# DAIRY WASTES – WASTE OR ASSET?

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## Abstract

With the world-wide drive in developed countries to further improve treated wastewater quality, removal of the nutrients nitrogen and phosphorus has moved to the forefront. However, many treatment facilities do not have enough carbon (BOD) in the influent wastewater to achieve those goals. Much research and pilot testing has been performed to identify supplemental carbon sources to increase the degradable carbon to achieve nutrient removal goals. Many cities still have industrial pretreatment programs in place to charge industries for discharging excess BOD. Many treatment facilities searching for alternative carbon sources are located in these cities that still have pretreatment surcharge systems in place. To reduce these charges, many industries have implemented their own pretreatment facilities, which was the original purpose of implementing pretreatment surcharges. However, the carbon removed from the industrial wastewater by these pretreatment systems could often be an asset to the treatment works

To further denitrify for alkalinity recovery to meet effluent pH limits, the J.D. Phillips Wastewater Reclamation Facility, located in Colorado Springs, Colorado required additional carbon. The search for an industry with a high BOD wastewater revealed a nearby dairy discharging whey into a nearby interceptor, on a sporadic basis, paying pretreatment charges ranging from $30,000 to $40,000 monthly. Simultaneously, the dairy approached the Utility to attempt to negotiate a reduced surcharge fee.

The successful use of acid whey, a waste product from the manufacture of cottage cheese, as a supplemental carbon source to increase denitrification, and the win-win solution developed for the Utility and the dairy is discussed. Recent field investigations into planned changes to Watercare Services trade waste regulations are also discussed.

## Keywords

Industrial pretreatment regulations, wastewater treatment, nutrient removal, supplemental carbon,

## 1. Introduction

As nutrient removal requirements become stricter around the world, wastewater treatment facilities face an ever increasing struggle to meet these limits on a cost effective basis. Phosphorus can be removed chemically, and nitrogen can be removed to lower levels by adding supplemental carbon in the form of chemicals. Using external chemicals for these purposes is not really sustainable or carbon footprint friendly, especially when there might be sufficient carbon available locally.

The J.D. Phillips Water Reclamation Facility (WRF) in Colorado Springs, Colorado, shown on Figure 1, was started up in April 2004. The activated sludge process at the facility is a 3-stage process consisting of an anaerobic zone, an anoxic zone and an aerated zone. Although the plant has no current total nitrogen or total phosphorus limits, the anaerobic zone was incorporated to provide a selector function to enhance sludge settleability, and the anoxic zone was incorporated to recover alkalinity. Colorado Springs, located on the east slope of the Rocky Mountains, transfers surface sourced drinking water from the west slope, due to the lack of water on the east slope. These waters are characterized by low alkalinity, which in turn translates to low alkalinity wastewater. During the treatment process, the alkalinity is consumed by the nitrification process, and denitrification is used at all of the Front Range treatment facilities to recapture alkalinity to meet the effluent pH limits.

**Figure 1. Aerial View of the J.D. Phillips WRF**

Upon start-up of the WRF, the permitted effluent pH limit of ≥6.5mg/L could not be met.

## 2. Problem Identification

An investigation into the cause of this issue revealed that the influent wastewater had a higher total Kjeldahl nitrogen (TKN) concentration than had been measured during the initial sampling and analysis program. During the design phase, the diversion point from the adjacent interceptor was moved from the plant site to a mile upstream to take advantage of gravity and eliminate a large pumping station. The owner assumed the wastewater quality would be the same, and declined reanalysis of the wastewater quality. During the initial sampling and analysis program, the TKN was measured at an average of 40 mg/L. During the follow-up analysis, the TKN was measured at an average of 52 mg/L. The primary effluent COD/TKN ratio decreased from 11 to 9.

### 2.1. Short-Term Solution

The short-term solution to meet the effluent pH limit was to add a caustic addition system using a pH meter and a feedback loop to raise the effluent pH above the permit limit. The annual cost for sodium hydroxide was approximately $100k.

### 2.2. Long-Term Solution

The long-term solution developed was a plan to evaluate the quality of the wastewater in various interceptors that could be diverted to the WRF to increase the COD:TKN ratio entering the facility. The search revealed a dairy discharging acid whey into a nearby interceptor, on a sporadic basis, and paying industrial pretreatment charges ranging from $30,000 to $40,000 monthly. Simultaneously, the dairy had approached CSU to attempt to negotiate a reduced surcharge fee to reduce their operating costs to maintain the dairy in operation and were also investigating land disposal of the whey to eliminate the pretreatment charges if a reduced surcharge could not be negotiated.

> ***Whey** or **milk plasma** is the liquid remaining after milk has been curdled and strained. It is a by-product of the manufacture of cheese or casein and has several commercial uses. **Sweet whey** is manufactured during the making of rennet types of hard cheese like Cheddar or Swiss. **Acid whey** (also known as "sour whey") is obtained during the making of acid types of cheese such as cottage cheese.*
> (Wikipedia)

### 2.3. Whey As A Supplemental Carbon Source

Before the whey could be used as a supplemental carbon source, analyses were required to determine its adequacy. Whey samples were collected from the dairy for 10 days and analyzed for the COD, BOD, and TKN fractions to evaluate its use as a supplemental carbon source in April, May and August of 2009 and the results are listed in Table 1.

**Table 1. Measured Quality of Local Acid Whey**

| Measured Parameter | Average Concentration (mg/L) | Range (mg/L) |
|---|---|---|
| TSS | 1,660 | N/A* |
| VSS | 1,660 | N/A* |
| COD | 66,630 | 77,800 – 61,500 |
| soluble COD | 63,400 | 66,900 – 58,200 |
| flocculated filtered COD | 58,720 | 64,700 – 51,400 |
| BOD | 29,600 | 34,000 – 27,000 |
| soluble BOD | 26,800 | 31,000 – 24,000 |
| TKN | 44 | 52 - 38 |
| $NH_3$ | 38 | 45 - 33 |

*Only one sample measured for TSS and VSS.

Although the Water Environment Research Foundation (WERF) *"Protocol to Evaluate Alternative External Carbon Sources for Denitrification at Full-Scale Wastewater Treatment Plants"* (Gu, et.al.) had not yet been published, a review of the document indicates that the procedures used to evaluate the quality of the acid whey as a supplemental carbon source generally followed the recommended protocol. Based on the quality of the acid whey listed in Table 1, a full scale pilot test protocol was developed and implemented.

### 2.4. Full Scale Pilot Test

As the first stage of the long-term solution, a full scale pilot test using acid whey as a supplemental carbon source to enhance denitrification was implemented. Temporary storage tanks were installed on the WRF site and acid whey was delivered by the dairy and stored in the tanks as shown on Figure 2. The dairy made cottage cheese only four days per week, and the weekly volume of acid whey was limited. The early stages of the pilot test were spent attempting to determine how to make four days per week of whey last for seven days of application. Whey addition into the primary clarifier effluent channel was started on August 16, 2009. Composite effluent $NO_3$-N was measured with a HACH kit at the WRF on a daily basis. Feed locations were changed over the next four months to determine the optimum whey feed location.

**Figure 2. Acid Whey Delivery to Temporary Storage Tanks**

Figure 3 shows the plant effluent composite $NO_3$ from the start of whey addition through the first few days of 2010 as well as the whey feed location.

**Figure 3. Plant Effluent $NO_3$ by Whey Addition Location**

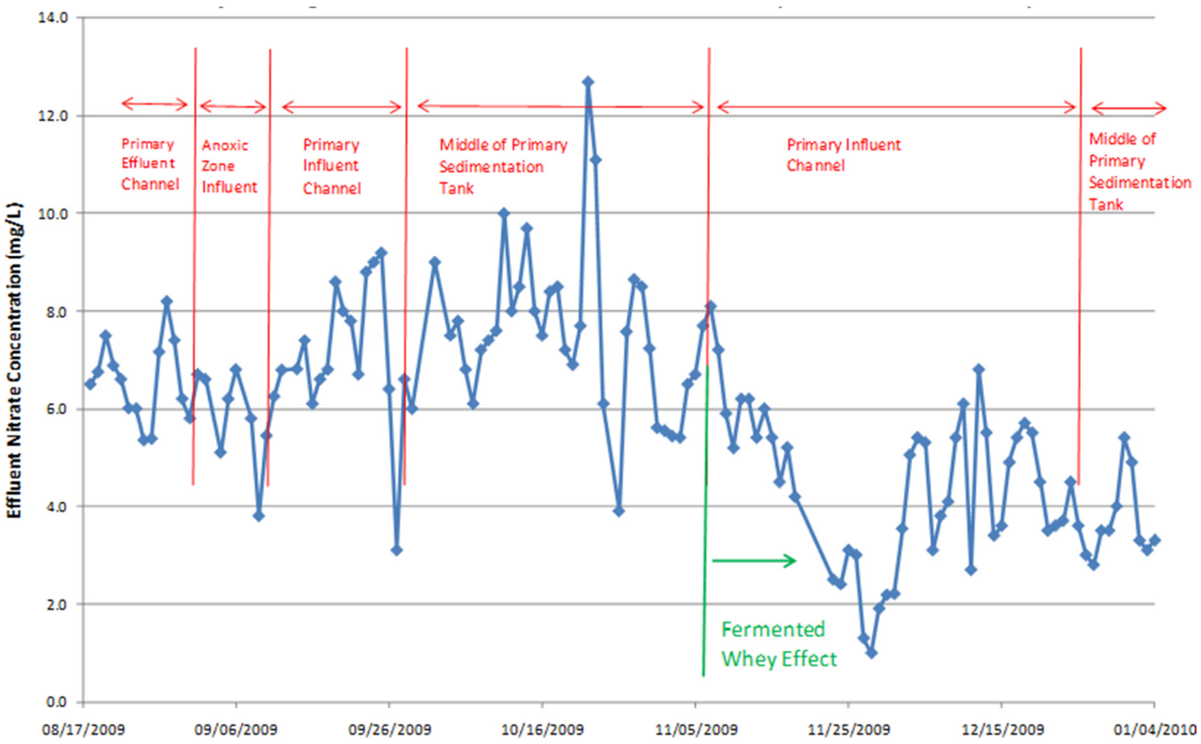
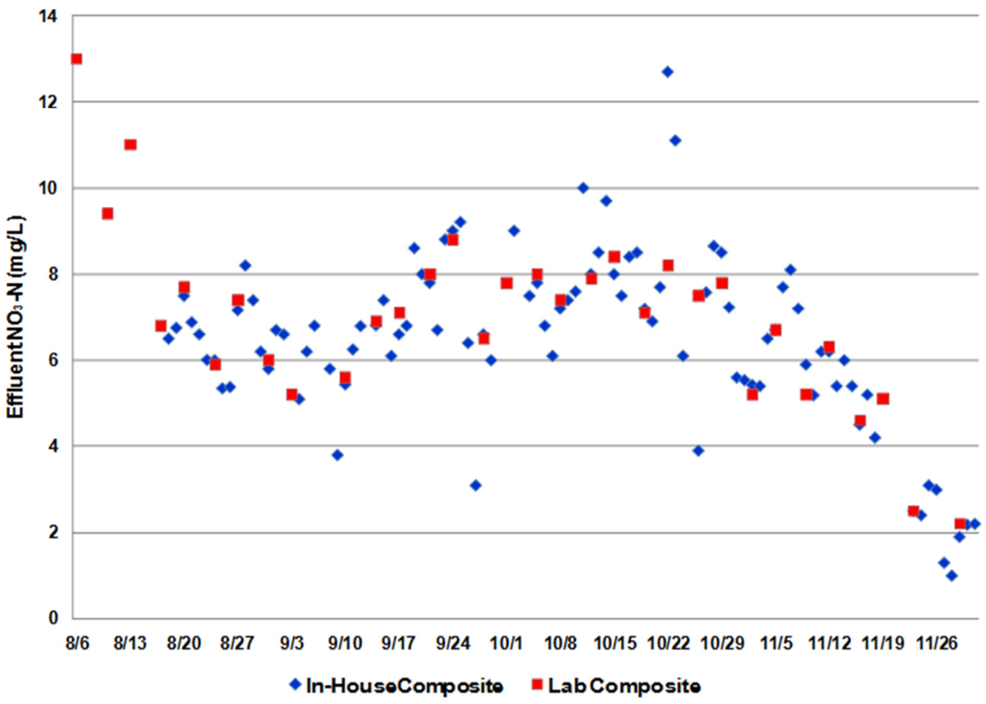


Figure 4 shows the effluent nitrate concentration just before and then after the whey feed was started on August 16, 2009. Composite effluent $NO_3$-N was measured with a HACH kit at the WRF on a daily basis (blue diamonds), and twice per week in CSU's certified lab (red squares) to confirm the HACH test procedure values. The first three data points and the historical data indicate significantly higher effluent $NO_3$-N concentrations ranging between 9-13 mg/L prior to the start of feeding whey. Following whey addition, the effluent $NO_3$-N concentrations typically ranged between 6-8 mg/L. There are occasional excursions from the typical effluent $NO_3$-N concentrations that resulted from missed whey deliveries, equipment failures, etc. In early November, plant staff switched whey storage from the temporary tanks to an offline grit removal tank and the dairy subsequently increased their delivery rate by approximately 25 percent. Whey is currently added to the primary clarifier inlet. An interesting note is that the longer the whey is stored on-site, the more effective it is as a supplemental carbon source as can be seen by the continued decrease in effluent $NO_3$ following the use of the grit tank for whey storage to concentrations typically ranging from 1-5 mg/L.

**Figure 4. WRF Effluent $NO_3$-N Concentrations after Whey Feed Started**



Since there appeared to be a decreasing trend in the effluent NO3 concentrations, effluent nitrate and ortho-phosphorus were both plotted with more care as shown on Figures 5 and 6. The results in both of these figures indicate significantly better removal following storage of the whey in the offline grit removal tanks. The whey is consistently delivered at approximately 38 °C, and the grit removal tank is below ground between the headworks building and the primary clarifiers, which probably allows a reasonable amount of heat retention. Because a significant reduction in effluent ortho-phosphorus was observed, it was assumed that fermentation of the whey was occurring in the grit storage tank generating volatile fatty acids (vfa). However, when the “fermented” whey was sampled at the WRF from the grit tank, it only contained 1.3 mg/L of acetic acid. Based on the P removal achieved as shown on Figure 6, the assumption that significant vfa could be generated by fermenting the acid whey remained.

**Figure 5. Activated Sludge Effluent $NO_3$-N**

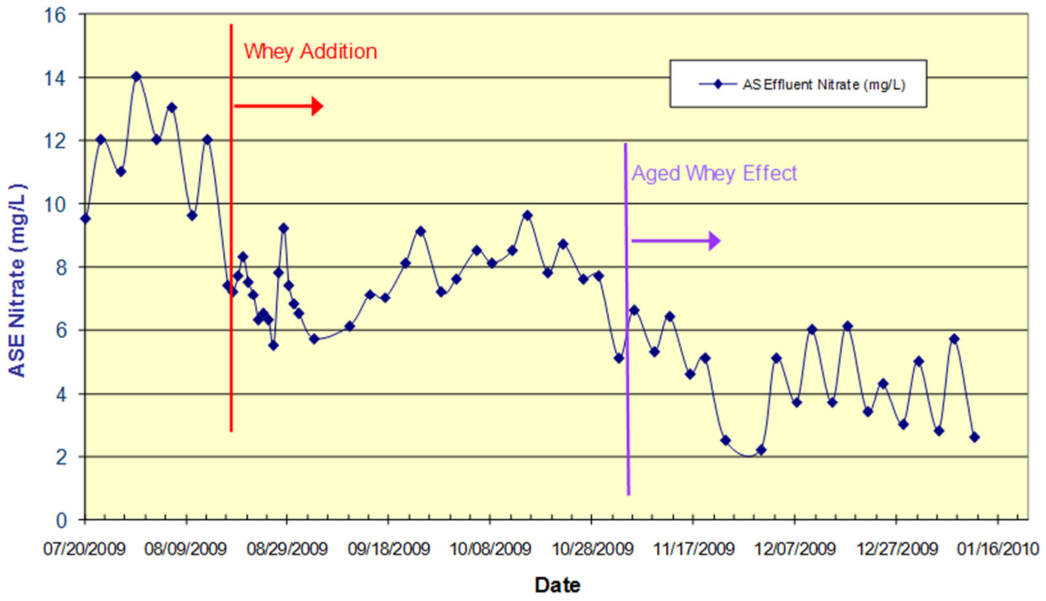
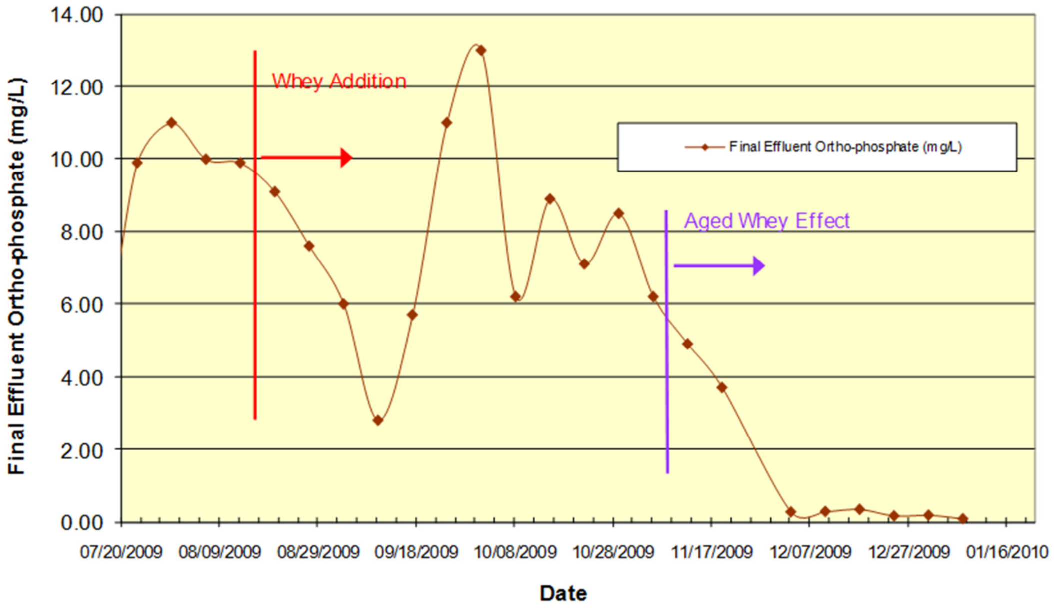


**Figure 6. WRF Final Effluent PO4-P**



Bench scale tests with whey stirred and heated whey indicated that vfas could be generated.

### 2.5. Bench Fermentation Test

A bench fermentation test was set up in the Utility laboratory to determine how much vfa could be generated under controlled fermentation conditions. Figure 7 shows the bench fermentation apparatus set-up, and the results of the various fermentation tests are shown on Figure 8. Volatile fatty acids in excess of 20,000 mg/L, with approximately equal concentrations of acetic and butyric acids were generated. The key to achieving the effective fermentation was to raise the whey pH from 3.2 SU to a range of 5.75 to 6.0 SU.

**Figure 7. Bench Acid Whey Fermentation System**

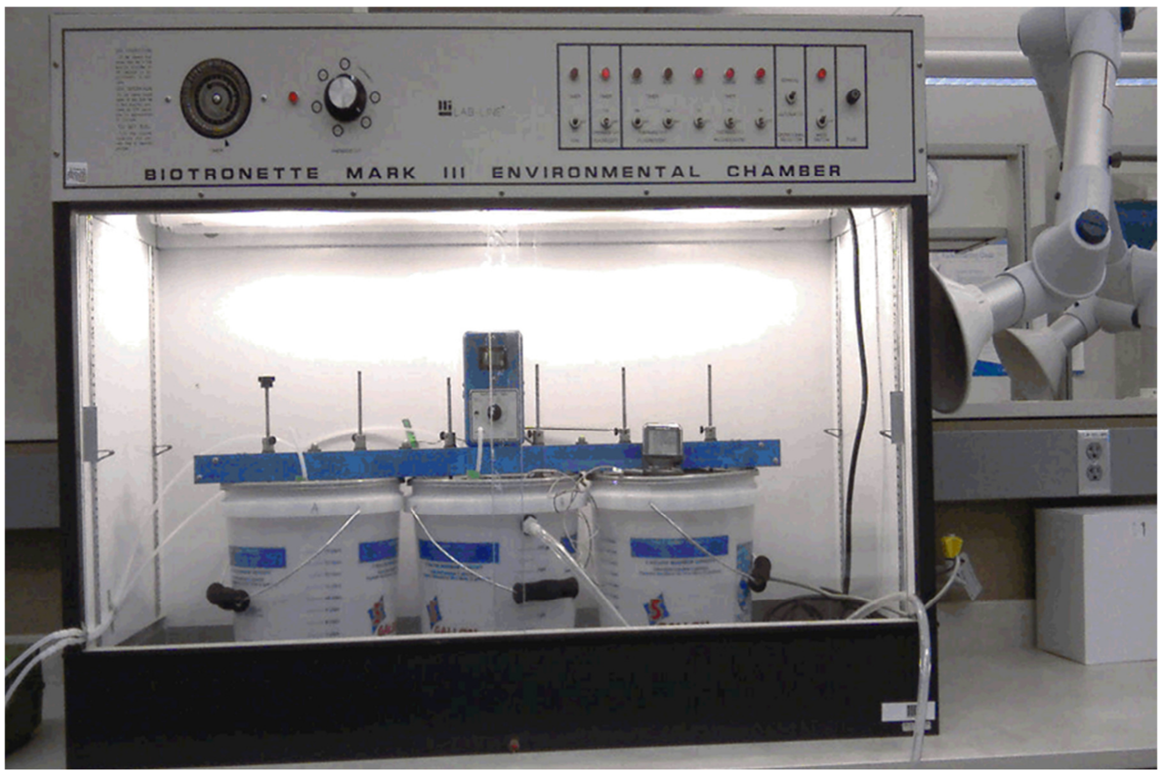
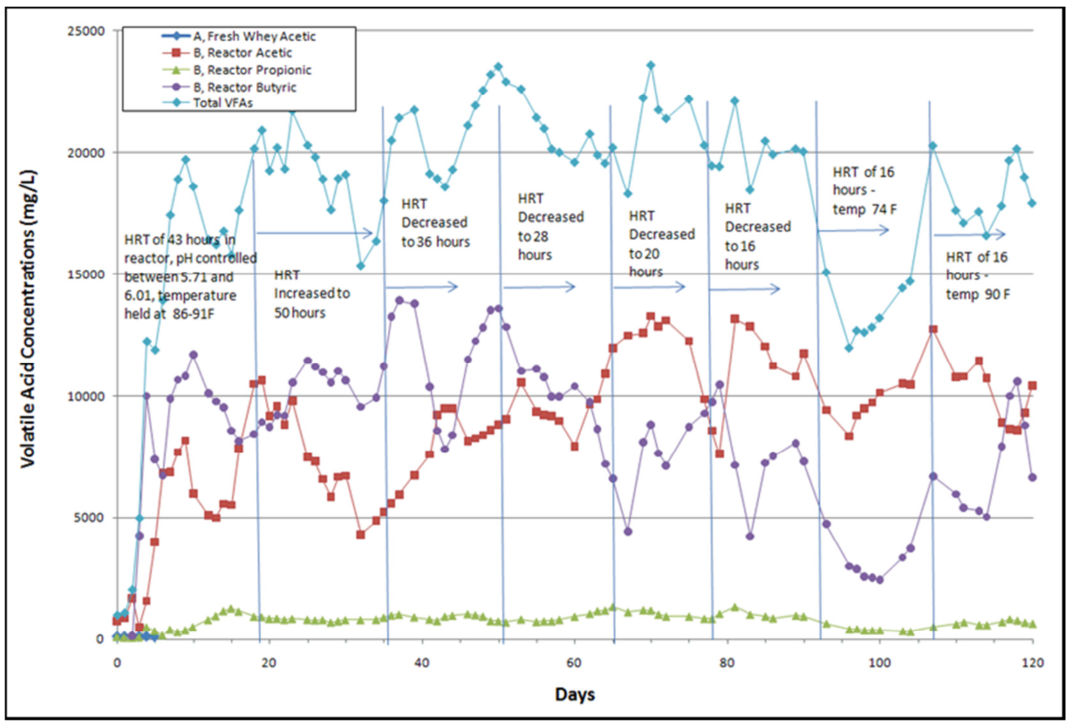


**Figure 8. Results of the Pilot Whey Fermentation Test**



Based on these results, it was determined that acid whey fermentation would generate significant vfas and allow the WRF meet the current permit limits for pH, and all the proposed future nutrient limits of 6.0 mg/L TN and <1.0 mg/L TP. A full scale whey receiving station and fermenter is currently under construction at the site.

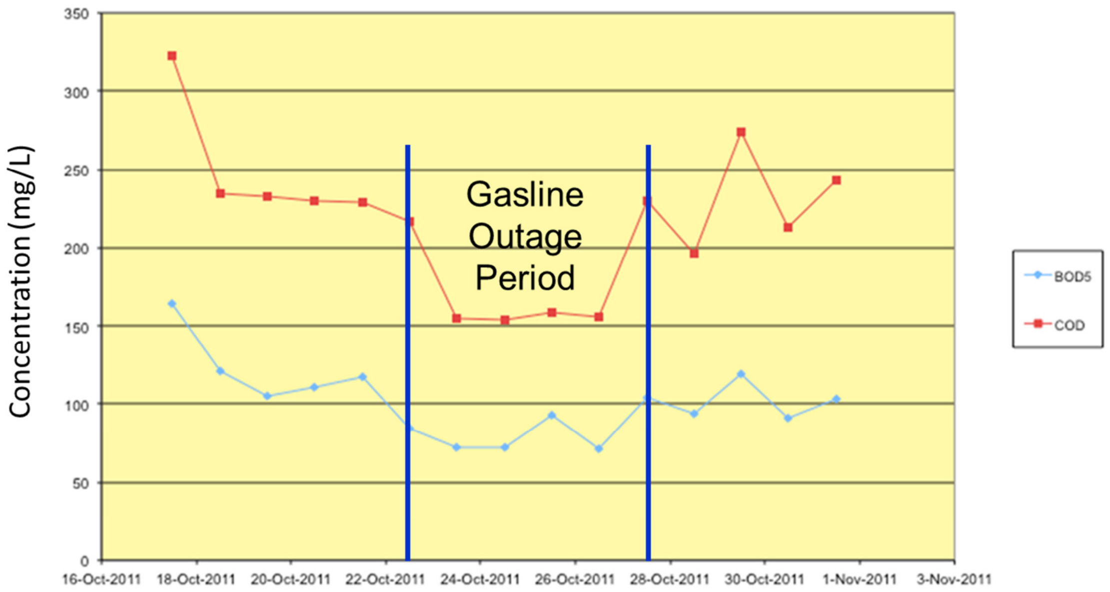
### 2.6. The Auckland Experience

Industry was once around 31% of the flows to the Mangere Wastewater Treatment Plant (WWTP). Currently it represents approximately 6% of the flow. In 2003 the WWTP was upgraded from a combination trickling filter/ oxidation pond based treatment facility to a full activated sludge process including nitrification/denitrification with UV disinfection. The industrial pretreatment regulations had not updated to represent these two fundamental changes in the influent make up and treatment processes. In 2011 Watercare commenced the process of reviewing its pretreatment regulations following a number of seasonally reoccurring technical issues with its denitrification processes.

Further analysis of the plants' influent and process configuration showed that the plant was not being provided with sufficient carbon during the peak summer months when industry closed for the Christmas maintenance period. Investigations were then conducted to identify solutions to the carbon issue. These included amongst other things, methanol dosing, and identifying industries that have sufficient carbon in their discharges to compensate for the seasonal low period.

The results of the industry investigation showed that the industry carbon loads alone would not be sufficient enough to overcome the seasonal carbon shortfall. This was due to the fact that the storage and release of the carbon rich wastes would be difficult to sustain for the extended seasonal low period and the total load of BOD was not able to compensate for the loss of domestic BOD load during the same period. This point was proven during one week in October 2011 when a large number of industries had to cease production for a number of days due to a widespread loss of their gas (energy) supply as shown on Figure 9.

**Figure 9. Mangere Influent COD/BOD During The 2011 Gas Outage**



The confirmation of these results encouraged investigation into other opportunities to remove regulations that did not support the denitrification processes at the WWTP. The regulated requirement to dose acid to bring industrial pH below 10 for any one discharger, and the resultant pH observed at the plant was investigated because a more alkaline wastewater is preferable for the nitrification/denitrification processes. It is also recognized that low pH is a major contributor to generation of $H_2S$ which causes corrosion of concrete sewers.

Watercare met with a number of industries discharging higher pH wastes to seek to pilot the trial of increases in the regulated levels of pH, accepting up to a pH of 12. A one month trial of the pH change has occurred with 13 industrial customers. The exact effect of this trial during the summer months of 2011 was inconclusive due to a particularly wet period during the trial. However, the previous years' technical issues did not occur over the key summer period. Further pH trials are currently underway to confirm the effect of raising the pH limits on:

- local sewers,
- interceptor sewers and
- the denitrification process.

## 3. Pretreatment Requirements

The objectives of the pretreatment requirements of the Clean Water Act (CWA) are to:

*a) To prevent the introduction of pollutants into POTWs which will interfere with the operation of a POTW, including interference with its use or disposal of municipal sludge;*
*b) To prevent the introduction of pollutants into POTWs which will pass through the treatment works or otherwise be incompatible with such works; and*
*c) To improve opportunities to recycle and reclaim municipal and industrial wastewaters and sludges.*[1]

At the time pretreatment requirements of the Clean Water Act (CWA) and the Auckland Drainage Act (ADA), ("The Acts") were designed, the focus on protecting treatment works from failing due to discharges from industry and other non-domestic sources was based on control of excess BOD and TSS.

At the time, the underlying intent of the pre-treatment requirements in The Acts are to:

a) To prevent the introduction of pollutants into treatment works which will interfere with the operation of a treatment works, including interference with its use or disposal of municipal sludge;
b) To prevent the introduction of pollutants into treatment works which will pass through the treatment works or otherwise be incompatible with such works; and
c) To improve opportunities to recycle and reclaim municipal and industrial wastewaters and sludges.

Over the past 40 years there have been considerable changes in the wastewater treatment industry. The Resource Management Act has come into force in New Zealand, placing pressure on treatment works to avoid, remedy or mitigate any adverse effects of its operation. This is a risk-based assessment that requires significant consultation with the community and the regulator. This same act has placed a significant driver for change on industry as well. Across the States and New Zealand, the traditional practice of treatment through oxidation ponds is being progressively phased out and replaced with complex nutrient removal processes. Operators are also pushed to allow for a new 'green-focus' and include energy resource recovery and energy generation capacity.

### 3.1. Why The Need to Change the Regulations

Colorado Springs Utilities (CSU) was facing the potential loss of an excellent supplemental carbon source as well as the revenue generated by the pretreatment surcharges. Many cities have lost industries to other cities with either no or more amenable pretreatment regulations. Auckland is facing loss of good BOD as a carbon source through industrial pre-treatment and prohibitive regulation as well as an artificially lowered pH in the industrial discharges. Industries are important to cities. Cities must find a way to work together with industries to develop win-win solutions to waste treatment. One option is to change the pretreatment regulations to be more accepting of industrial wastes containing useful constituents.

### 3.2. Impact on Colorado Springs Utilities Pretreatment Program

With the removal of the whey from the dairy's effluent, the BOD concentration of the effluent dropped significantly. However, the dairy effluent BOD remains above the surcharge threshold, so they will still pay a surcharge, but at a reduced amount for treatment of the remaining wastewater. Through this arrangement, the dairy has reduced the BOD surcharge by approximately 70%, a definite win-win outcome. In addition to the BOD surcharge reduction, the dairy reduced the TSS surcharge by 50%. Colorado Springs Utilities have revised the tariff program for high strength surcharges to make allowances for beneficial sources of BOD. CSUs new industrial pretreatment regulations can be found on Colorado Springs Utilities (CSU) web page.

### 3.3. Watercare Services Trade Waste Program

Auckland is currently in review of its pre-treatment legislation. The new legislation needs to come into effect before July 2013 and it is important that any potential changes to the regulations are understood along with any adverse effects on the plant treatment processes.

## 4. Conclusions

The time has come to change the way we look at industrial waste discharges to POTWs. Industrial wastes may no longer be a problem, but may be a considerable asset. The education of the public and private sector are key in working out equitable arrangements. The institutional issues can be worked out, but may take some time. Considering the cost of more conventional supplemental carbon sources, treasure may be found in your own backyard. The process of investigating industrial wastes as potential carbon sources, evaluating their quality as a supplemental carbon source and working through the issues has been an educational, energizing, fun and productive activity within the utilities.

### 4.1. Colorado Springs

CSU has recognized the opportunity for “free carbon”, and has actually signed a contract with the milk processing plant to accept their acid whey for the next ten years. CSU was sufficiently concerned about the potential availability of this waste product over the long term that is was deemed urgent to lock in the agreement as soon as possible. At the time this agreement was developed, the new pretreatment regulations had not been completed. Therefore, in the short-term, the milk plant still paid the BOD and TSS surcharge, but the Utility purchased the acid whey at the cost of the surcharge. At the end of the ten-year contract, an analysis will be performed to identify the true market value of the acid whey.

### 4.2. Auckland

The primary legislated mandate for Watercare's operations was reviewed by the central government in 2009/10. This has resulted in a revised interpretation of how industrial wastes are regulated, moving away from the Auckland Metropolitan Drainage Act of 1960, to the Local Government Act, while duly recognizing the Resource Management Act. In particular, the focus has moved from minimizing the utilities costs to now maintaining costs to customers at minimum levels. This has provided the catalyst for a review of the industrial pretreatment legislation. This review has led to the conclusion that the generic Auckland trade waste regulations need to be updated with a focus on customer specific, local conditions for each of Auckland's larger industrial customers.

## 5. References

The National Pretreatment Program, 40 CFR §403.2

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