IMPROVING RELIABILITY AND OPERATOR CONFIDENCE IN TOTAL SUSPENDED SOLIDS SENSORS

James Portlock, *Maintenance Operator,* Yarra Valley Water

ABSTRACT

Using online total suspended solids sensors to measure the suspended solids of the mixed liquor in the aeration basins at their sewage treatment plants, Yarra Valley Water's treatment plant operators had very low confidence levels in the instrument's readings.

Sampling results, operator feedback and observation of instrument performances through changing plant conditions confirmed the instruments were not performing satisfactorily.

A subsequent series of investigations and team learning experiences raised operator confidence levels in sensor readings from below 20% to around 80%, increased the instruments accuracy in comparison with sampling results, and reduced plant operational problems and operator stress.

Other benefits realised throughout the process arose from including the whole team on the journey of discovery enabled by the building and retaining of 'in-house' expertise.

1.0 INTRODUCTION

A regular discussion point at weekly operations toolbox meetings and monthly team meetings was the dissatisfaction and mistrust in the performance of the total suspended solids (TSS) sensors used to measure the suspended solids of the mixed liquor (MLSS) in the aeration basins at 9 sewage treatment plants (STP) located throughout the northern and eastern Melbourne metropolitan region.

It was a common issue at all treatment plants, spanned 4 instrument manufacturers and 2 different measuring techniques and lead to an increase in operator stress levels due to the extra operational and contract labour costs required for process rehabilitation, higher plant running costs and increased licence excursions.

Influencing the way each plant was affected by having incorrect MLSS readings was the type of process used at the plant e.g., IDEA, BNR, EA, SBR; and whether the MLSS reading was falsely high or low and therefore a range of operational problems were being contributed to including solids carry over from aeration basins into tertiary filters due to settled solids being collected during decant, reduced micro-organism populations from over wasting resulting in high final-effluent nutrient levels and associated inefficiencies related to labour, power and chemical costs consumed in process rectification and rehabilitation.

One example includes a plant where the instrument's reading, in between calibrations, rose from 5000 to 6300mg/l whereas the actual measured MLSS levels had risen from 5000 to 8500 mg/l. This was mechanically overworking the aeration blowers by increasing both their operating backpressure and the volume of air required to achieve dissolved oxygen setpoints. The greater than anticipated thickness of the mixed liquor then required an increased amount of wasting in a short period affecting wasting timetables and increasing associated labour costs.

Despite adjustments being performed against NATA accredited external lab results, measured values of TSS instruments were regularly requiring readjustment the following month due to apparent 'drifting' of the instruments reading by greater than 10% over the period. Results from internal moisture analysis tests being conducted periodically seemed just as random and were adding to the confusion.

Figure 1 shows the results of 6 month's data collected from an instrument that was adjusted to equal lab results initially and remained unadjusted for the remainder of the period. Sensor head checks and cleans were conducted fortnightly with fouling over that period found to provide little, if any interference. It shows minimal correlation between instrument readings, internal moisture analysis tests an external lab results and was typical of the performance of some 20 instruments.

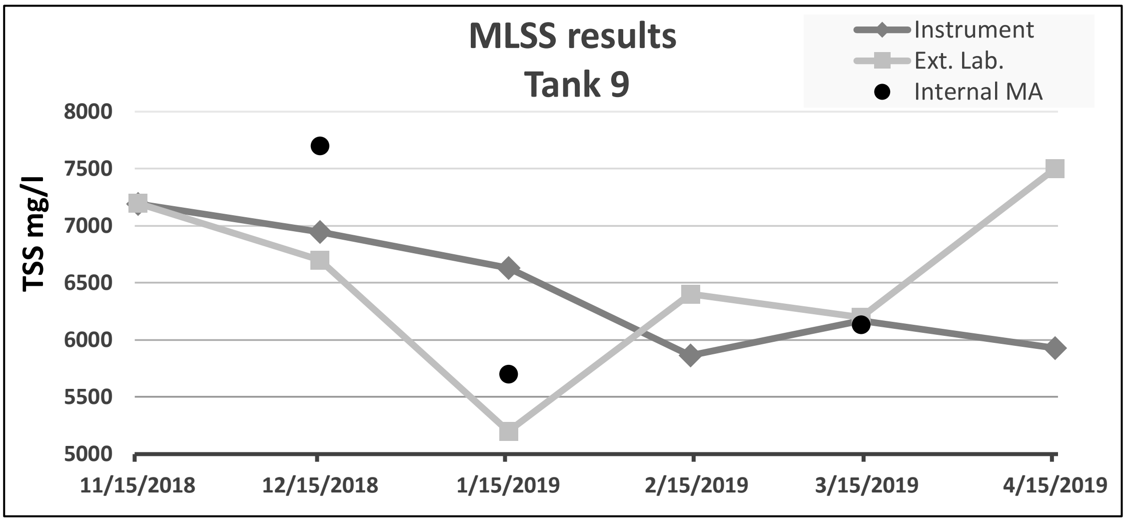


Figure 1: ***Graph showing instrument readings vs. external lab results over a six-month period following an initial calibration. Periodic internal moisture analysis test results also shown.***

2.0 DISCUSSION

2.1 Where do you start?

Spanning 9 treatment plants, 10 unhappy operations personnel, a large geographical area, only 1 person to investigate who had no prior experience with these types of instruments, each instrument possessing its own unique installation characteristics and failures being contributed to at every plant, the issue presented a wide scope of challenges, contributing to an initial period of procrastination while pondering the question "Where do you even start?".

Assistance with the answer was presented in March 2020 with the introduction of the COVID-19 virus in Melbourne, having a sudden and severe impact on work arrangements and personnel movements.

Rather than a group of operators looking after a group of plants, a single operator to single plant approach was adopted. This style of operation allowed an opportunity for the treatment plant trainee to gain experience in the responsibility of running a treatment plant and the 'ownership' mentality that often spawns as a result. Combined with the fact that the trainee was relatively new to the TSS issue and therefore was not yet as 'fed up' with the instruments meant that he expressed an elevated level of interest in seeking to find a solution to the problem and the issues it was contributing to at 'his' plant.

With two TSS instruments of the same manufacturer installed identically opposite each other in two separate reactor tanks and a keen young operator on-site full-time providing motivation, the Whittlesea treatment plant became the site for a pilot study in a somewhat natural fashion.

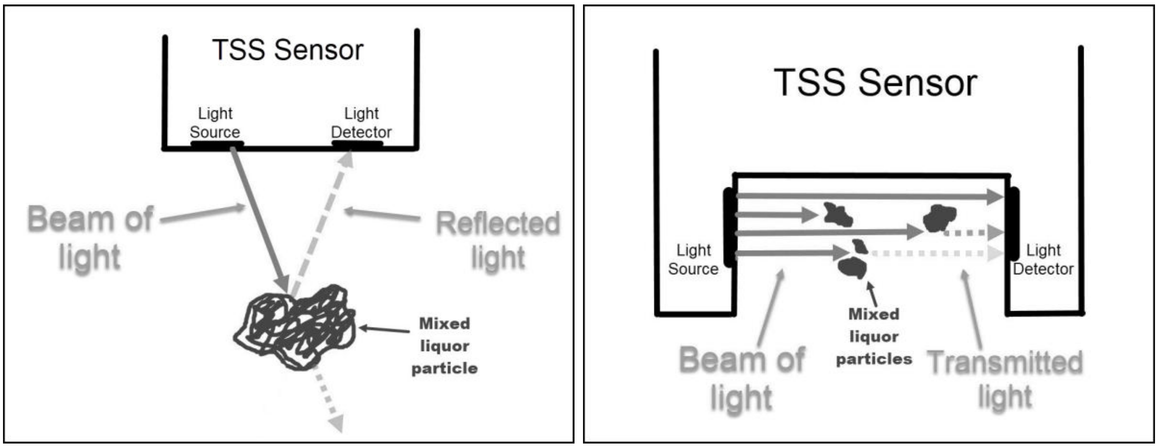
2.2 Internal or external results?

One of the initial questions was whether to use internal or external lab results for reference and calibration of the instruments. Each method presented potential sources of error as there was no verification equipment for the internal moisture analyser used and the external lab samples had potential to lack uniformity at the sampling stage due to a lack of control over sampling procedure and personnel.

It was decided to use the internal moisture analyser once suitable equipment to allow for its calibration had been purchased. The analyser utilises the thermogravimetric principle (weigh, heat, weigh) and was deemed suitable due to its certified performance once calibrated with the ongoing ability to verify calibration, its portability and ease of use allowing for multiple onsite tests to be conducted by the one sampler using similar sampling techniques each time with results achieved after 20 minutes and at minimal cost.

2.2 Why every instrument?

The suspended solids instruments used at YVW are reagent-less, solid state devices with no moving parts and have very little reason to 'drift'. The principles they rely on are 1. Scattered light measurement or 2. Transmitted light measurement as shown in Figure 2.



(a) (b)

Figure 2: ***Artist's impression of the 2 TSS measuring principles used at Yarra Valley Water sewage treatment plants. (a) relies on sensing the amount of light that is reflected by the particles in a liquid i.e. More light sensed by its detector, higher TSS value. (b) relies on sensing the amount of light that is transmitted (not absorbed or reflected by particles) through a liquid i.e. More light sensed by its detector, lower TSS value.***

Despite the installed models spanning 3 different reputable manufacturers and using 2 different measuring principles as described, every single instrument was exhibiting similar unsatisfactory performance. This either pointing to every instrument possessing a similar issue rather than each installation having its own unique problem or a common issue external from the instrument. This would then potentially allow for the learnings of the pilot study to be applied across other sites.

2.3 Read, read, read.

An important part of the process was in taking the time to study each of the instruments operation manuals to understand each measuring technology used and the programming differences used by each manufacturer to achieve similar results. Each manual being read several times over in conjunction with site visits for checking and recording of each instruments' existing settings and installation conditions to ensure they matched our application.

Providing important assistance with understanding the subject well was the necessity to read 4 different instrument manuals. Each manual providing a unique perspective and the information when combined as a whole, presented a clearer picture on the subject than the reading of any of the manuals individually.

2.4 Maintain some internal knowledge and discuss it!

My role as Maintenance Operator utilises my trade background in electrical/instrumentation and whilst working closely with our contract partners, also maintains a focus on this area directly within the team through regular attendance at weekly toolbox and monthly team meetings. This allows for consistent, direct, and open two-way communication on matters relating to instruments and assists in maintaining ownership values and retaining knowledge within the team and provides consistency for numerous contract partner personnel and over changes in contract partnerships.

It facilitated a staged approach to the learning process that transpired over many months whilst occurring in parallel timewise with the pilot study and my own learnings from product manuals and allowed for team discussions encompassing topics including:

- the physical properties of light and its interaction with objects
- the different technologies used to detect suspended solids and their advantages/disadvantages
- the relationships of trends produced by MLSS instruments to the process and location where they are installed and how each differs depending on process or location
- the effects of seasonal or sudden changes in particle size, shape and colour on MLSS readings in aeration basins
- the many real-world situations encountered in the taking of a grab sample and methods employed to minimise the risk of lab analysis sample error

and was a part of the process that proved crucial in reshaping the team's attitudes towards the instruments and their performances.

2.5 Was there a fix?

Having a significant impact and realised through the study and understanding of the operation manuals there was found to be a common aspect in the setup of each instrument that if modified, would potentially be more suitable for our application. It was applied at the Whittlesea pilot site with promising results.

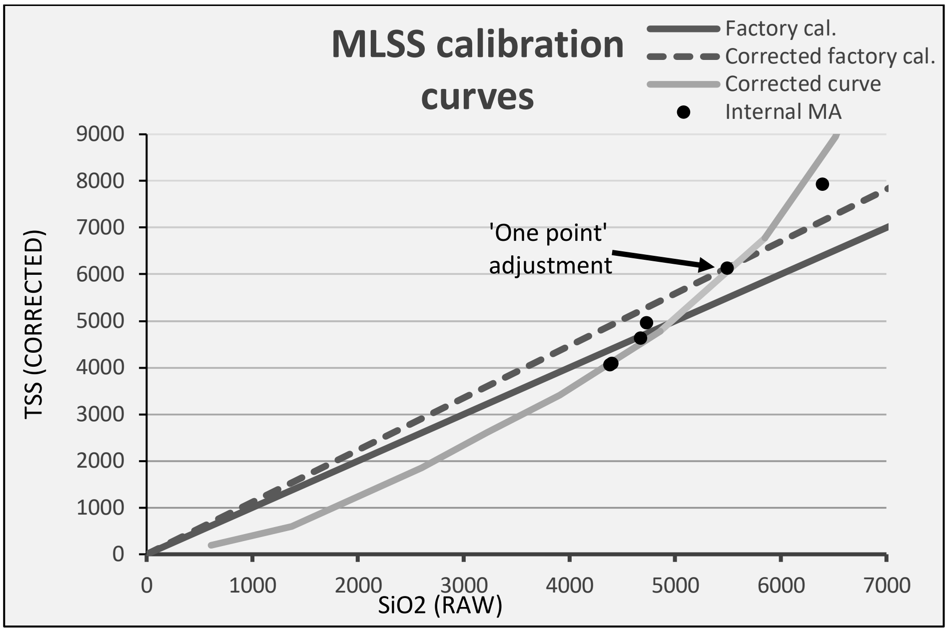


Figure 3: ***Graph showing internal moisture analysis test results against a 'one point' adjustment of single-slope and multi-slope corrections to the factory calibration.***

As shown in figure 3, MLSS instruments are factory calibrated using a material possessing uniform properties of light absorption and reflection over its weight to volume range (often silicon dioxide, a white sand), giving a straight slope. This 'raw' value must then be 'corrected' to suit the matrix being measured. The adjustment is usually 'one-point' and can be used to correct the straight-line slope of the 'raw' value, or it can be used to correct a multi-sloped 'curve' suited to a mixed-liquor that possesses much different light absorbing and reflecting characteristics due to the random nature of its particle size and shape.

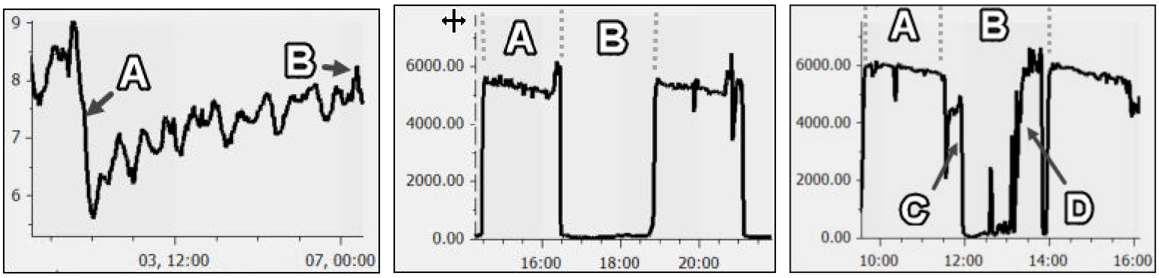
In YVW's case, all instruments were set to use a one-point adjustment of the straight-line factory calibration and it can be seen in Figure 3., against internal moisture analysis test results, the application of a one-point adjustment to a multi-sloped 'curve' would provide more consistent correlation between instrument reading and sample test results.

Changing to use of the multi-sloped curve at the Whittlesea pilot site reduced error between instrument readings and sample results to less than 10% error in over 80% of the results. It was then implemented at the other 8 sites with similar positive results.

Implementation of the curve differed between manufacturers and measuring technologies. Instruments using the technology described in Figure 2(b) came supplied with pre-programmed curves suitable for use with mixed liquors whereas those using the technology in Figure 2(a) did not, requiring the manual programming of a curve through a process of mounting the TSS sensor in a manually agitated mixed-liquor sample taken from the aeration basin, recording readings, conducting moisture analysis tests on that sample and then carrying out a series of concentrations and dilutions to the sample, repeating the previous steps for each concentration over the expected range of the instrument.

2.6 What else did you learn?

Along the journey and through a better understanding of the instruments, many discoveries relating to instrument performance and their ability to assist in reading plant performance were made. Examples are provided in Figure 4.



(i) (ii) (iii)

<u>Figure 4:</u> ***SCADA trends of instruments as described in the text below.***

Figure 4(i) shows the reading of an instrument installed in a BNR being affected (A) by a sudden darker change in colour of its MLSS due to black sludge being returned to the reactor from a lagoon. The colour change gradually reduced to previous levels over five days (B). Actual suspended solids levels changed very little over the period with the instrument showing a drop of some 3000mg/l due to the reduced reflective nature of the measured medium.

Figure 4(ii) Instrument installed in an IDEA reactor showing a cycle of aeration (A) and settling/decanting (B). Figure 4(iii) shows the same reactor with MLSS levels increased enough to cause sludge blanket settling issues (C) followed by 'carry over' of the sludge during the decant phase (D).

3.0 CONCLUSION

The development of a framework for a 'system' through study, education, communication, time and natural occurrences has set the team in the similar direction of using the instrument as a source of valid information to assist in the operation and fault diagnosis of treatment processes. This has in turn produced beneficial flow-on effects primarily being reduced operator stress but also increased efficiencies of mechanical and electrical equipment, chemical dosing systems, reactor tank and filter operation and sludge handling systems.

4.0 ACKNOWLEDGEMENTS

To Yarra Valley Water's treatment plant operations team for being open and accepting throughout the whole of the journey.

To Chris Hughes for his unwavering enthusiasm to find answers.

5.0 REFERENCES

TSS sensor operation manuals of the following manufacturers: WTW, Endress + Hauser and Cerlic.