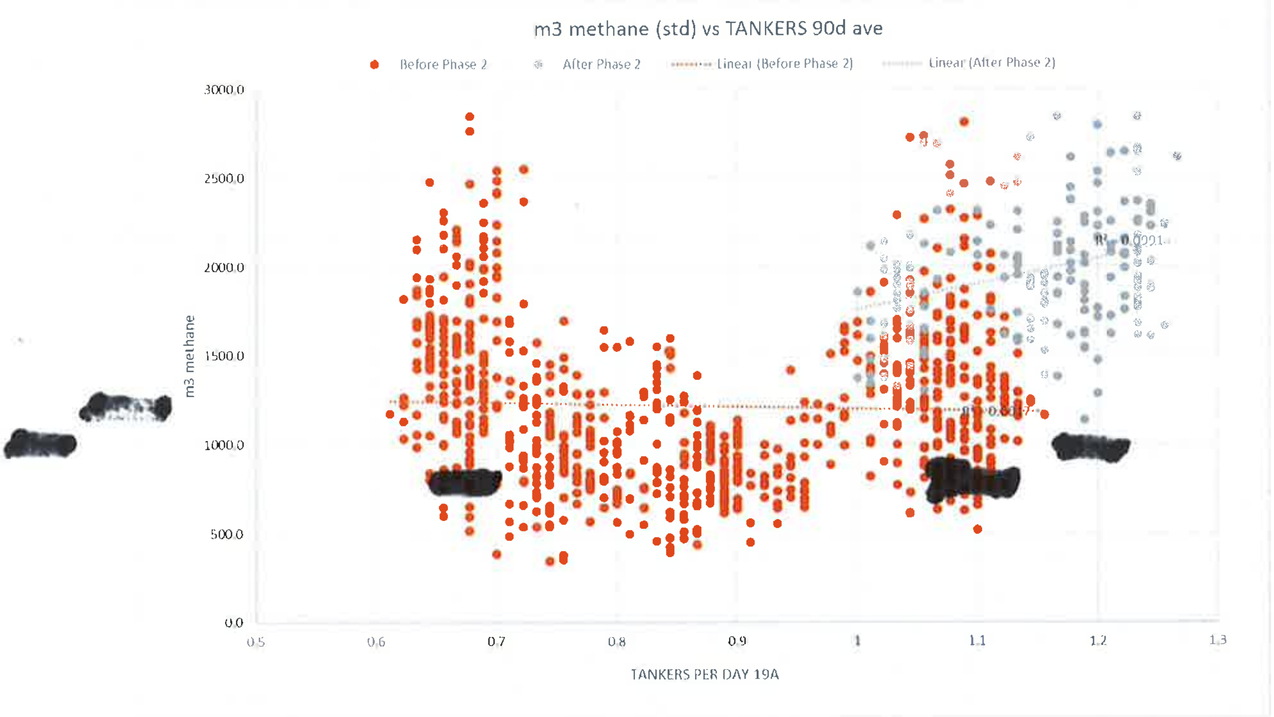

Figure 10: 90 day average of Tanker numbers vs m3 of methane produced.

All of the phase 2 data points (grey) show average tanker loads of between 1 and 1.3 per day. Where as for the period before Phase 2 (orange) the 90 day average is between 0.6 to 1.15. Certainly it appears from this, that Phase 2 has higher methane volumes which increases with increasing frequency of tanker loads. Whereas in the period before Phase 2 biogas does not appear to increase with increasing tanker volumes. This may indicate some effect of Ecocatalyst in breaking down the fat rich tankered waste. Given the fat rich nature of the tankered waste, increased volumes are not without a risk to the GWF process and in particular may contribute to the crust layer. Efforts to install a recieval tank which can have targeted dosing of Ecocatalyst onto the fats are a prudent investment.

Nutrient Balance

One of the claimed actions of Ecocatalyst is to assist in degradation of cellular material. Theoretically, this would be an advantage by decreasing the sludge volume to dewater and inceasing the release of nutrients. Nutrients such as phosphate but particuarly nitrate / ammonia are a limiting in the industiral system at GWF. As a result of these limitations, aqua ammonia and phosphoric acid are dosed into the MBR.

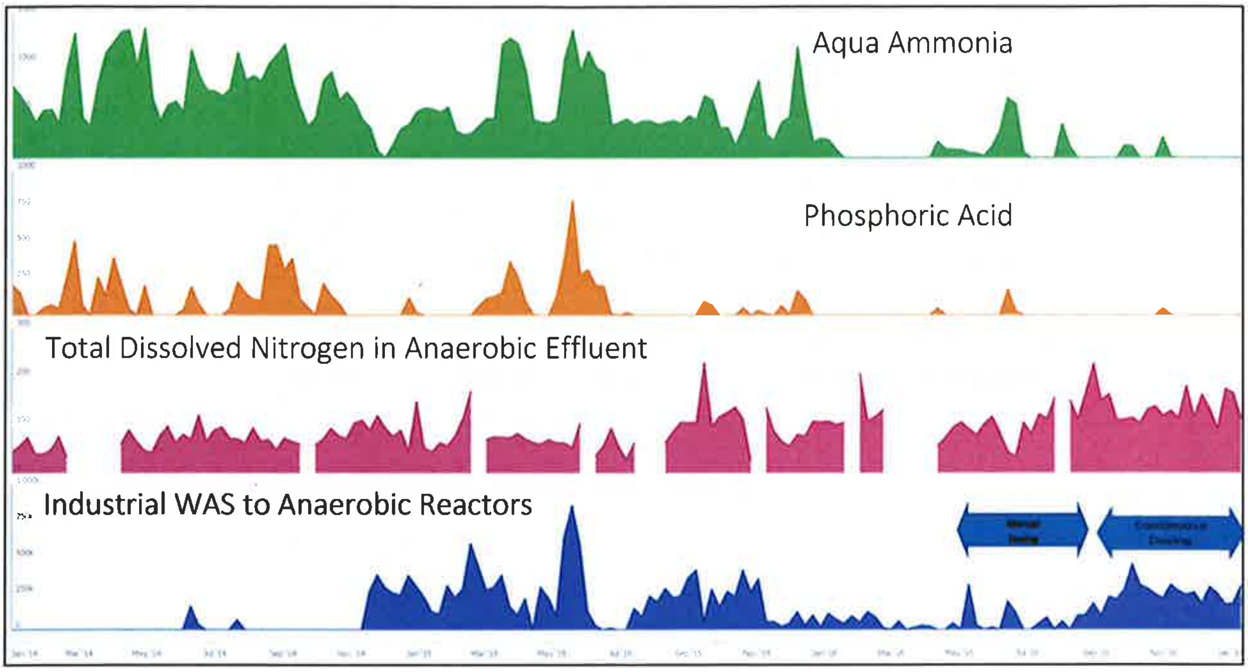

Figure 11: Aqua Ammonia (green) and Phosphoric Acid (orange) dosing to the MBR and Dissolved Total Nitrogen in the Anaerobic Effluent (purpled) to the MBR and Industrial Waste Activated Sludge to the Anaerobic Reactors (Blue).

Figure 11 shows the historical trends of aqua ammonia and phosphoric acid dosing to the MBR along with the dissolved total nitrogen load in the anaerobic effluent. It is clear from this, that the volume of both chemials required during Phase 2 has been significantly less than in previous time periods. The reason for the reduced nutrient demand can be seen by examining the amount of total dissolved nitrogen exiting the anaerobic reactors during this period (sustained at >100kg_N/day). The mean dissolved total nitrogen before Phase 2 was 83.4kg/day and during phase 2 was 138.3kg/day (Figure 11C below).

On average the volume of chemicals dosed into the MBR before Phase 2 was 490L/day of aqua ammonia[redacted] and 76L/day of phosphoric[redacted]. In the period since continuous dosing a mean average of 24L/d of aqua ammonia[redacted] and 2.1L/day of phosphoric acid[redacted]. This represents a saving of around [redacted]day.

It is unlikely that this reduction in chemical useage has been solely due to Ecocatalyst use. An increase in anerobic effluent nutrients could also be expected in line with the volume of IWAS directed to the AR's. Certainly during the Phase 2 period IWAS to the anerobic reactors has been sustained at above the average (Blue Trace in Figure 11 or figure 12D). However, historically there have been many periods with a high IWAS volume but without a corresponding increase in ARE nutrients. It would seem likely that high ARE total dissolved nitrgoen is a product of both high IWAS levels wasting to the AR's and the presence of Ecocatalyst to assist in cellular breakdown.

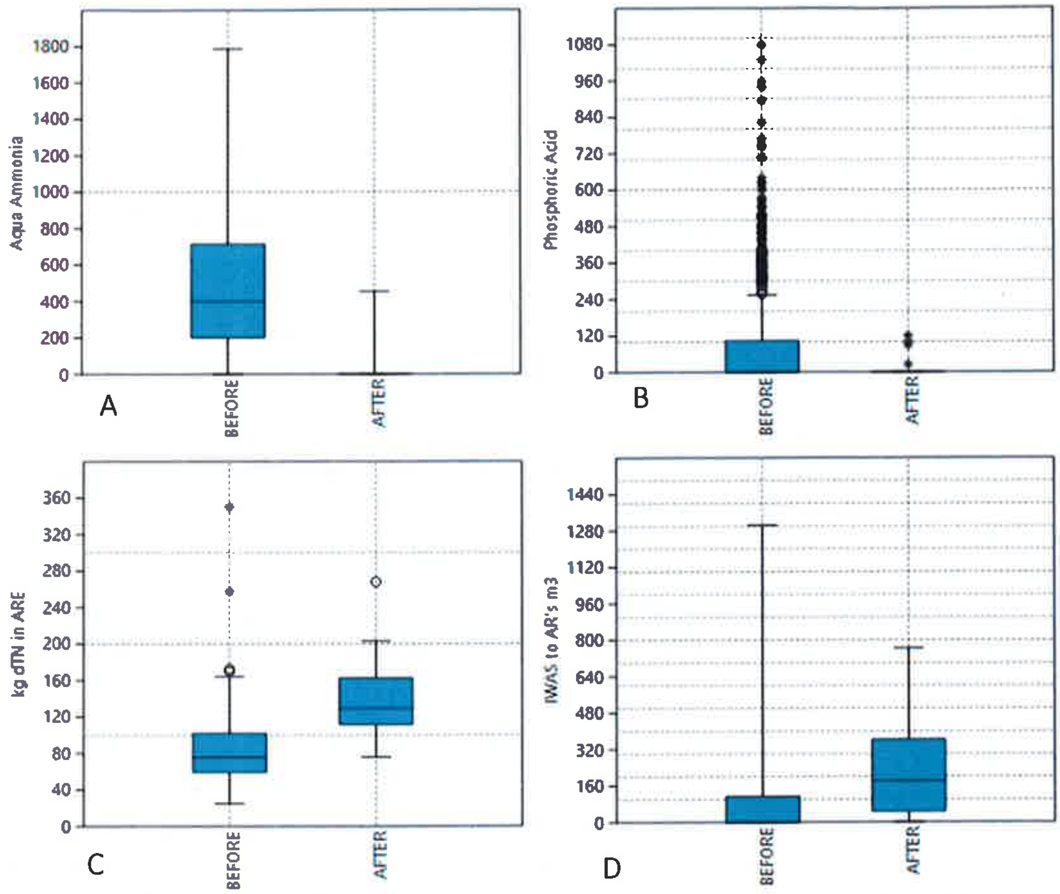

Figure 12: Before and After the start of Phase 2. L per day of Aqua Ammonia (A) and Phosphoric Acid (B) dosing to the MBR. Total Dissolved Nitrogen in the Anaerobic Effluent (C) and IWAS to the AR's (D).

Conclusions & Recommendations

Crust

The strategy of dosing at the domestic inlet to target fats in the domestic system before they get to the anaerobic reactors appears to be an effective tactic. A distinct thinning of the crust upstream of the first set of hatches has been observed. Automated dosing is currently directly onto the crust at hatches 1, 2, and 5/6 (see Figure 2). The crust in this region of the AR's has thinned. **It is recommended that the hoses be lengthened to allow for dosing further down the anaerobic reactors.**

Measurements of crust after dumping of several ML of Domestic Foam into the AR's indicated drastic increase in crust depth. **It is recommended that domestic foam not be pumped into the anaerobic reactors**

Attempts to solubilise the crust using solely Ecocatalyst are quite expensive, it is **suggested that some system of physical movement (ie water blasting) would assist in reducing the cost of keeping the crust under control.**

Biogas

Biogas production has been boosted by continuous Ecocatalyst dosing and by increased numbers of 19A "yoghurt tankers". **The proposed receival tank for tankered waste would allow dosing directly into this high fat waste and mitigate some of the risks.**

Nutrient Balance

The mean dissolved total nitrogen exiting the AR's before continuous Ecocatalyst dosing was 83.4kg/day and since then has risen to 138.3kg/day. The average amounts of aqua ammonia dosed into the MBR have been reduced significantly: ammonia 490L/day to 24L/d and phosphoric 76L/d to 2.1L/day. This is a saving of an average of [redacted]day. No actions are required for management of nutrients.