HIGH RESOLUTION MEASUREMENTS IN THE WASTE WATER INDUSTRY: CASE STUDIES

Robert Dexter
DCM Process Control Ltd.
Luke Sutherland-Stacey
University of Auckland

ABSTRACT

In the water and wastewater industries, historic best engineering practice for quantification or characterisation of water or wastewaters involved grab-sampling campaigns. Lab measurements are then undertaken using standard methods techniques which have a considerable per sample cost.

These grab sampling techniques are often intended to capture representative samples of complex industrial and environmental processes, but may fail to do so if insufficient data points are collected compared to the inherent variability of the measured system.

An alternative to grab sampling methods is on line instrumentation. In this paper we demonstrate by way of case studies the advantage of using short term high frequency monitoring of wastewater applications in New Zealand and Australia.

KEYWORDS

UV-VIS, in-situ, real-time,

1 INTRODUCTION

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These grab sampling techniques are often intended to capture representative samples of complex industrial and environmental processes, but may fail to do so if insufficient data points are collected compared to the inherent variability of the measured system.

An alternative to grab sampling methods is on line instrumentation. In this paper we demonstrate by way of case studies the advantage of using short term high frequency monitoring of wastewater applications in New Zealand and Australia.

In this paper we demonstrate by way of case studies the advantage of long term high frequency monitoring of wastewater applications in New Zealand and Australia.

1.1.1 Equipment

The spectrometer (spectro::lyser, s::can Messtechnik GmbH) used in this work is an in situ probe about 0.6m in length and 50mm in diameter . The spectrometer measures the attenuation of light in the UV-VIS spectrum between 200 and 750nm. In the case studies described in this field work the path length varied from 0.5mm to 100mm.

Various components of wastewater absorb light in different regions of the UV-VIS spectrum, and the spectrometer can detect the total absorption from all the compounds present. Each measurement takes about 15 seconds. The probe is automatically cleaned by a compressed air system and data is logged on a control computer so the system can operate independently for long periods of time. For more information see Langergraber et al. (2003).

2 CASE STUDIES

2.1 NITRATE

Influent usually has low nitrate concentration, as sewer conditions tend be not particularly favorable for conversion of ammonia and proteins. Nitrates arriving at the inlet to a WWTP can be indicative of unexpected upstream discharges and cause problems with treatment processes.

The use of UV-VIS instrumentation for real-time quantification of nitrate is well established in literature (e.g Langergraber *et al.,* 2003).

A UV-VIS probe recently deployed at the inlet to a WWTP detected unexpectedly high nitrate concentrations. The cyclic pattern in increased nitrate load (figure 1) corresponded with plant upsets. Plant staff we able to track the discharges upstream to recently opened factory, and take remedial action.

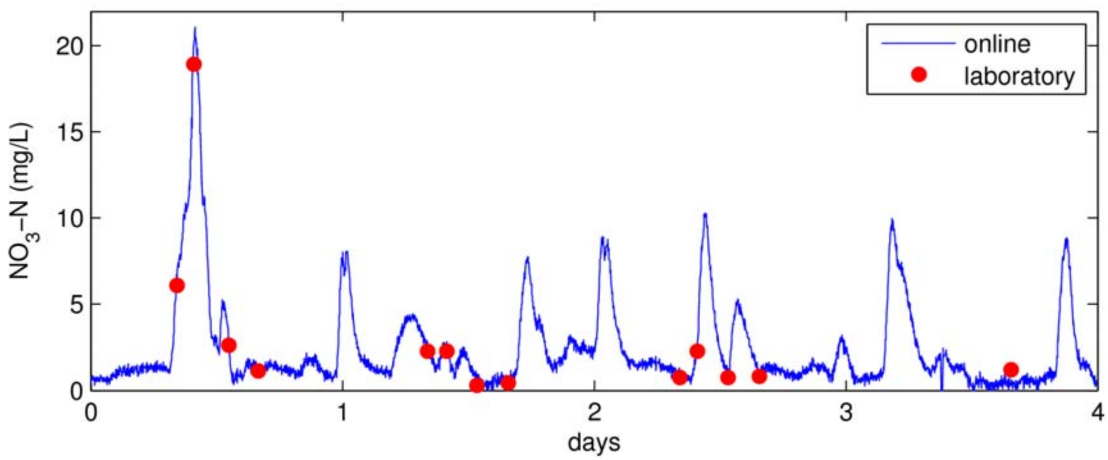

Figure 1: Nitrate concentration at the inlet to a WWTP determined with online (blue line) and grab sampling (red circle) methods.

2.2 SULPHIDE

Hydrogen sulphide (H_2S) is generated in the aqueous phase of wastewater by bacterial reduction of sulphate under anaerobic conditions. Accumulation of hydrogen sulphide in sewers poses significant problems in wastewater transport and treatment systems. Bacterial oxidation of hydrogen sulphide on pipe walls exposed to atmospheric oxygen produces sulphuric acid, which actively destroys concrete structures and pipes at a corrosion rate of several millimetres a year. The gas is also toxic to humans in even relatively low concentrations and poses a health risk to sewage workers. At even lower concentrations hydrogen sulphide is foul smelling, and has a significant adverse impact on any exposed communities.

Photograph 1: An example of corroded equipment at a WWTP (Photo: Alan Neethling)

Hydrogen sulphide production occurs in the sewage system on the Gold Coast of Australia. Approximately 2800km of sewer mains (60% pressure 40% gravity) are distributed across a large low lying coastal area with significant canal and broad water frontage. Sea water ingress results in high sulphate concentrations, which is subsequently exposed to reducing conditions and high retention times during long journeys through pressure mains to (one of) only four Waste Water Treatment Plants (WWTPs). The combination of geographical features and year round warm climate combines to produce high corrosion and odour potential environments.

Recently the authors of this paper have published work detailing how UV-VIS techniques can be used to measure dissolved sulphide in real time (Sutherland-Stacey *et al.,* 2008). A comparison of analytical and real-time results is given below in figure 2.

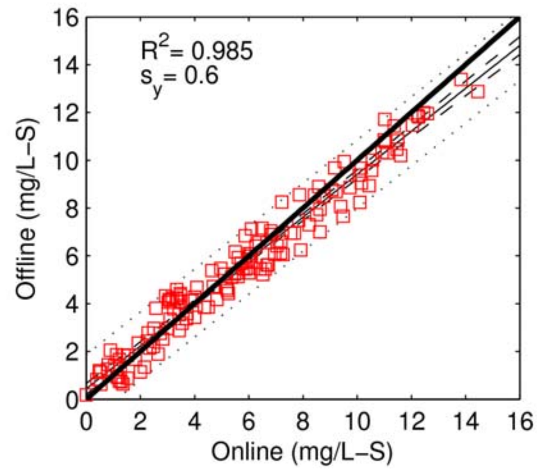

Figure 2: Comparison of total dissolved sulphide measured in real time and corresponding grab samples after Sutherland-Stacey et al., *(2008) with additional data points.*

Following the validation of the new technique a number of field studies have been undertaken to asses the efficacy of various sulphide control strategies (Corrie *et al.,* 2009 in press). Authorities on the Gold Coast actively attempts to suppress sulphide generation. Several chemical dosing strategies are employed, including addition of oxygen gas to rising mains.

2.2.1 Oxygen Injection

By supersaturating the waste with oxygen gas and en training oxygen bubbles in waste water there could be sufficient oxygen available to prevent development of anaerobic biomass and immediately treat any incidentally arising reduced sulphur compounds. This treatment strategy is termed Oxygen Injection (OI). The cost to the GCC to run the OI strategy is of the order \$1M p.a., significant infrastructure is involved, and there are non-trivial safety issues associated with oxygen enriched environments.

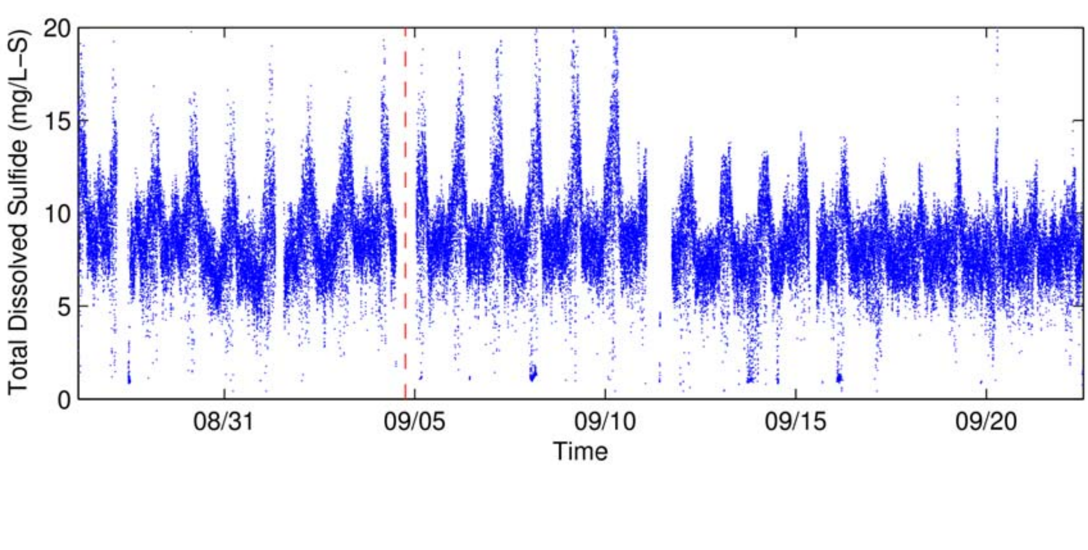

Figure 3: Sulphide measurement at the inlet of a WWTP. The data to the left of the red line was recorded before the oxygen injection system was initialised (the control); the data to the right was recorded after initialisation (the test). Gaps in the data were caused by intermittent site power problems.For some time management at GCW have been unsure of the efficacy of OI in suppressing sulphide formation.

Grab sampling methods have been unable to return consistent results and existing hydrogen sulphide gas sensors are unable to monitor dissolved sulphide in pressurised mains. As such the council has been unable to quantify the effect of the OI strategy directly. Some indirect quantification was possible, for example the cost related to plant repairs due to corrosion has not been reduced by OI.

Monitoring to test the effectiveness of OI has also returned inconclusive results. At time oxygen injection appears to have negligible effect on sulphide concentration (figure 3) but at other times the suppression effect is clear (figures 4,5). Over short distances under controlled conditions the suppression is clear.

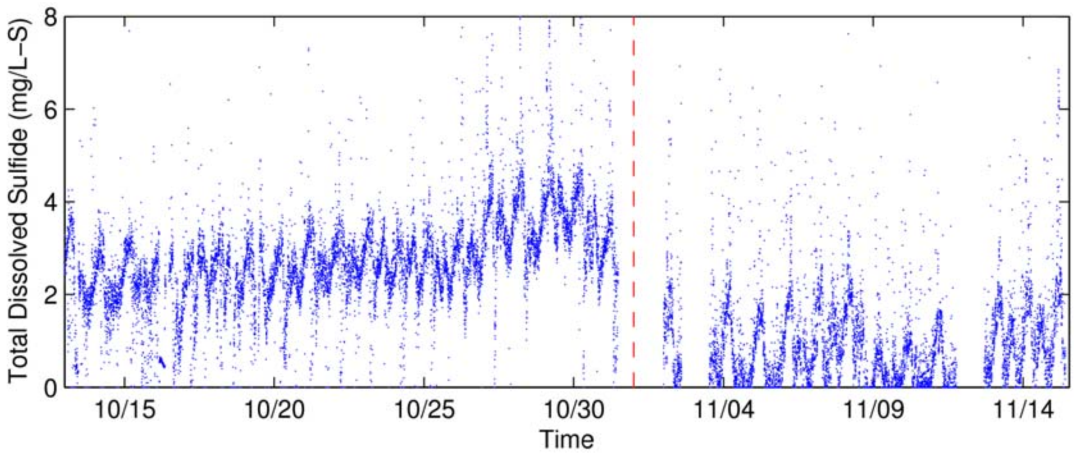

Figure 4: As for figure 3, but at a different WWTP inlet.

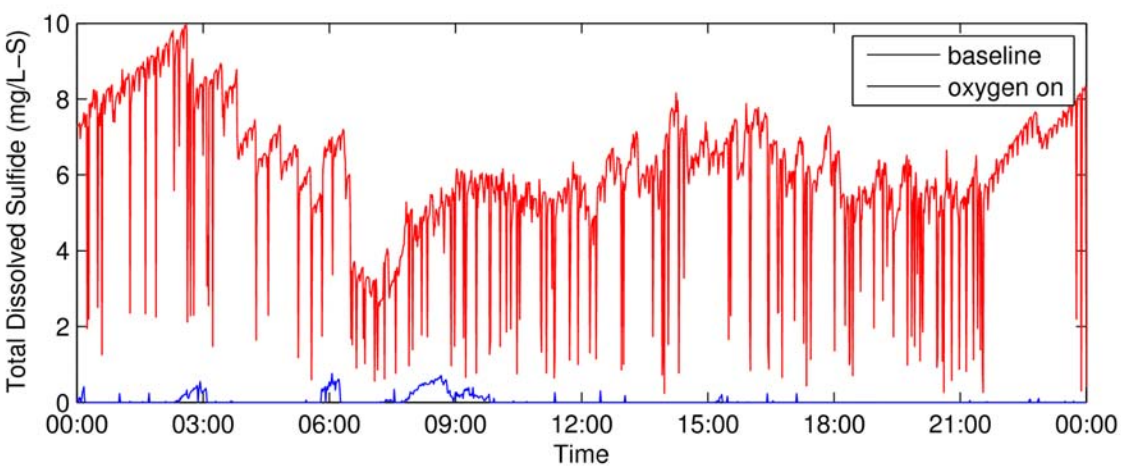

Figure 5: Oxygen Injection in a short length of pipe.

2.2.2 Caustic Dosing

Hydrogen sulphide gas is distasteful to the public because of its odour. By increasing the pH of septic wastewater above 9 by addition of a base, dissolved hydrogen sulphide is converted to the bisulphide ion which cannot gas out (Jefferson et al. 2002). If employed at the inlet of a WWTP this strategy allows sulphide to be trapped in the wastewater for treatment later in the process.

To test this lime was added to influent from a rising main at the inlet of a WWTP. By measuring the dissolved sulphide concentration, flow and pH just before addition and after primary settling (photograph 2).

Data logged with the online system allowed the sulphide mass balance across the primary clarifier to be determined. When the caustic dosing system is running no sulphide loss is detected (figure 6).

Photograph 2: A sensor package was deployed from the gantry into the primary clarifier tank. The housing for a power supply is visible in the foreground. A second sensor was installed at the plant inlet. (Photo: Alan Neethling)

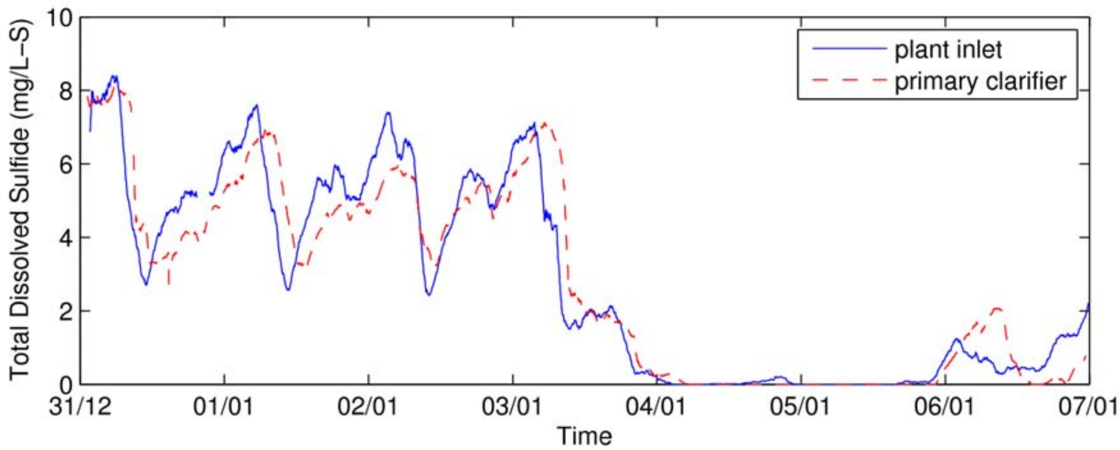

Figure 6: Sulphide concentration during lime dosing, the concentrations are similar at both locations indicating very little hydrogen sulphide gas escaped to the atmosphere. (in this chart no correction is made for the retention/lag time of some hours between the inlet and clarifier- resulting in an offset between the two trends). The drop on the 4th is due to a rain event.

2.3 FAT AND PROTEIN

UV/VIS sensors have been installed at a number of dairy factories in wastewater outlet streams. Protein is known to absorb light in the ultra violet region of the spectrum. Fat tends to scatter visible light. With such signals it was a simple matter to calibrate the UV/VIS sensor against off-line lab samples to provide a continuous time series measurements of fat and protein losses (figure 7).

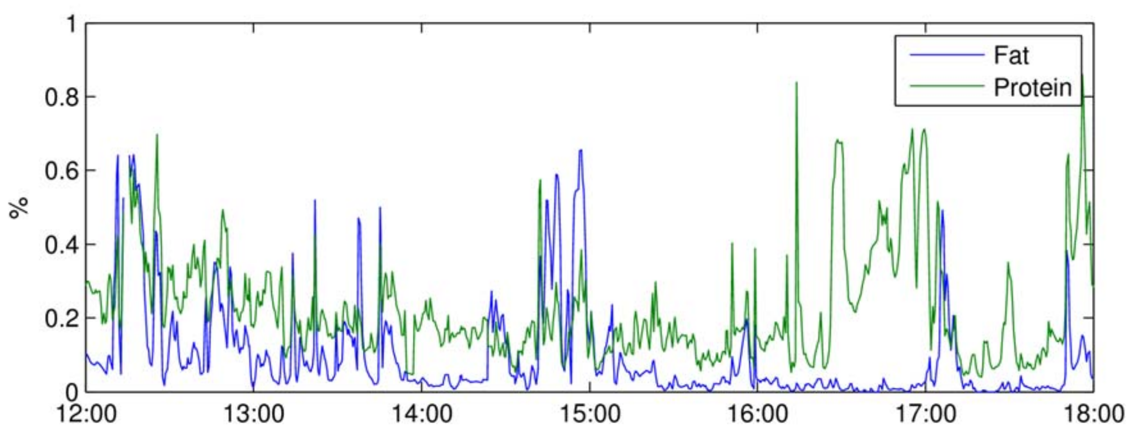

Figure 7: Concentration of Fat and protein in dairy factory effluent. As a comparison 'Blue Top' milk contains about 3% fat and protein.

Work in partnership with dairy groups to use real time feedback to minimize avoidable product losses is ongoing.

2.4 HAEMOGLOBIN

The meat processing industry generates large volumes of high strength wastewater. It has been estimated that about one cubic metre of water is required to process a cattle beast In New Zealand wastewater from the meat processing industry is often discharged into municipal sewers or directly to waterways, the ocean or applied to land.

As a contributor to municipal sewer networks abattoir wastewater can at times constitute a significant fraction of the total volume of wastewater and can be detrimental to wastewater treatment systems as it increases nitrogen load and oxygen demand. It can be a significant challenge for WWTPs which receive slaughterhouse waste to deal with the short and long term fluctuations inherent to industrial processes.

Recent research has resulted in a online UV/VIS technique for measurement of Haemoglobin in wastewater streams.

2.4.1 WWTP INLET

A spectrometer was deployed to the inlet structure of a wastewater treatment plant which received the waste-water of domestic and industrial origin from the city of Timaru, New Zealand. Indicative ranges for commonly quoted wastewater parameters were 300-1500 mg/l TSS and 1000-7000 mg/l COD. Large volumes of animal blood enters the sewer from an upstream slaughterhouse. The plant has since been replaced by a new facility, although the influent composition remains largely unchanged.

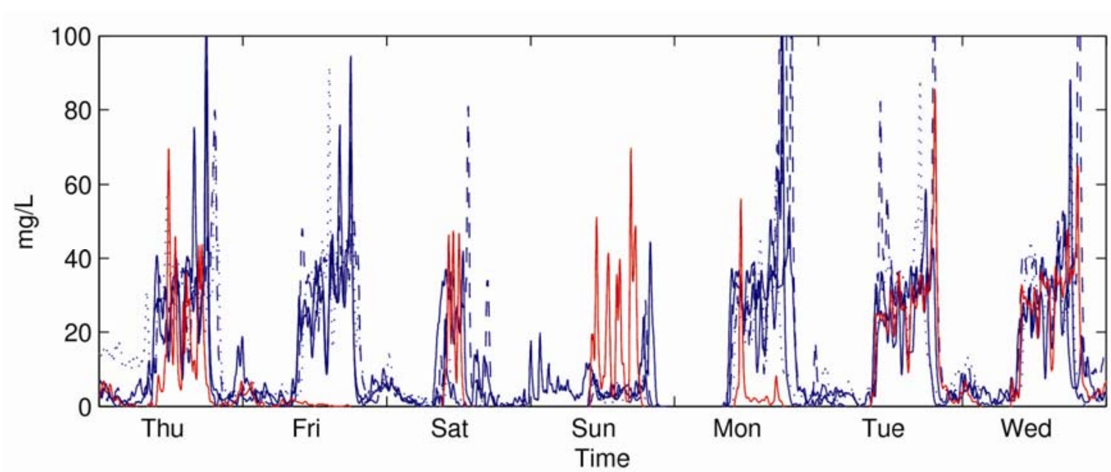

Figure 8: Haemoglobin concentration at the inlet to a WWTP. Typical weekly profiles (blue, various line styles) contrast with an atypical profile falling over Easter weekend (solid red).

At the WWTP inlet only O_2Hb was detected. Haemoglobin concentration is generally low at night but high during the day. At around 6pm on weekdays concentration increases suddenly then drops away to zero. On Sundays haemoglobin concentration is usually lower. This pattern is not followed on Easter weekend (in 2005, the year this data was collected, Easter weekend fell on 27th March - 1st April). Instead, when public holidays occurred, haemoglobin concentration was much lower and on the Easter Sunday haemoglobin concentration was unusually high. All these features are consistent with a daytime shift production with most work carried out on weekdays and followed by a daily final wash down. The plant operates at reduced capacity over public holidays accounting for the observed reductions in haemoglobin load. An indicative time series is provided in figure 8.

The slaughterhouse upstream of Site A operates seasonally. In mid 2005 the plant shut for seasonal maintenance. Corresponding to the shut there is an absence of haemoglobin signal in the wastewater influent for this time period.

2.4.2 SLAUGHTERHOUSE WASTEWATE

Targeted monitoring was carried out in the settling and final discharge stages of a small on-site slaughterhouse WWTP to investigate the feasibility of giving real-time feedback about product loss to slaughterhouse staff.

Photograph 3: Bloody wastewater in a clarifier in primary settling tank at a slaughterhouse.

Haemoglobin concentration varied significantly over the course of the trial (figure 9). Subsequent treatment strategy involves addition of caustic and base to remove proteins. It is therefore likely that smart feedback systems could optimise chemical use with the haemoglobin concentration information.

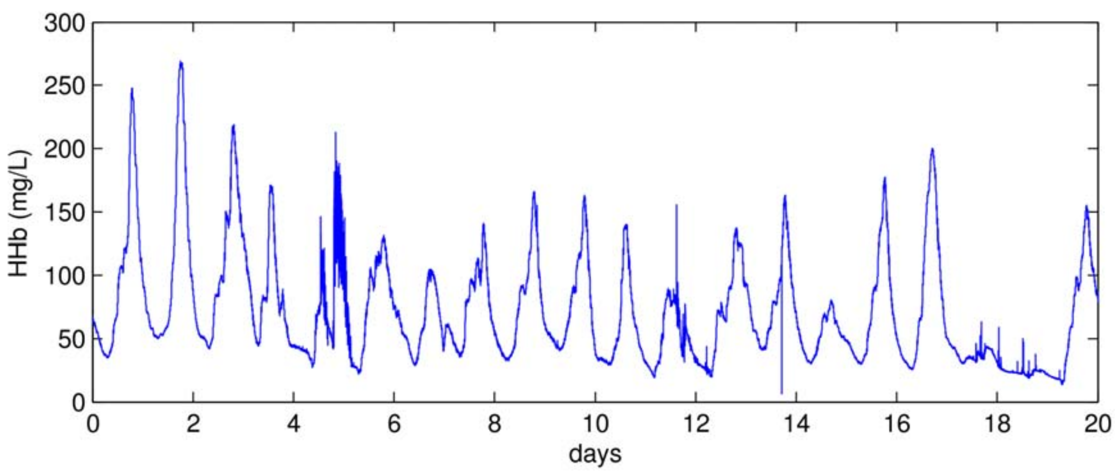

Figure 9: Haemoglobin concentration in the settling tank of a slaughterhouse WWTP.

2.5 FRUIT JUICE

Fruit juice and wine processing generates large volumes of high load wastewater. Standard practice for quantification of this waste is by daily composite samples and COD analysis. Significantly more information about these processes is potentially available by monitoring in real time with modern advanced instrumentation.

A spectrometer was installed at the waste outlet of a juice factory. UV-VIS data was converted to time series by use of advance Non-Negative Matrix Factorization techniques (e.g. Lin, 2007). With such mathematical operations time series corresponding to the main variabilities within the waste stream were extracted (figure 10). Inspection of the eigenvectors indicates the variability is mainly due to changing concentration of different phenolic pigments, in particularly anthocyanins (Harnly *et al.*, 2007). Since these chemicals represent lost product there may some scope to provide real time feedback to operators about loss rates.

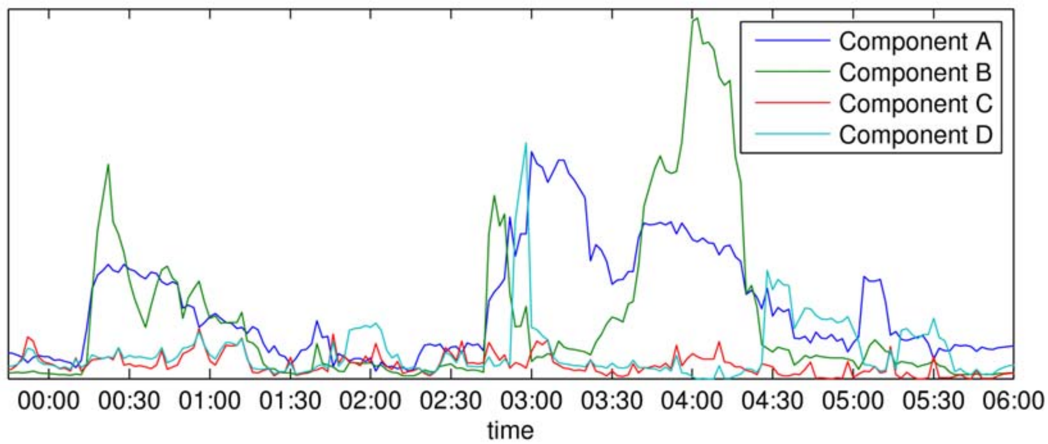

Figure 10: Juice product loss. Components A, B and D correspond to different juice fractions. Component C is related to solids load.

3 CONCLUSIONS

1) The sheer volume of data available using on line sampling methods is vastly superior to historic sampleing techniques.

2) The clarity of trends available through such a rapid sampling technique is clearly advantageous to any designer or process engineer.

3) The ability to separate out components which currently would fall into a bulk parameter such as CODf allows much better design and operational fractionation for dynamic modeling or on line control .

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