Planted Gravel Flow System: Nutrients

Project Report by Natalie Melgoza

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Abstract

Wastewater discharged onto the wetlands of the DEWATS in Newlands-Mashu was tested for phosphate, ammonium-N, nitrate, nitrite and alkalinity. Plant uptake of phosphate resulted in a phosphate concentration reduction of 41% with average effluent values of 31.7 mg/l PO_4^{3-} while ammonium levels only decreased by 10% with effluent values of 66.3 mg/l NH_4-N. Nitrate was not detected and nitrite levels were found to be under 0.20 mg/l NO_2^-. There was little change in alkalinity.

Introduction

The decentralized wastewater anaerobic treatment system (DEWATS) at Newlands-Mashu in Durban, South Africa, receives wastewater from approximately 80 households. The wastewater contains various nutrients of uncertain daily concentrations.

The DEWATS consists of 3 streets, each with a settler, an anaerobic baffled reactor (ABR), 2 anaerobic filters and a siphon tank connected to street 1 that discharges onto the wetlands. ABRs in Street 1 and street 2 consist of 7 chambers while street 3 consists of 4 ABR chambers. The wetlands consist of a vertical planted gravel flow (H-PGF) followed by a horizontal planted gravel flow (H-PGF). Wastewater from street 1 accumulates in the siphon tank until the siphon's maximum water level sets off an automatic discharge of the contents onto the wetlands.

The goal of this project was to obtain information about the nutrient levels in the wastewater discharged onto the wetlands and determine how much those levels change. The nutrients of interest were phosphate, ammonium, nitrate and nitrite. Alkalinity was also measured.
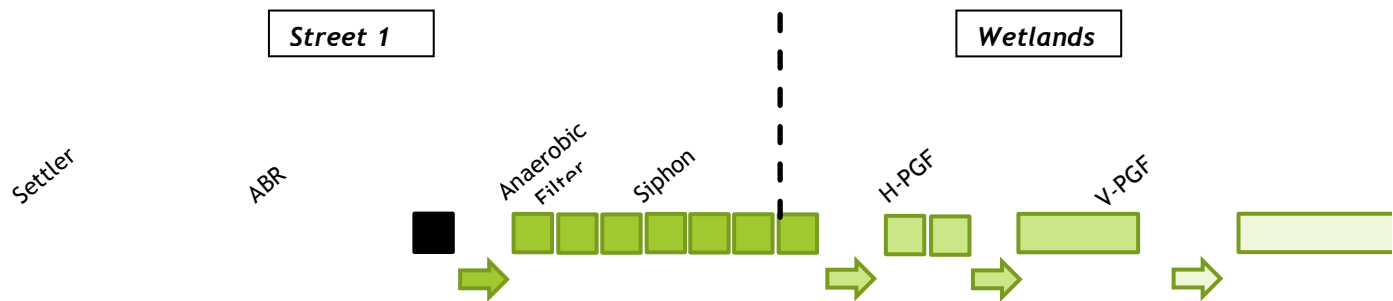

Figure 1. A flow map of the wastewater within the Newlands Mashu DEWATS.

Analytical Methods

A colorimeter pertaining to an Aqua-Check® field kit was used to obtain concentrations of nitrite and nitrate while spectrophotometry was used to obtain concentrations of phosphate, ammonium-N and nitrate. Alkalinity was measured via titration. Additionally, pH was also measured by colorimetry. Spectroquant® kits were used to prepare samples for photometric measurements and autoselectors replaced blank samples. None of the samples were diluted for testing.

All glassware was rinsed at least three times with distilled water between measurements and air-dried or wiped with Kimtech Wipes®.

Phosphate

For a measuring range of 3.1-92.0 mg/l PO_4^{3-}, 1.2 ml of Spectroquant® reagent was added to 5 ml of sample. A 10 mm rectangular cell was filled with the prepared solution and measured.

Ammonium-N

For a measuring range of 2.0-75.0 mg/l NH_4-N, 0.2 ml of sample was added to 5 ml of Spectroquant® reagent NH_4-1 and mixed. 1 level microspoon of reagent NH_4-2 was then added until dissolved. Solutions were left for 15 minutes of reaction time after preparation. A 10 mm cell was filled with the prepared solution and measured.

Nitrate (2 methods)

For a measuring range of 6.0-30.0 mg/l NO_3^-, 2 Aqua-Check® test tubes were filled with sample. 2 small level spoons of the first Aqua-Check® reagent were added to one test tube and dissolved by shaking. Solutions were left for 2 minutes of reaction time. 1 big level spoon of the second reagent was then added to test tube and dissolved by shaking. Solutions were left for 6 minutes of reaction time and then measured. The second test tube served as a blank.

For a measuring range of 2.2-88.5 mg/l NO_3^-, 1 level microspoon of Spectroquant® reagent NO_3-1 was added to a dry test tube. 5 ml of reagent NO_3-2 was then added and shaken for 1 minute until reagent dissolved. 1.5 ml of sample was slowly added to this solution as the test tube was tilted. The solution was the immediately mixed. Solutions were left for 10 minutes of reaction time and then measured.

Nitrite

2 Aqua-Check® test tubes were filled with sample. 1 big level spoon of Aqua-Check® reagent was added to one test tube and dissolved by shaking. Samples were left for 3 minutes of reaction time and then measured. The second test tube served as a blank.

Alkalinity

2 drops of indicator reagent were added to 5 ml of sample. Samples were titrated with acid and measurements were read in mmol/l H^+. Readings were converted to values of calcium carbonate using 1 mmol/l H^+=50.04 mg/l $CaCO_3$. pH of samples was required to be within the range of 4.2-8.3.

Sampling

Samples were taken at two locations. One sample was taken at the siphon tank containing the accumulated wastewater from street one. This sample represented the inlet to the V-PGF. At this sampling location, the water depth was measured by submerging a wooden 2 m stick into the siphon and measuring the length of the stick that was wet. The water depth was associated to the amount of wastewater present in the siphon before it was discharged onto the wetlands. A second sample was taken at the outlet tank of the H-PGF. Water depth at this tank was also measured.

Both samples were taken within 10 minutes of each other. Samples were taken daily at 3 different times. Planned times for sampling (9:00 Am, 11:00 AM and 1:00 PM) were subject to weather, water depth in the siphon tank, and equipment. Samples at 10:00 AM, 12:00 PM and 3:00 PM were also taken.

Samples were collected for a total of 8 days within 2 weeks. Each sample was used for all tests.

Figure 2. A map of the sampling taken at the inlet and outlet of the wetlands.

Results

The following bar graphs show concentration values corresponding to phosphate, nitrite, ammonium-N and alkalinity. Each bar represents an average of concentration measurements taken at three different times in one day; although it was not always possible to measure at all three times for some days. The error bars correspond to the maximum and minimum concentration values for the day. The first week of testing, Jul 6- July 9, was excluded from the *average percent concentration reduced* calculation for ammonium and alkalinity while Jul 6 – July 8 was excluded from phosphate and nitrite calculations (Table 1). The exclusion is due to late analysis of the samples after more than 3 days of storage. Nitrate was not detected by colorimetric or spectrophotometric methods. The pH for all samples ranged from 6.9-7.6.
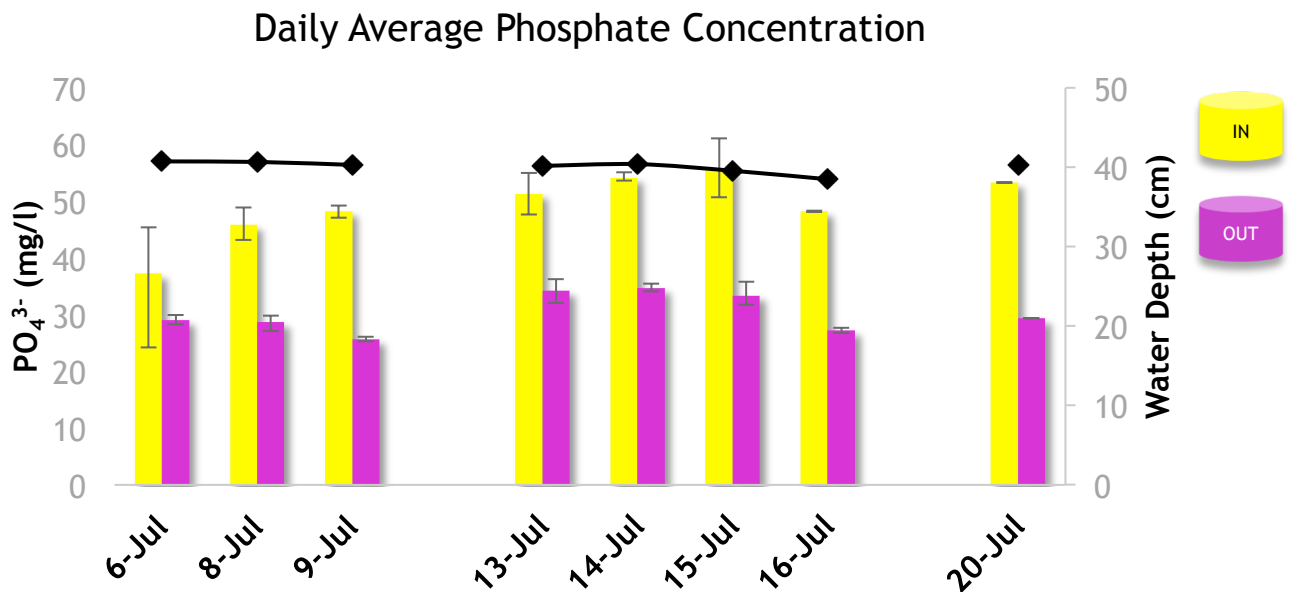

Figure 3. Phosphate daily average concentrations are represented by bars. Water depth within the full siphon tank was measured for every composite sample and is represented by black diamonds. Values for water depth also represent daily averages.
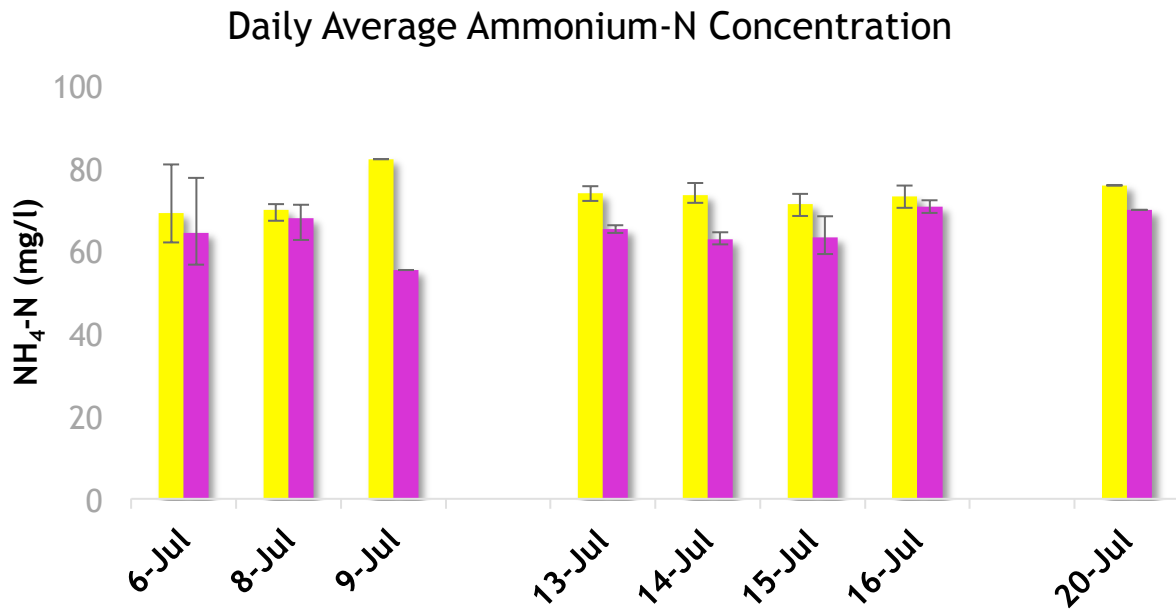
Daily Average Ammonium-N Concentration

Figure 4. Ammonium-N daily average concentrations are shown.

Daily Average Nitrite Concentration
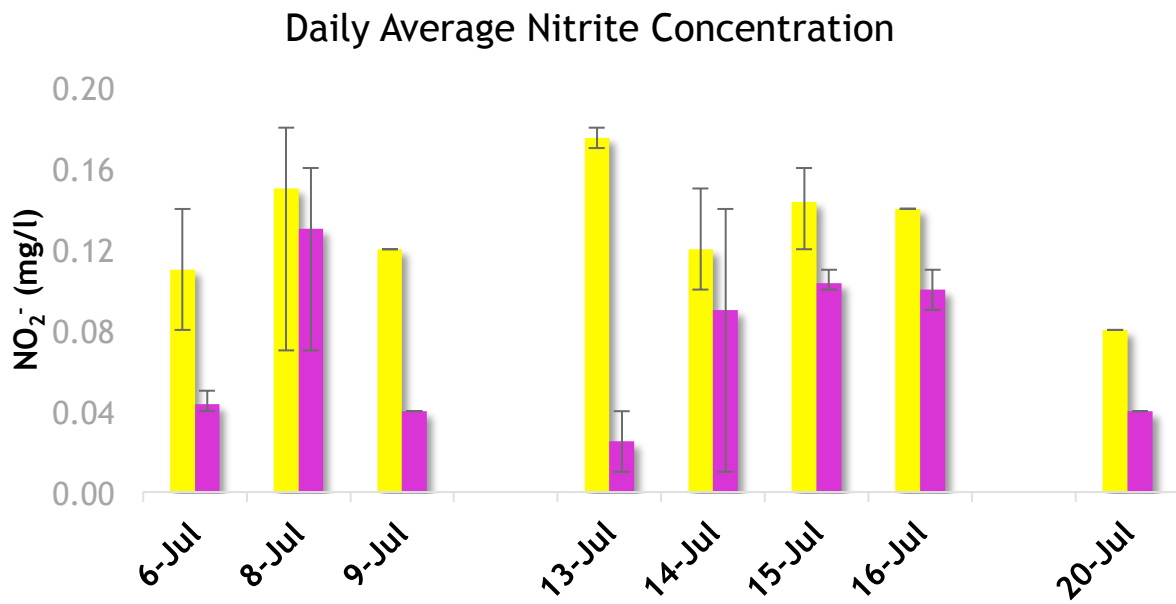
Figure 5. Nitrite daily average concentrations are shown. Nitrate was not detected.
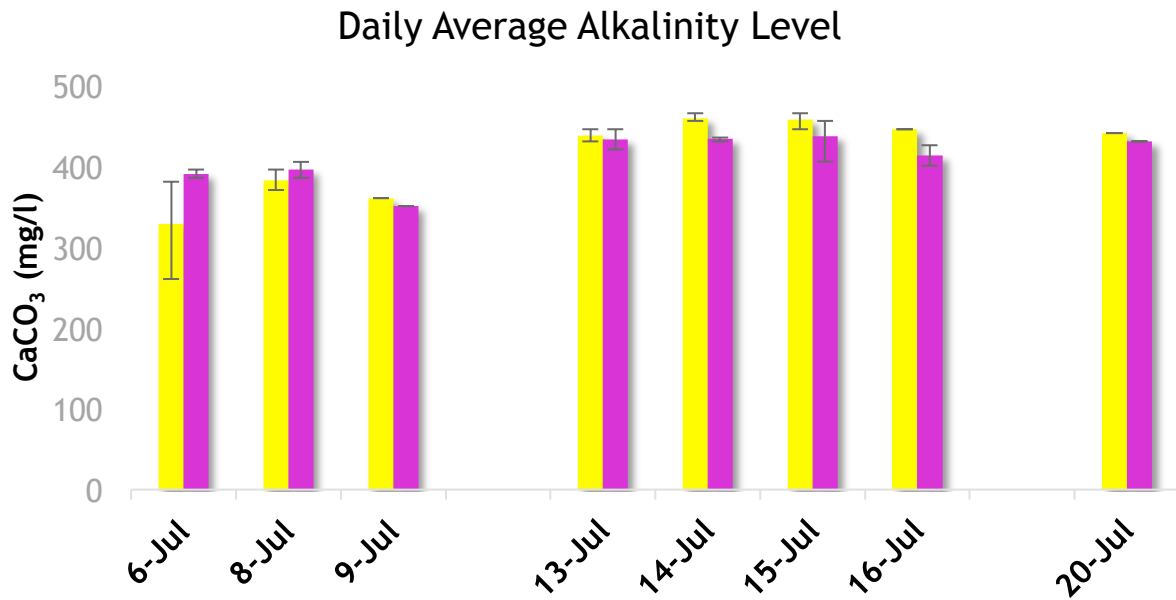
Daily Average Alkalinity Level

Figure 6. Alkalinity daily average values are shown in terms of calcium carbonate concentration.

	Average IN (mg/L)	Average OUT (mg/L)	Average % Concentration Reduced
Phosphate	51.8	31.7	41
Ammonium-N	73.5	66.3	10
Nitrite	0.13	0.07	47
Nitrate	NOT DETECTED	NOT DETECTED	NOT DETECTED
Alkalinity	448	429	2

Table 1. Average concentration values for phosphate, ammonium-N, nitrite and alkalinity are shown. Average concentration reduced is shown as a percentage on the right column. All values were obtained from daily averages. Table values for phosphate and nitrite exclude daily averages of July 6 and July 8. Table values for ammonium-N and alkalinity exclude daily averages of July 6, July 8, and July 9. Exclusion of daily averages was due to late analysis of stored samples.

Discussion

Water depth in Figure 3 shows that the corresponding samples were always collected when the siphon tank was at full capacity before being discharged onto the wetlands. The average depth was 40 cm. It was not guaranteed that the wastewater would be discharged onto the wetlands right after sampling. It may have been the case that the siphon tank was slowly reaching the last few centimeters of its maximum water level for several hours. This could mean that a sample collected during one hour may have been the same sample collected two hours later. Although water depth at the outlet tank of the H-PGF was measured, it was suspected that the water present in the tank accumulated due to pipe blockage.

Influent phosphate concentrations were approximately 51.8 mg/l PO_4^{3-} while effluent values were approximately 31.7 mg/l PO_4^{3-} which resulted in the nutrient with the most significant reduction in concentration (Figure 3). Phosphate measurements for samples collected on July 6 and July 8 were subject to late testing after 3 days of storage. Phosphate information can be correlated to the Plant uptake of phosphate within the wetlands. However, phosphate levels are still above municipality standards.

Ammonium-N influent concentrations (73.5mg/l NH_4-N) remained high at the effluent (66.3 mg/l NH_4-N, Table 1). Photometric methods for ammonium-N were revised using a standard. For a standard of 50.0 mg/l NH_4-N, the spectrophotometer read 49.9 mg/l NH_4-N. Ammonium data for July 6, July 8, and July 9 were subject to late measurements after 4 days of storage.

Nitrate concentrations were not detected. Concentrations were below the detection limits of the colorimeter (6 mg/l NO_3^-) as well as the spectrophotometer (2.2 mg/l NO_3^-). In addition to the wetland samples, a sample from the ABR inlet in street 1 was collected on Jul 14 and measured for nitrate. Nitrate was not detected at the inlet of the ABR by photometric methods.

Nitrite was detected in the influent at an average of 0.13 mg/l NO_2^-. Effluent values were detected at an average 0.07 mg/l NO_2^- (Table 1). Nitrite concentration was also measured for the sample collected at the ABR inlet of street 1 on July 14. The nitrite concentration for the ABR inlet, siphon, and outlet of H-PGF were 0.22 mg/l NO_2^-, 0.10 mg/l NO_2^-, and 0.01 mg/l NO_2^- respectively. Nitrite data for July 6 and July 8 were subject to late measurements after 5 days of storage.

There was an average decrease of 2% in alkalinity values. Alkalinity data for July 6, July 8 and July 9 were subject to late measurements after 5 days of storage.

Concluding Remarks

By obtaining dimensions of the siphon tank and calculating a theoretical water volume, the concentration data can be used to obtain a mass balance of the nutrients in question.

The time of discharge was at random hours but always within an expected time period. It is recommended that the discharge time be approximated by measuring the water depth several times within the hour. This may help determine how much time the water spends in the siphon before being discharged onto the wetlands.