Final Report

Aerobic Wastewater Pond Trickling Filter

Full Project Title

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Contents

1.0 Executive Summary

The objectives of the project were to:

- Identify current industry practice for the removal of Nitrogen from aerobic pond wastewater by the use of Trickling Filters (TF).
- Characterise wastewater parameters.
- Construct a TF.
- Compare two media types use in the TF.
- Measure performance and commission and validate trickling filter.
- Prepare design parameters based on volume and waste characteristics.

Based on previous AMPC research and an extensive literature review a TF was constructed using Cold Room Panels (CRP) and spaced media to allow aeration using: Plastic moulded blocks (cross flow) PVC (commonly used in cooling towers); and fragmented Hebel lightweight concrete. Flow rate was varied to simulate varying recommended conditions.

The net result was that no N was removed and, on reflection of the literature and design, it was concluded that aeration was more of a key factor than depth of media or flow rate. It appears that the literature examples and trials are not readily translatable across industries or specifically, waste streams.

However, it was also found that the high Ammonia in the presence of Phosphorus and Potassium created Struvite by means of mechanical energy as the flow passed over the media. It was likely that reject water from the on-site Reverse Osmosis plant increased the available K but the overall effect of high EC on a TF has not been reported in the literature; it is felt that this also may be a contributing factor.

The build-up of Struvite was such that any biological organisms or bacteria would appear to have been covered by the Struvite. Total P had reduced greater than the minimal Total N values indicating an interesting phenomenon when high EC levels are experienced in the wastewater.

As a stand-alone TF under the circumstances encountered it would not be of value as initially hoped. The potential remains as a low capital and operational cost method to reduce TN in wastewater but requires further investigation. A major observation, post-trial, is that there is a great variation in published data with little data on denitrification. Maybe, rather, there is data but the source and nature of the wastewater and the applicability to non-similar inputs is not transferable. The majority of papers are directed at BOD reduction and the mechanisms supporting microbiological growth to achieve that reduction and is also the same for Nitrogen removal.

A fully controlled laboratory examination of inputs and outputs to identify cause and effect would be highly desirable.

2.0 Introduction

2.1 Purpose

Abattoirs typically use/or have used anaerobic and aerobic lagoon treatment systems to primarily to remove Nitrogen (N)and Phosphorus (P) prior to irrigation of the wastewater to crops or other. Recent innovations such as Anammox and Bio-digesters also remove N and P but are costly. Trickling Filters (TF) specifically target N but at a reduced capital cost.

The trial site had reached the imposed limit of allowable N for irrigation disposal; a TF was proposed to trial a system using two different media types to reduce N.

2.2 Scope

TF were primarily designed to remove organic loads from wastewaters measured by Biological Oxygen Demand (BOD) or Chemical Oxygen Demand (COD) reduction; of which, Nitrogen (N) was a component. Targeted Nitrogen (N) removal was a later use to which a TF could be put. In a low-rate biofilter, with a Carbon/Nitrogen (C/N) ratio of 2 to 4, and ideal conditions, ammonia reduction is possible and can reach 70% N reduction [Nozaic and Freese, 2009]. However, a previous AMPC Project (GHD, 2014) indicated a TF could remove BOD/COD but not N; this is contra to several papers identified in the Literature Review.

3.0 Project Objectives

The project objectives and how they fit within milestones are shown at Table 1:

Table 1: Objectives and Milestone

Serial	Objective	Relevant Milestone and Timeline
1	Literature review of bio-trickling filters	MS1. Deposit to enable bucket chemistry evaluation trials to be concluded and undertake final literature review. (15/12/20)
2	Wastewater physical characteristics	MS2. Deposit on contract signing (~5%) to enable bucket chemistry evaluation trials to be concluded and undertake final literature review. MS 2. Report comprising results from bucket chemistry stage, including review to remaining scope, budget and timeframes (design and modelling of proposed system). MS 2. Milestone report submitted to, and approved by, AMPC MS 2. Go / No Go / Redirect decision required (including opportunity to review scope, budget and timeframes). (15/12/20)
3	Design a bio-trickling filter for Stanbroke based on pilot scale test of nutrient removal	MS3. Purchase third party components (second-hand shipping container, pipes, pumps, testing equipment, filter media). MS3. Milestone report submitted to, and approved by, AMPC. (4/1/2021)
4	Identification of maintenance issues and media replacement mechanisms	MS3 plus MS4. Modifications to shipping container and establishment of shipping container, contents onto site, including concrete plinth to seat container and trial equipment.

		MS4. Milestone report submitted to, and approved by, AMPC. (1/3/2021)
5	Demonstration working biofilter	MS5. Dry and wet commissioning including evaluation of results and continuous processing/system improvement (for a period of 3 months). MS5. Milestone report submitted to, and approved by, AMPC. (31/5/2021)
6	Report on results and bio-trickling filter design methodology	MS6. SnapShot and Final Report submitted to, and approved by, AMPC, including future R&D recommendations. MS.6 If the Final Report includes confidential information that should not be distributed to wider industry, two versions of the report should be submitted: • a full report, marked Confidential, for AMPC's internal use only; and • a publishable report with all sensitive data removed for distribution on AMPC's website. (30/7/2021)

4.0 Methodology

The primary purpose of the TF was to remove N as the Total Nitrogen was excessive as shown in Table 2 below:

Table 2: Aerobic Lagoon Wastewater Characteristics

		6-year long term average	
Test	**Units**	**Avg**	**SD**
BOD5 (mg/L)	mg/L	57	21
TSS	mg/L	78	60
pH	**unit**	**8**	**0**
DO	**mg/L**	**4**	**1**
EC	uS/cm	3756	356
Cl	mg/L	983	225
COD	**mg/L**	**152**	**44**
O & G	mg/L	5	3
VA (mg/L)	mg/L	140	81
TP	**mg/L**	**23**	**5**
Na	mg/L	317	51
TN (1)	**mg/L**	**175**	**26**
Alkalinity (CaCO3)	mg/L	985	100

NB: (1) TKN (Total Kjeldahl Nitrogen) is the total concentration of organic nitrogen and ammonia. In this case the TKN approximates TN which approximates Ammonia.

Following on from an extensive Literature Review, a filter was constructed as a box type structure. Appendix 1 discusses the general design parameters for a TF. Appendix 2 provides the schematic design of the trial unit while Appendix 3 shows the as-built structure. There was some difficulty in the distribution of water with the first iteration being simple holes in the pipe, to variations in nozzles, to the final use of shower heads (Appendix 3, Fig. 3-2). Blockages occurred for each nozzle/head type with algal growth.

Two media types were used for comparison. One was a plastic media with a large surface area and is used extensively in cooling towers; the other was broken Hebel™ lightweight concrete. These are discussed in Appendix 1.

A primary design parameter was to use ‘no moving parts’ and minimize energy costs. Several designs have rotating arms to deliver wastewater evenly, have air pumps, and recirculation systems. Constant wastewater flow was provided by a small pump to achieve the equivalent of about 2m3/m2/hr.

Wastewater ex-TF was sampled weekly for simple base parameters and sent to a NATA registered laboratory for analysis. Results from the trial were disappointing and discussed in Section 5 below. The project was suspended although design parameters were devised based on the theoretical data available.

5.0 Project Outcomes

The trial ran for 9 months and was hampered somewhat by covid restrictions and but minor issues such as blockages due to algal clogging of sprinkler heads were resolved. Essentially, the primary aim to remove TN from the aerobic wastewater was not achieved; it was believed that the primary cause was lack of adequate aeration. In developing the trial unit, the various design parameters were believed to have been considered and were within available design criteria.

Appendix 5 records the 11 x laboratory test results between February and November 2020 for TN, TP, DO, and EC. It was considered that these four parameters would be sufficient to indicate performance. A general observation of the data indicated:

1. TN: the majority of values remained the same with few exceptions until about 5 months when the maximum reduction was about 12%; far less than the predicted 90% maximum but the results were not consistent. The Plastic media was marginally better than Hebel™.
2. TP: the reduction in phosphorus was not anticipated with consistent reductions in the 12% range. Plastic media achieved marginal but better consistent results than Hebel™.
3. DO: the data in Table 5.3 shows a significant increase in DO in the output flow from the TF. This is a good result but was unexpected. Both media types achieved similar results.
4. EC: minor reductions were recorded in both media types with similar results.

Discussion of the results was inconclusive as to why the TN was not reducing. It was believed that free air flow may be the cause and a new trial unit was designed. The redesigned trial unit is shown at Appendix 6. Additionally, a preliminary full-scale design commenced and this is shown at Appendix 7 (this design meets the best of the design criteria available but would still need to be proven).

The old unit was dismantled prior to replacement but a crystalline substance was observed on the surface of the media. The project was halted pending the crystal analysis. On receipt of this analysis the project was halted; this is discussed in Section 6 below. The crystal analysis data is shown in Table 5-5 with images of the material at Figures 5-1 and 5-2.

6.0 Discussion

Appendix 8 is the discussion arising out of the Milestone 1 Report when the non-performance of the TF to remove TN was believed to have been due to lack of air circulation within the structure. It was not until the old unit was dismantled that the accretion of a crystalline substance was noticed. The DO results would seem to indicate that aeration was not the primary issue. Subsequent laboratory analysis of the crystalline material (Table 3) indicated a high concentration of Calcium, Magnesium and Phosphorus.

Table 3: Crystalline Material (also included as Table 5-5)

Crystals/Struvite (1)	
Sample Date/Time	23/02/2021 0:00
Sample Description	Plastic Media
Total Nitrogen (%w/w)	4
Electrical Conductivity (1:5) (ÂµS/cm)	2490
Calcium (Ca) (mg/kg)	75900
Magnesium (Mg) (mg/kg)	77300
Sodium (Na) (mg/kg)	1020
Potassium (K) (mg/kg)	569
Phosphorus (P) (mg/kg)	115000

***Notes: (1). Struvite** is Magnesium Ammonium Phosphate with formula: $NH_4MgPO_4 \cdot 6H_2O$.*

The following was the discussion from Milestone 1 prior to receiving the analysis of the crystalline material:

> "While there is a long discussion on HLR and OLR, the requirement for aeration in the literature has been specifically lacking in terms of need and effect. The HLR and OLR appear to have been developed and reported in relation to specific waste scenarios but there is a lack of general applicability, or potability, of recommended concentrations and flow rates across various waste streams or industries.
>
> Oxygen is a key component in the Nitrification process (Table 4) but additional aeration did not seem to be indicated where the output DO (Table 5-3) had increased in both media types. However, on reflection, the increased DO in the output may be the result of turbulence at the end of the process while there was insufficient throughout the media.

Table 4: Nitrification [Sun et al., 2010. Ref 5)]

Nitrification: $NH_4^+ + 1.5\ O_2$ ----- > $NO_2^- + H_2O + 2H^+$

$NO_2^- + 0.5\ O_2$ ---- > NO_3^-

And later anoxic heterotrophic denitrification of the oxidized N-species to N_2.

Denitrification: NO_3^- + 4g COD + H^+ ---- > 0.5 N_2 + 1.5g biomass

> Additionally, the Carbon:Nitrogen ratio may also be important for Nitrogen removal. Most TF's have been used to remove BOD and COD from waste streams where the Carbon has been relatively abundant. From Table 4 it can be seen that COD (and hence Carbon) is required for the final Denitrification. Sun et al. (2010) demonstrated good N removal at a C/N ratio of 2.1-4.4 C/N for domestic wastewaters. In Stanbroke's case, BOD is relatively low with no measure of COD or available Carbon.
>
> The references do not discuss high EC loads and if that has any effect to inhibit micro-organism growth. It is noted that both EC and Total Phosphorus decreased slightly; this is likely to be caused through mechanical

energy as the wastewater moved through the media creating Struvite (Magnesium Ammonium Phosphate - $NH_4MgPO_4 \cdot 6H_2O$). It is not known if this inhibits micro-organism growth as well as EC."

This crystalline build-up is shown in Figure 5-1 on the plastic media. This crystal material is not readily identifiable on the Hebel™ shown in Figure 5-2. Although the physical appearance between the two media is very different it is not known what has caused this difference. No sample was taken from the Hebel™ as sampling of the 'black' material was not possible without contamination by the Hebel™ itself.

As a comment on Struvite – from personal experience, when anaerobic ponds were desludged using a floating sludge pump, some of the Phosphorus from the sludge mobilised into the water column and the effect of the additional P in the wastewater for irrigation caused the formation of Struvite on the irrigation pump impellers. The pumps seized from this build-up.

7.0 Conclusions / Recommendations

The TF is a BOD/TN reduction system that has been used for decades primarily in Sewage Treatment Plants but extended to other waste streams. While there is a range of research material available, it appears that the examples and research are not directly transferrable. The primary difference in the treatment of Abattoir aerobic pond wastewater by a TF in this case appears to be the influence of Reverse Osmosis highly saline reject water.

The primary conclusion on the failure to remove TN was the formation of a crystalline material observed on the plastic media. It exhibits the same characteristics as Struvite and composition shown in Table 4 above. The reason for the accretion of Calcium is not known. It is presumed that the Hebel™ lack of performance is related in some way to the plastic media but is not proven.

From the references and examples in the literature, a TF should work on aerobic wastewater with a few variables unknown on the presumption that the high EC reject water is removed. However, there may be sufficient energy in the TF to create Struvite type crystals but at a lesser rate on the media.

Given the experience of this trail project, it would be recommended that a laboratory examination of a TF be undertaken to examine the variables affecting TF performance. The primary variables would be aeration, C:N ratios, and EC effects. Pump rates and retention times for optimisation should also be examined. It is noted that MLA/AMPC work has been done previously on purpose built systems to create Struvite to strip Phosphorus but added Magnesium was a requirement.

8.0 Bibliography

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9.0 Appendices

Appendix 1: Trial Unit/Basis of Design

The following is taken from the Milestone 1 Report previously submitted. Appendix 2 provides a schematic layout of a trial unit to enable the 'bucket chemistry' on the use of the TF as an N removal technique. This original design was based on flow rate parameters per surface area and depth of media. The subsequent shortfall in performance appeared to be a lack of aeration within the unit. Aeration was not considered critical at this juncture because of the primary traditional design/construction types used in sewage plants, and the test builds used for research. Additionally, some sources recommended re-circulation of the wastewater (this is later discussed in results).

There are no transferable empiric design criteria or rules for a TF in regards to size-flowrate-depth-media for N removal; only general principles and what was achieved under specific treatment scenarios. A pilot-scale experiment should therefore be conducted to custom design a TF for the specific wastewater characteristic.

However, there are general guidelines and are summarized below:

1. **Hydraulic Loading Rate (HLR)**: 1 – 3 m^3/m^2/hr (Ref 3)

Table 1-1: Recommended HLR (Ref 3)

	Hydraulic Loading Rate 1-3 m3/m2/hr			
1m3/hr =	16.67	L/min =	0.28	l/s
3m3/hr =	50.00	L/min =	0.83	L/s

Unfortunately, the HLR does appear to be confusing and this was only discovered post Lit Rev. Most Lit Rev sources talk about cubic meters per hour. GHD (Ref 1) has an HLR of about 4m3/m2/d; this is a significant difference. This difference is discussed in Section 7.

2. **Organic Loading Rate**: about 0.06 kg BOD/m^3 media/d (64g/m^3/d) (Ref 2)

Table 1-2: Organic Loading Rate (Ref 2)

TYPICAL LOADING RATES FOR SINGLE-STAGE NITRIFICATION (Ref 3)		
TF Media	%	Loading Rate
	Nitrification	(g BOD/m3/d)
Rock	75-85	(160-96)
	85-95	(96-48)
Plastic	75-85	(288-192)
Tower TF	85-95	(192-96)

Ref 2 provides guidance that "...the organic volumetric loading rate must be limited to approximately 80 grams BOD_5/m^3/d"

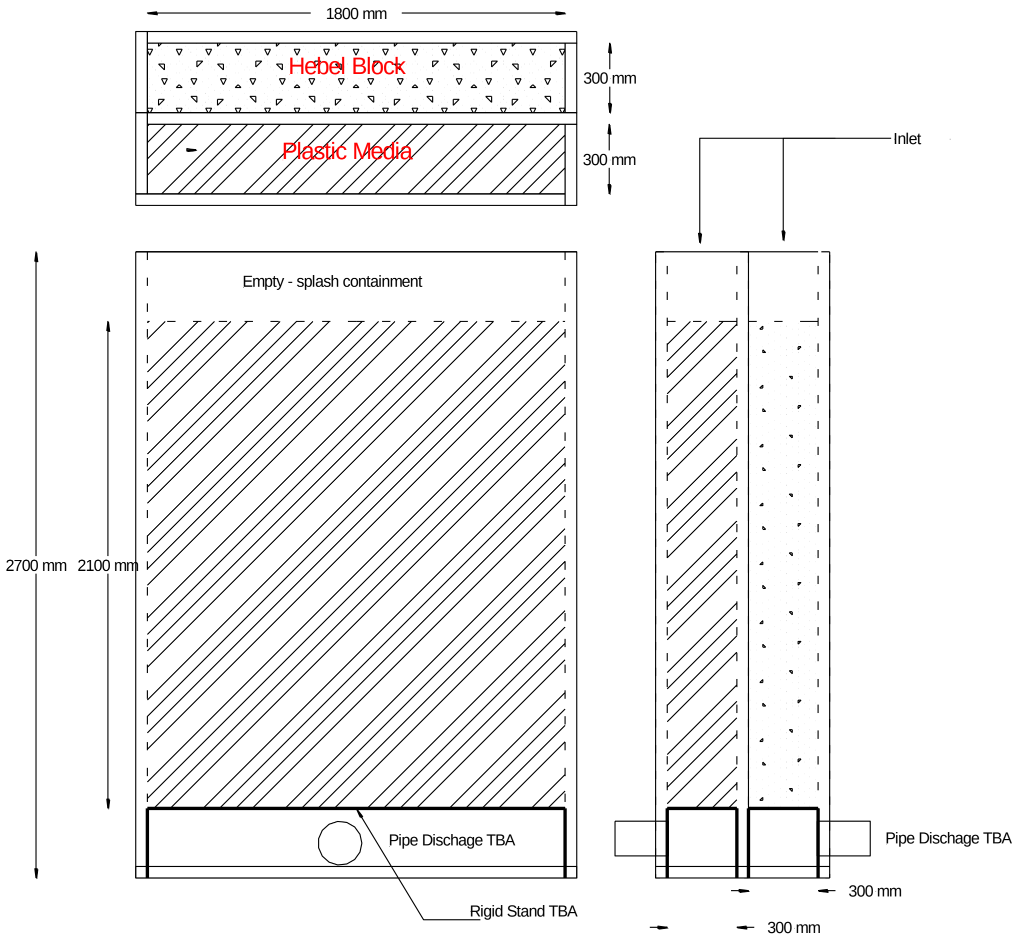
"Organic loading rate – for plastic media it is typically 1- 2 kg BOD/m^3.d and it is possible to achieve well over 80 – 90 % BOD reduction. Even higher loads (up to about 4 kg BOD/m^3.d) are possible but above 2 kg BOD/m^3.d is more of an odour risk (and forced ventilation may be required if the filters are higher than about 4 – 5 m depth)" (Ref 1).

Again, there is wide variation in BOD loading rate and is discussed in Section 7.

3. **Bed Depth**: from 1 – 2 m but generally closer to 2 m. However, Hydraulic Retention Time is alluded to without any specific reference in relation to bed depth. Primarily related to flow rate per m^2 and volume of media. GHD (Ref 1) use a bed depth between 4 – 12 m.
4. **pH**: better to maintain pH between 6.5 – 8.0
5. **Temperature**: Generally, not an issue in Australia but is more effective at higher temperatures but above 25^oC is not charted.
6. **Dissolved Oxygen (DO)**: Ref 2 (USEPA) offered that the maximum nitrifying growth rate is reached at a DO concentration of 2 – 2.5 mg/L but also offers that concentrations greater than 2.0 mg/L may be required. It also notes that loading rates per surface area and retention times may also have an effect. There is no clear definitive benchmark for varying TF variations.
7. **Aeration**: Some papers recommend separate air inputs to the media to increase oxygen to promote microorganism growth. This involves air pumps additional to the process.
8. **Filter Media**: General consensus is that plastic media with high cross flow (Appendix 4) provides more area for the bacteria to grow and better gas transfer than the traditional rock media. From previous work on bio-filters to remove odour, broken Hebel™ has a high surface area and is porous but has less gas transfer when used for water (conversely, Hebel™ is better than plastic media for air forced systems such as a bio-filter).
9. **Recirculation**: "The major benefit of recirculation in nitrifying trickling filters is the reduction of the influent BOD concentration which makes the nitrifiers more competitive. This in turn increases the nitrification efficiency and increases the dissolved oxygen concentration." (Ref 2). However, the literature is mainly concerned with medium to high BOD loadings and low DO. The aim was to design a system for relatively low BOD aerobic lagoon wastewater. Recirculation also involves separate storage for the first process material.
10. **Sloughing**: Some of the literature suggests a separate settling tank where the microorganisms that dissociate from the media can be collected for disposal and/or digestion.
11. **Start-up Duration**: Most sources indicate a delay in results of several weeks to establish a beneficial bacterial film.

Appendix 2: Trial Unit Schematic

Figure 1-1: TF Schematic Drawing



Appendix 3: Trial Unit

Figure 3-1: Plastic Media

Figure 3-2: TF As-built

Appendix 4: Plastic and Hebel™ Filter Media

Figure 4-1: Plastic Media

Figure 4-2: Hebel™ Media in the TF

Figure 4-3: Hebel™ Media Showing Initial Bacterial/Algal Growth

Appendix 5: Trial Results

The input Raw Wastewater characteristics are shown in Table 2: Aerobic Lagoon Wastewater Characteristics. Raw input values for TN, TP, DO and EC were recorded and matched against output values from Feb 2020 to Nov 2020.

The results are displayed below (dates are common for all sampling):

Table 5-1: Total Nitrogen

	TN (mg/L)		
Date	Raw In	Out Hebel™	Out Plastic
20/02/2020	160	160	170
14/04/2020	180	180	180
1/05/2020	180	180	180
13/05/2020	170	170	170
28/05/2020	200	210	200
8/07/2020	160	150	140
31/07/2020	190	190	190
13/08/2020	190	180	170
10/09/2020	180	180	180
16/11/2020	190	180	180
23/11/2020	190	180	170

Table 5-2: Total Phosphorus

TP (mg/L)		
Raw In	Out Hebel™	Out Plastic
23	22	21
21	19	18
16	20	20
27	20	19
27	26	23
20	19	18
24	21	12
26	22	15
24	21	19
26	24	24
26	23	23

Table 5-3: Dissolved Oxygen

DO (mg/L)		
Raw In	**Out Hebel™**	**Out Plastic**
6.7	8.1	7.6
4.1	2.5	4.3
3.6	4.9	4.3
2.3	5.1	5.2
5.6	6.5	5.5
2.4	6.8	7.1
1.1	5.2	4.9
4.6	7	4.7
2.2	6.2	5.5
4.3	5.3	4.5
2.7	6.9	6

Table 5-4: Electrical Conductivity

EC (uS/cmL)		
Raw In	**Out Hebel™**	**Out Plastic**
3260	3220	3190
4680	4580	4540
4750	4640	4630
4540	4390	4390
3650	3580	3500
4020	3840	3900
4130	3960	3880
4200	3920	4090
4170	4000	3880
3880	3870	3800
3940	3850	3780

Table 5-5: Solids Analysis (Struvite?)

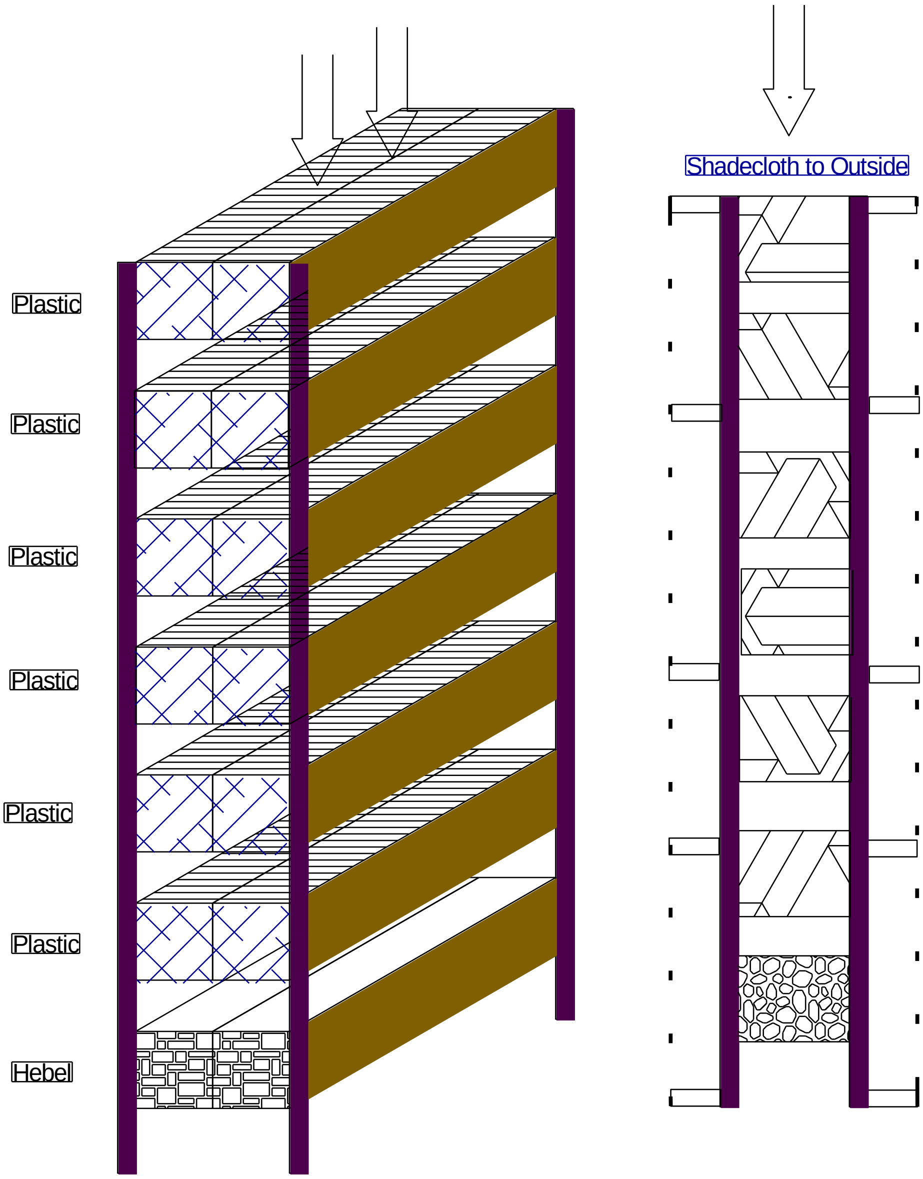
Crystals/Struvite	
Sample Date/Time	23/02/2021 0:00
Sample Description	Plastic Media
Total Nitrogen (%w/w)	4
Electrical Conductivity (1:5) (ÂµS/cm)	2490
Calcium (Ca) (mg/kg)	75900
Magnesium (Mg) (mg/kg)	77300
Sodium (Na) (mg/kg)	1020
Potassium (K) (mg/kg)	569
Phosphorus (P) (mg/kg)	115000

*(**Struvite** is Magnesium Ammonium Phosphate with formula: $NH_4MgPO_4 \cdot 6H_2O$.)*

Figure 5-1: Crystalline Build-up (Struvite) on Plastic Media

Figure 5-2: Growth on Hebel™

Appendix 6: Redesigned Trial Unit



Redesigned trial unit:

1. 6 x Plastic media approx. 600 (w) x 1200 (l) x 300 (d) mm.
2. 1 x Hebel™ media basket at base.
3. Space between media about 200 mm
4. Shadecloth offset to prevent spray in high wind.
5. Spaces allow natural air circulation.
6. Simplistic structure – Hebel™ at bottom adds stability. May need tie down.
7. Total Height about 3.5 m.

Appendix 7: Preliminary Full-Scale Design

(Reference: DJ Nozaic and SD Freese. PROCESS DESIGN MANUAL FORSMALL WASTEWATER WORKS. Water Research Commission, Waterscience CC. WRC REPORT NO. TT 389/09 APRIL 2009.)

There are different kinds of biofilter fixed film treatment processes, high rate biofilter, anaerobic biofilter and low rate aerobic biofilter. Both high rate and anaerobic are not intended to produce an effluent of adequate standard for final disposal. Usually, the high rate biofilter is used as a pre-treatment or a first stage of two to reduce the COD of strong effluents before discharge to sewer

Because of the light weight of plastic media, it can be constructed deeper than stone filters as much as 4 to 6 m. However, this requires good ventilation and design. Ventilation is of prime importance, filters up to 4 m deep have been reported to have adequate natural ventilation. It is important that flow of air is unrestricted.

The media usually has a specific surface area of about 100 to 120 m^2/m^3, depending of inlet flow rate m^3/d and COD concentration g/m^3, COD loading can be around 20 to 70 g COD/ m^2.d. However, for low-rate filter a loading of less than 10 g COD/m^2.d is preferable. Depth of 2 to 4 m is common; however, ventilation efficiency should be considered.

Different types of bacteria in the biofilm attached to the media undertake the oxidation of carbonaceous and nitrogenous material. Only at the presence of appreciable concentration of dissolved oxygen, nitrification can occur. Nitrifying bacteria usually appear in the lower levels in a filter or in the secondary stage and can be displaced by high loadings on a filter. Both COD (carbonaceous oxidation) and ammonia (nitrification) reductions are temperature-dependent, lower temperatures reduce the efficiency of biofilters. Temperature effect is more sever in nitrification. It has been reported, in a 40 mm broken rock media biofilter, BOD removal reduced from 94% to 89% and ammonia removal was reduced from 70% to 15% when sewage temperature dropped from 17°C to 9°C. Biofilters are not efficient in ammonia removal in Winter. Filters with a lower organic loading are less susceptible to temperature effects, recirculation may also result in denitrification. Recirculation ratios of about 0.25 to 0.5:1 are common and acceptable. Also, high nitrated effluent can be achieved by ensuring adequate volume of media is available.

Example: Design a biofilter plant for a 1 ML/d works treating a COD of approximately of 250 mg/l. Based on low-rate biofilter.

Biological load:

COD of wastewater = 250 mg/l (average measured from Stanbroke)
Ammonia (TKN) concentration of = 200 mg/l (average measured from Stanbroke)
COD load = 1ML/d x 250 mg/L= 250 kg/d
Ammonia load 1ML/d x 200 mg/L = 200 kg/d

Low-rate Plastic Media Biofilter:

Select 10 g COD/m^2.d and media specific surface area 100 m^3/m^2
COD loading = 10 g COD/m^2.d × 100 m^2/m^3 = 1 kg COD/m^3.d
Filter volume = 250 kg/d / 1 kg COD/m^3.d = 250 m3

Select filter height of 3 m (can be increased to 4 m if required)

Area of filter = 83 m^2 - Diameter = 10.3 m
COD strength is low enough not to need recirculation, if recirculation added the size may be reduced or efficiency increased

Check pumping rate to the TF = 1000 m^3/d / 83 m^2 = 12 m^3/m^2.d (approximately 12L/s for the total area)

Assuming 80% reduction in COD and 50% ammonia at ideal conditions, the effluent characteristics should be 50 mg/L COD and 100 mg/L ammonia. C/N ratio in this case is 200/200 = 1 which not a preferable ratio for efficient nitrogen removal, a ratio of 3 to 4 is more suitable. It seems this is not the case in abattoir wastewater.

For a pilot scale reactor of 1 m^2 area and 3m depth, the loading should be equal to 12 m^3/m^2.d. This HLR can be increased during the trial to investigate optimum conditions.

Appendix 8: Discussion of Trial Unit Operation

It would appear that TF's can achieve good results in an economic fashion but the major observation, post-trial, is that there is a great variation in published data with little data on denitrification. Maybe, rather, there is data but the source and nature of the wastewater and the applicability to non-similar inputs is not transferable. The majority of papers are directed at BOD reduction and the mechanisms supporting microbiological growth to achieve that reduction and is also the same for Nitrogen removal.

Of the design precepts identified in Section 3.1.2, there are three primary variants, viz., Organic Loading Rate (OLR), Hydraulic Loading Rate (HLR), Depth of Media, and Aeration. The remaining criteria are generally acceptable or not feasible; i.e., temperature, pH, media type and recirculation. For example, it is not planned at this stage to treat the full wastewater production volume or recirculate TF output back into the TF as occurs for COD/BOD reduction. It may be necessary at a later date but is not warranted until basic parameters and success is observed.

There is a seemingly strong correlation between OLR and HLR and presumes an inherent hydraulic residence time based on flow volume to media volume and depth. It remains unclear what the relationship should be from the various references as the loading rate varies from about 1 kg BOD to 18 kg BOD per 1 m^3 of media per day. The same occurs for HLR with recommendations ranging from 1 m^3/m^2 media surface area/day to 3 or more m^3/m^2 media surface area/hr; this is a significant difference. Variation in organic and hydraulic loading can be explained in terms of low and high-rate TF's and the purpose of the TF.

The only other reasonable variable factor was aeration. The trial design allowed for aeration but appeared to be insufficient. Some references used air pumped into the chamber to aid nitrification. This will be addressed in the next trial but without an air pump but using natural airflow (see Appendix 6).

Traditional TF's were in-ground tanks with a rotating arm and were generally large in area (GHD (Ref 1) used a HRL of 4 $m^3/m^2/d$; an OLR of 1.6 kg BOD/m^3/d that required a circular tank of 30 m diameter and from 4 – 12 m deep). Admittedly this was for raw wastewater but is dependent upon both HLR and ORL. Total volume per day would then determine the volume (in terms of depth) of media as the HLR is fixed. It also presumes a low, fixed BOD concentration. Stanbroke average raw BOD was 3000 mg BOD/L for 2019. For Stanbroke this gives a total BOD of 6000 kg/d. The GHD 30 m diameter TF HLR allows 754 kg BOD/d regardless of media volume; hence Stanbroke would need a surface area about 8 times that of the GHD (Ref 1). Media volume would then need to be calculated. The drawback may be depth of media when the HLR is fixed; that is, greater the volume of wastewater, with a fixed surface area the only variable to accommodate BOD is media depth.

HLR and OLR based design for BOD loads are suitable when BOD is the issue; specific design based on N loading and removal is lacking. The importance may be in balancing the flow rate, BOD loading and media volume, hence the missing Hydraulic Retention Time (HRT) to allow the microorganisms to work. It is noted that a certain BOD/N loading is required in the Nitrification/De-nitrification process (Table 4). HRT can be calculated from HLR and depth but recommended HRT's are lacking; low BOD and high HLR means less media volume and low HRT and vice-versa.