USING REMOTE ON-LINE DATA ANALYTICS TO IDENTIFY YOUR SEWER RATS

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ABSTRACT

Over the Christmas and New Year holiday period 2020/21, the Rotorua Wastewater Treatment Plant (WWTP) was hit by at least three, separate, inhibitory discharges from unidentified sources. These caused significant loss of nitrification, with elevated ammonia concentrations in the treated effluent for several weeks. While this did not cause an immediate breach of concentration-based resource consent conditions, the annual consented total nitrogen (TN) load limits were exceeded.

Historically, trade waste monitoring in Rotorua has been limited to spot or 24-hour composite samples, typically on a monthly basis, with analysis at an accredited laboratory. However, given the severe incidents over the 2020/21 holiday period, which were not without precedence, the historical monitoring programme evidently did not provide an appropriate level of trade waste management.

Rotorua Lakes Council (RLC)'s wastewater system operations contractor, TRILITY, had a strong desire to identify potentially inhibitory discharges to the WWTP and improve WWTP performance and reliability. So, in a first for New Zealand, TRILITY engaged the Israeli company Kando, through their Auckland-based agent Detection Services, to supply and install on-line condition data analysis and sampling equipment at strategic locations in the Rotorua sewer network between November 2021 and February 2022. This included targeted data gathering from known trade waste dischargers, as well as at key pump stations and the WWTP inlet. Using artificial intelligence (AI), Kando's software calculated a real-time "Pollution Index" (PI) at each monitoring location based on indicative parameters, and tracked out-of-spec discharges from source to WWTP.

While good performance of the Rotorua WWTP was maintained through the 2021/22 holiday period, the three-month project identified significant out-of-spec discharges from two known trade waste discharges, plus suspected, significant, unknown discharges in other parts of the network. Samples of out-of-spec discharges were collected by automatic sampling, with the samplers triggered by Kando-identified Pollution Events (PE). Analysis of samples by conventional laboratory analysis and respiration-based toxicity testing (RBTT) confirmed the inhibitory nature of several discharges.

Through Co-Lab Water Services, which manages RLC's trade waste compliance, rapid feedback was provided to key trade waste dischargers where PEs were identified. This allowed inadequate trade waste management practices to be quickly addressed, with one key trade waste discharger making significant improvements over a three-month period.

Following the three-month trial, TRILITY will be undertaking a full-scale, 12-month, Kando monitoring programme to hone in on areas of the network where unidentified PEs were detected during the initial survey period.

KEYWORDS

Trade waste, Pollution Events (PE), Kando, nitrification, inhibition, WWTP risk management

1 INTRODUCTION

RLC is responsible for the provision of wastewater collection, treatment and disposal services to approximately 23,000 households and businesses within Rotorua City and several lakeside communities around the district. Several drivers, including rapid growth, ageing infrastructure assets, poor lake water quality, and the need for improved treatment standards, led RLC, in 2017, to consider alternative service delivery models to that which existed at the time. The Rotorua lakes, amongst which most residents of the district live, are considered taonga (treasure), and the preservation of their quality and mauri (life-sustaining force) is of the utmost importance.

RLC resolved to look for a partner who could bring enhanced asset management and service delivery capabilities and who could implement capital improvements to the Rotorua City wastewater treatment process. As a result, after a two-year competitive procurement process, RLC, in November 2020, let a ten-year contract to TRILITY (Rotorua) Ltd. for the management and operation of wastewater services in the district, with provision for the future design and build of a major upgrade to the Rotorua WWTP.

One of a number of issues that TRILITY has focussed on is the identification and reduction of treatment process-inhibiting wastes entering the network from trade premises. Several such incidents had occurred in the past resulting in serious disruption to the biological treatment processes.

The Rotorua WWTP includes two activated sludge-based, biological treatment processes; a five-stage Bardenpho, and a membrane bioreactor (MBR). The Rotorua WWTP achieves a high level of TN removal through the processes of nitrification and denitrification. Such a high level of TN removal is required to meet resource consent conditions. Over the Christmas and New Year holiday period 2020/21, routine process monitoring results indicated that the Rotorua WWTP was hit by at least three, separate, inhibitory discharges from unidentified sources. These incidents caused significant loss of nitrification, with elevated ammonia concentrations in the treated effluent for several weeks. While this did not cause an immediate breach of concentration-based resource consent conditions, it did result in annual consented TN loading limits being exceeded.

RLC has a trade waste bylaw in place (RLC, 2017), which is based on the Model Trade Waste Bylaw (Standards New Zealand, 2004). Historically, monitoring of trade waste discharges in Rotorua has been limited to spot or 24-hour composite samples, typically on a monthly basis, with analysis at an accredited laboratory. Given the serious incidents over the 2020/21 holiday period, which were not without precedence, the historical monitoring programme evidently did not provide an appropriate level of trade waste management. TRILITY had a strong desire to better understand trade waste discharges into the Rotorua network, and to reduce the risk of future treatment process failure and to ultimately ensure the future upgrade of the plant working under a new and tighter consent is in the best position to attain a sustained high-quality product.

Israeli-based Kando had previously undertaken a trial for TRILITY in Australia, effectively identifying trade waste discharges of significant concern. Through 2021, TRILITY and The Wastewater Specialists developed a programme for Rotorua with the help of Kando’s analytics capabilities, and Kando’s Auckland-based New Zealand agents, Detection Services. The result was a three-month trial of the Kando technology in Rotorua between November 2021 and February 2022, through which significant advances were made in understanding the impact known trade waste dischargers and as yet unknown discharges could have on the Rotorua WWTP.

2 ROTORUA WWTP

2.1 DESCRIPTION

The Rotorua WWTP treats municipal wastewater from its 80,000 inhabitants, along with trade waste discharges, and septic tank and campervan wastes. Dry weather flow is 17,400 m^3/d, which increases to peak instantaneous flows of 960L/s due to significant stormwater inflow and infiltration into the sewer system. On an annual basis, the average daily flow (ADF) treated through the Rotorua WWTP is 19,400 m^3/d.

The Rotorua WWTP comprises inlet screening and grit removal, primary sedimentation, and activated sludge treatment in the form of separate MBR and 5-Stage Bardenpho processes, with secondary clarifiers following the Bardenpho reactor. Treated wastewater is irrigated to commercial pine trees in the Whakarewarewa forest. The volume of primary effluent treated through the MBR is fixed at 5,600 m^3/d, with the remaining flow treated through the Bardenpho. This means that the flow and load treated through the Bardenpho reactor can increase significantly in wet weather. The MBR is configured for nitrogen removal, with ethanol dosed to both the MBR and Bardenpho reactors to aid the denitrification process.

2.2 RESOURCE CONSENT REQUIREMENTS

Bay of Plenty Regional Council (BoPRC) resource consent 60739 permits irrigation of treated effluent from the Rotorua WWTP to land in the Whakarewarewa Forest, subject to the following conditions:

- Maximum daily discharge of 44,000 m^3/d, with a maximum application rate of 5mm over 24hrs.
- During any 12-month period, a maximum TN load of 51 tonnes p.a.

To put the nitrogen loading condition into context, to comply with the 51 tN/p.a. consent condition, at an ADF of 19,400 m^3/d, average total nitrogen concentrations in the treated effluent need to be <7.2 g/m^3.

2.3 CHRISTMAS 2020/21 INCIDENT

Multiple toxic shock events severely impacted the Rotorua WWTP process during December 2020 and January 2021. Though there is no evidence substantiating the nature of the material coming into the plant, the events can be tracked by the loss of nitrification in both the Bardenpho and MBR reactors. As shown in Figure 1, significant increases in ammonia, as measured by online instrumentation and confirmed by laboratory analysis, occurred on three occasions, followed by short periods of recovery. Unfortunately, these three successive events eventually led to the nitrifying bacteria's complete decimation and a significant pH imbalance.

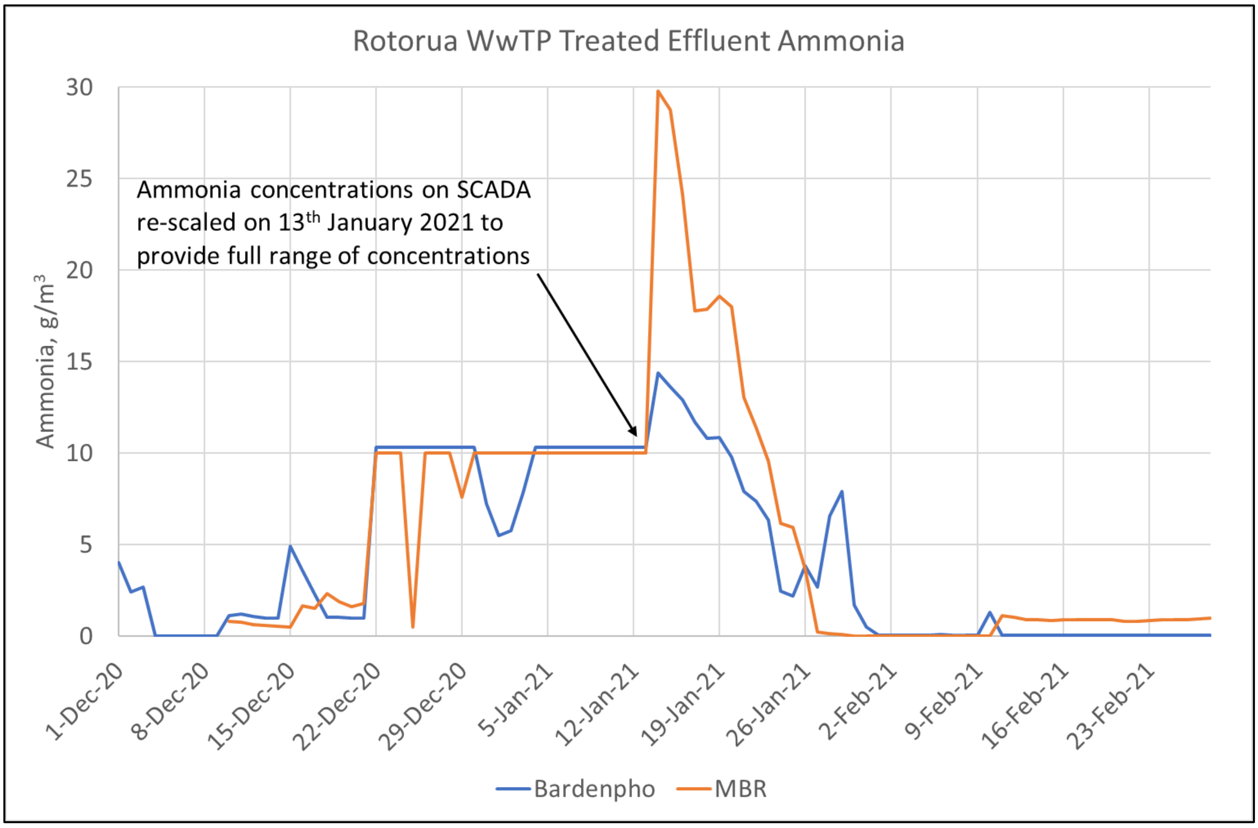

Figure 1: On-line Ammonia Measurements During the Toxic Events

At the time of the incident, no on-line influent monitoring was undertaken to forewarn the Operations Team of the potential toxicity of incoming wastewater. However, as part of the investigations, TRILITY and RLC instigated hourly influent sampling, with discrete samples measured for pH and conductivity. On 13 January 2021, this hourly influent sampling captured an extreme pollution event, as shown in Figure 2. The scale of this event was shocking, with the pH of the entire incoming wastewater stream dropping to <2 for a period of two hours.

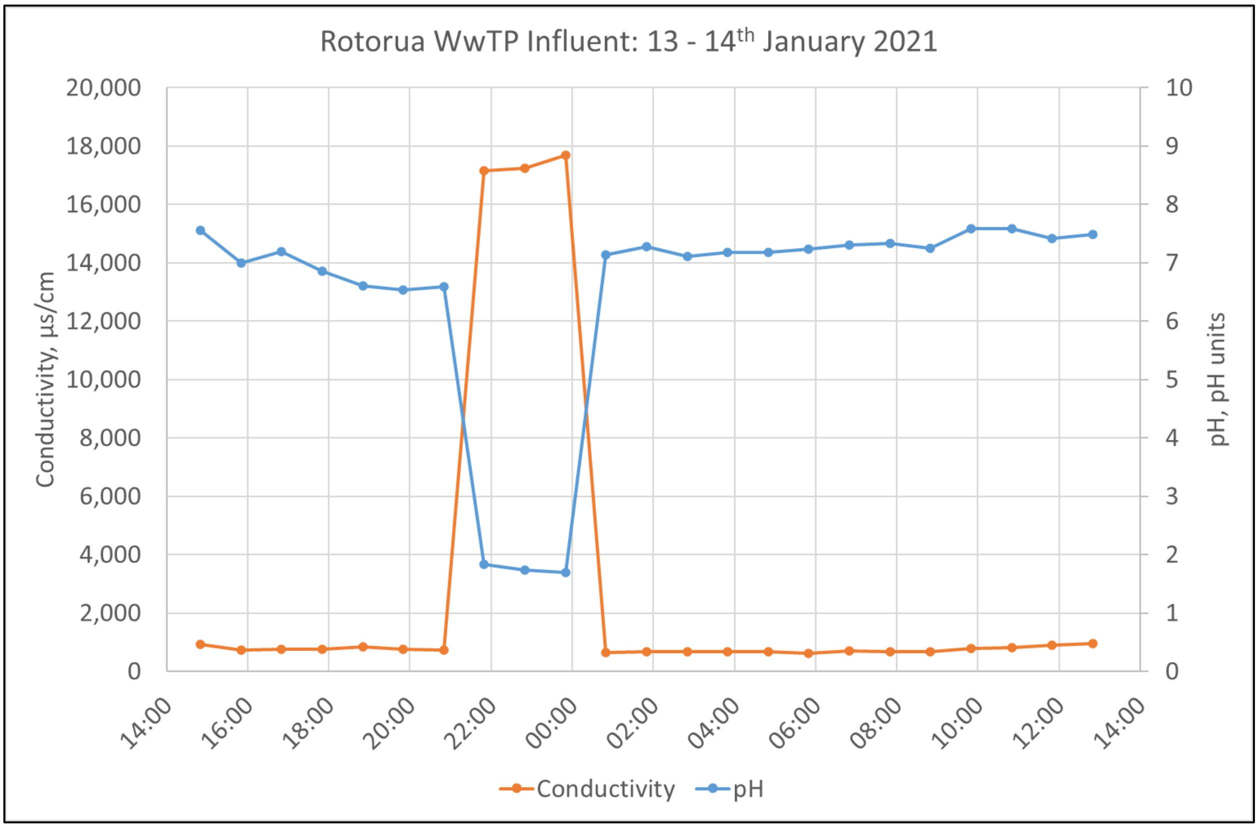

Figure 2: Discrete, 24-hour Influent Sampling Showing a Dramatic Pollution Event

Biomass from a healthy activated sludge plant contains a range of bacteria, protozoa, and other higher life forms such as rotifers, tardigrades, and nematode worms. In general, the greater the diversity of higher life, the healthier the biomass is likely to be, and the higher the level of performance that is likely to be achieved. Madoni (1994) developed a sludge biotic index (SBI) as a measure of biomass health. Biomass from the Rotorua WWTP is routinely examined microscopically, with SBI calculated as an indication of biomass health. In general, biomass from the Rotorua WWTP scores well against Madoni (1994)'s SBI, most commonly indicating a biomass in very good health. However, when ammonia breakthrough occurred as a result of the process upset in December 2020, biomass health plummeted, as shown in Figure 3. Following the repeated inhibition of the treatment process, it took several months for the biomass to return to its normal, very good, health.

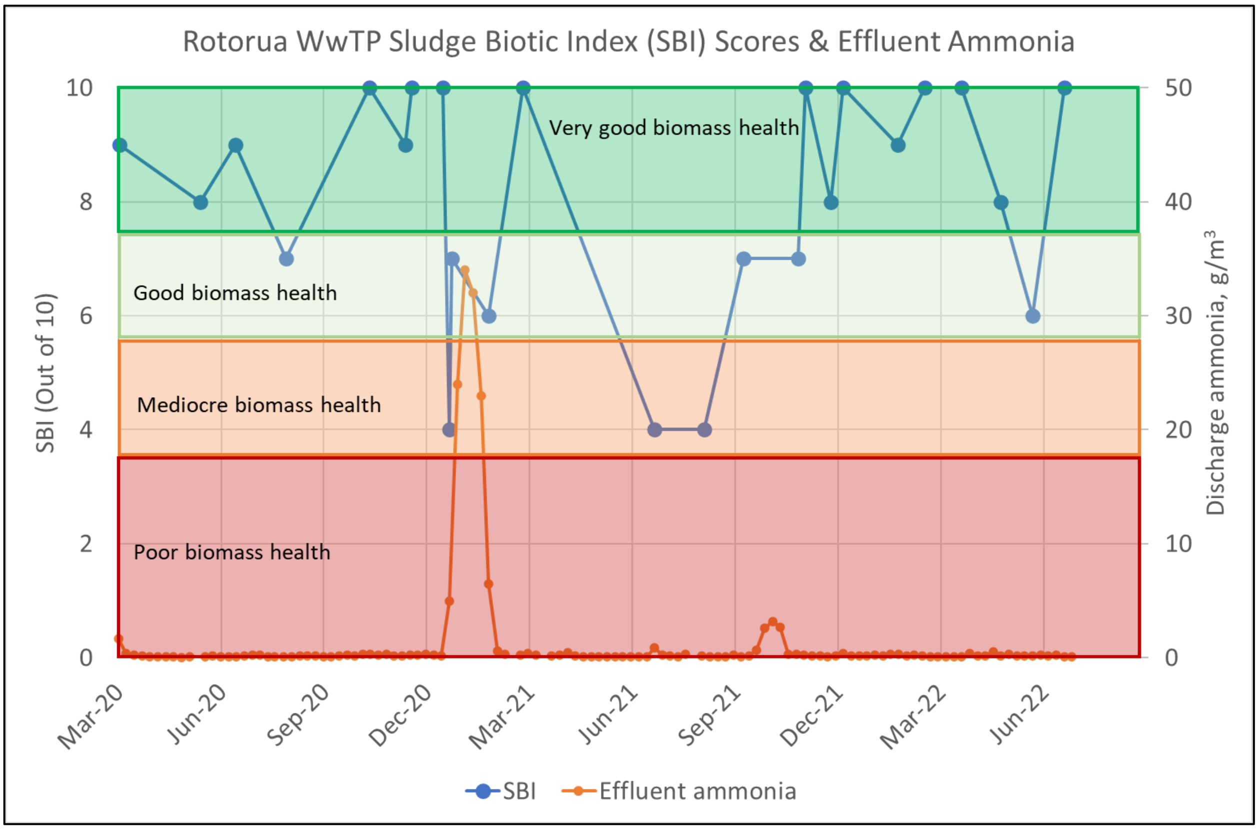

Figure 3: Rotorua WWTP Sludge Biotic Index

2.4 INCIDENT RESPONSE & PROCESS RECOVERY

Regarding the incident classification and protocol, the Operations Manager was assigned as Response Manager (remote due to Covid-19), with on-ground support from the Operations Team. Notifications and incident investigation were delegated to the Operations Manager. As per the protocol, notification was provided to the effected parties, and TRILITY internal support was engaged.

As part of the incident response, the Bardenpho reactor was reseeded with viable biomass from the Hamilton WWTP. 15,000 L/d of nitrifying thickened waste activated sludge (WAS) was added to the Bardenpho reactor for a period of seven days. No immediate improvement was noticed from this action, possibly because the reseeding volumes may have been too low. In addition, as shown in Figure 3, some of the influent entering the plant during the reseeding period may have counteracted any potential improvements from reseeding.

In early January 2021, the anoxic zones in the Bardenpho reactor were operated as additional aeration zones to focus on nitrifier reestablishment. This had been used in other TRILITY sites in the past, and nitrification at the Rotorua WWTP resumed shortly after. Monitoring and adjustments to aeration levels continued until the plant had become stable, and process performance had returned to normal by the 3rd week in January 2021.

The cost involved in responding to the incident was in the order of $30,000 for external services and testing. However, this doesn't reflect the disruptions to normal day-to-day operations, or the resulting breach of resource consent shown in Figure 4.

This event was the main driver to look at measures to prevent future incidents, rather than responding to such incidents as and when they should occur.

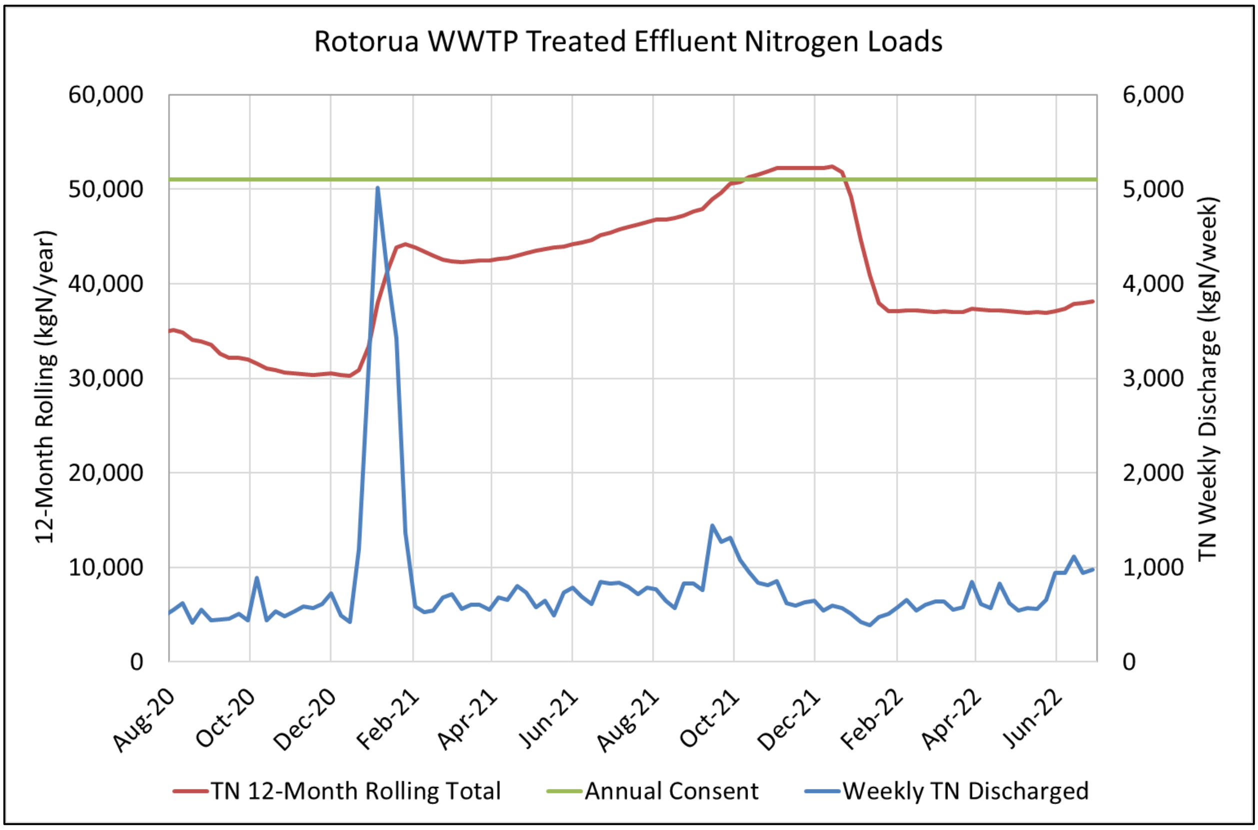

Figure 4: Impact of Unknown Discharge(s) on Rotorua WWTP Consent Compliance

3 MONITORING PROGRAMME DESIGN

3.1 TRADE WASTE DISCHARGERS

At the time of the incident, RLC was aware of four key trade waste dischargers in Rotorua. These trade waste dischargers are summarised in Table 1.

Table 1: Trade Waste Dischargers in Rotorua

	Description of Activities
Business 1	Collection and processing of a variety of waste products
Business 2	Meat processing
Business 3	Commercial laundry
Business 4	Paint and solvent processing

Three of the four key trade waste dischargers are located in the west of Rotorua, with Business 4 located in the eastern part of the network. Wastewater from Businesses 1, 2 and 3 is collected, along with some municipal wastewater, in the Depot Street pump station (PS). Wastewater from Business 4 is collected, along with municipal wastewater from a large part of the network, in the Hona Road PS. While Depot Street and Hona Road PSs pump directly to the Rotorua WWTP, their wastewater enters the WWTP through separate pipelines.

3.2 KANDO

Kando's smart Internet of Things (IoT) units continuously collect wastewater data from the sewer network and transmit it into the cloud, where machine learning (ML) algorithms transform the data and derive a real-time PI at each monitoring location in a network. To reflect the risk to the WWTP, calculated PI values consider the proximity of monitoring locations in relation to the WWTP. For example, at the outer extremities of the reticulation network, an increase in electrical conductivity (EC) from 500µS/cm to 1,500µS/cm is unlikely to pose a risk to the WWTP, given the further dilution available through the network. Therefore, all other measured parameters being equal, this would result in a relatively low PI score. However, an increase in EC from 500µS/cm to 1,500µS/cm at the inlet to the WWTP would indicate a much higher risk to the WWTP and, all other measured parameters being equal, would therefore be attributed a relatively high PI score.

From the calculated PI at each monitoring location, the system identifies PEs. Kando's data analytics then determines whether PEs measured at one location in the network can be linked to PEs at other, upstream or downstream, monitoring locations, thus tracking pollution from source to WWTP. PEs, and potentially other factors such as a specific pH, can be used to trigger sample collection by automatic samplers (autosamplers). When an autosampler is triggered, the system sends notifications to designated personnel via email and/or SMS.

EC, pH, oxidation-reduction potential (ORP), temperature, PI, and PE data is relayed in real-time to a cloud-based user interface. Simplistically, this data can be viewed as time series plots, with a range of data analytics also available through the same portal. Any designated PEs and samples collected are date/time stamped. If necessary, all data can be extracted from Kando in CSV files.

Once a dataset has been 'cleaned', Kando's AI algorithms process the inputs to provide real-time analysis, enabling rapid event and trend identification which is then transmitted back to Kando. Kando's online dashboard provides easy access to live oversight of the whole network, mapping developing wastewater conditions, profiling discharges, and alerting to potentially damaging events in real time.

3.3 MONITORING LOCATIONS

In total, eight monitoring locations were selected for the three-month trial period. These included the discharge from each of the four known trade waste dischargers, with a common monitoring location for two due to their close proximity. Monitoring was also set up in the Depot Street and Hona Road PSs, two separate inlets into the WWTP, and the combined WWTP influent.

At each of the installed monitoring locations, IoT data gathering units were installed. In addition, five autosamplers were deployed, with these samplers initially installed in the locations considered to be the highest risk; Business 1, Business 4, Depot Street PS, West Inlet, and the WWTP Inlet. Due to unexpected PEs measured in the Hona Road PS, the autosampler from Business 4 was redeployed to Hona Road PS partway through the monitoring period.

An example of Kando's data gathering units and sampling equipment, installed in a manhole at the Hona Road PS, is shown in Figure 5.

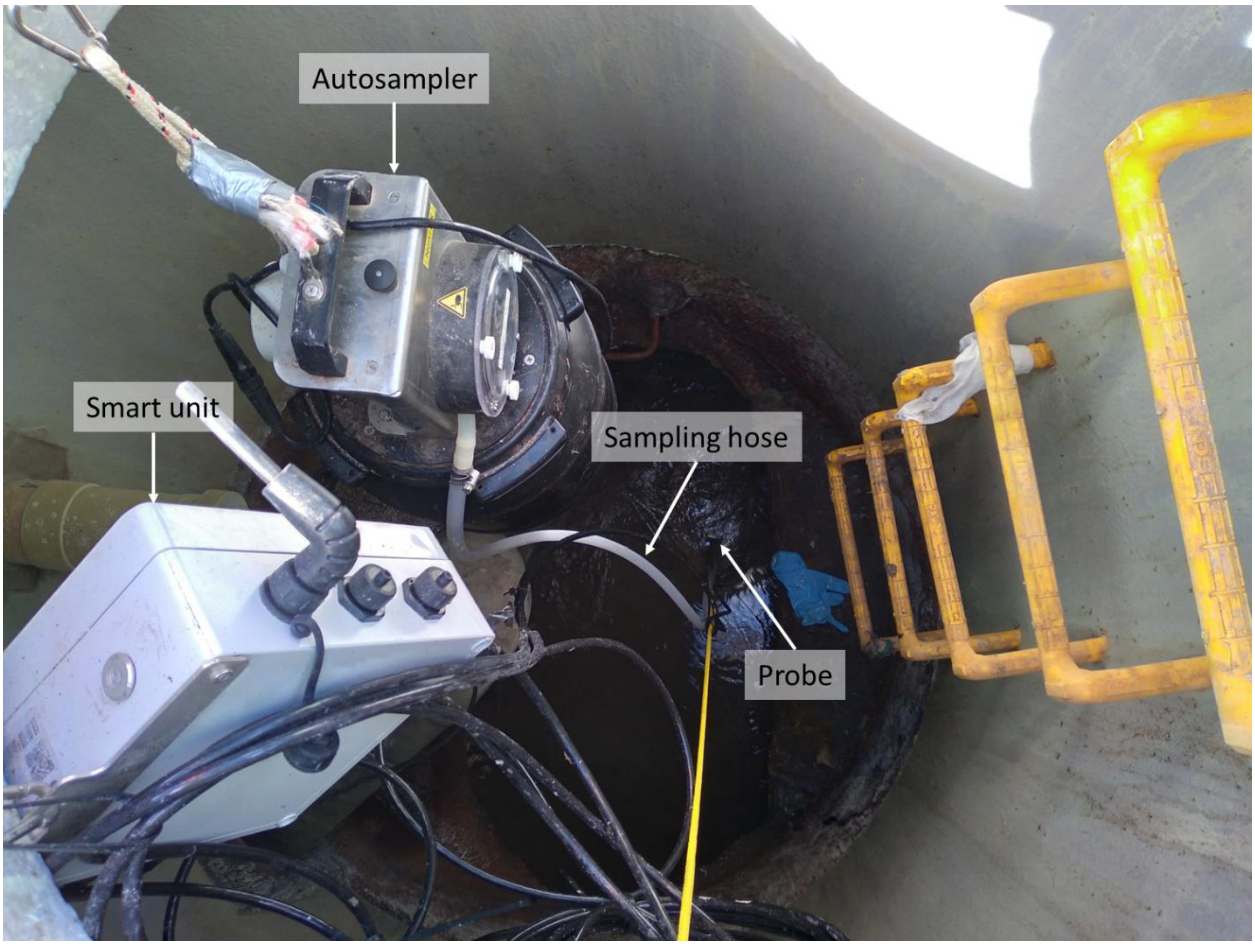

Figure 5: Kando IoT Data Gathering Units Installed at Hona Road PS

3.4 SAMPLE COLLECTION & ANALYSIS

When an autosampler was triggered, samples were generally retrieved from the autosampler the same day or the following day when autosamplers were triggered during the night. After sample retrieval, autosamplers were inspected for blockages and reset.

Providing the autosampler collected sufficient sample volume, samples were submitted for two different analyses; one for RBTT, and one for conventional laboratory analysis. The samples for conventional laboratory analysis were handed over to the RLC laboratory immediately. In contrast, the RBTT samples were stored in a fridge and couriered in batches at the start of each week. Samples were logged in a spreadsheet by the time, date, and location of the autosampler and collection time. The Kando data recorded in this spreadsheet (EC, pH, etc.) is characterised by when the autosampler was initially triggered. Laboratory results were then added as they were received.

3.4.1 RESPIRATION-BASED TOXICITY TESTING

RBTT is an established laboratory method used to determine the inhibitory effect of different wastewaters on biomass from a biological wastewater treatment process. The procedure for undertaking RBTT is outlined in *Guidelines for the Testing of Chemicals: Activated Sludge, Respiration Inhibition Test (Carbon and Ammonium Oxidation)* (OECD, 2010). The test procedure includes separating out any inhibitory effect on nitrifying bacteria from that on the general biomass. This is important because nitrifying bacteria are much more susceptible to inhibition, and nitrification is a key biochemical process in wastewater treatment. Separating the impact on nitrifying bacteria from the general biomass is achieved by running one set of tests using all biomass from an activated sludge plant, then repeating the tests after adding a nitrification inhibitor to the same biomass. Allylthiourea (ATU) is the most commonly used nitrification inhibitor.

3.4.2 CONVENTIONAL LABORATORY ANALYSIS

Samples submitted for conventional laboratory analysis were analysed for an extensive suite of determinands, as recommended by Kando. This analysis comprised pH, conductivity, TSS, VSS, COD, $cBOD_5$, TKN, nitrate, nitrite, TN, oil & grease, TDS, phenol, VOC, Ag, Al, As, B, Ba, Be, Ca, Cd, Cl, Co, Cr, Cu, Fe, Hg, K, Li, Mg, Mn, Mo, Na, Ni, P, Pb, S, Sb, Se, Si, Sn, Sr, Tl, V, and Zn.

4 RESULTS

4.1 OVERVIEW

As the three-month monitoring programme progressed, the homepage of the Kando user interface displayed areas of the network in which concerning discharges were detected. This is shown in Figure 6, with the colour of the Depot Street and Hona Road PS catchments having changed from default green to orange.

Many PEs were detected during the three-month period. This paper presents a small proportion of the data collected, PEs identified, and the insights that were learned through the monitoring programme. EC, pH, ORP, temperature, PI, and PE data presented in the following sections was extracted from Kando for presentation.

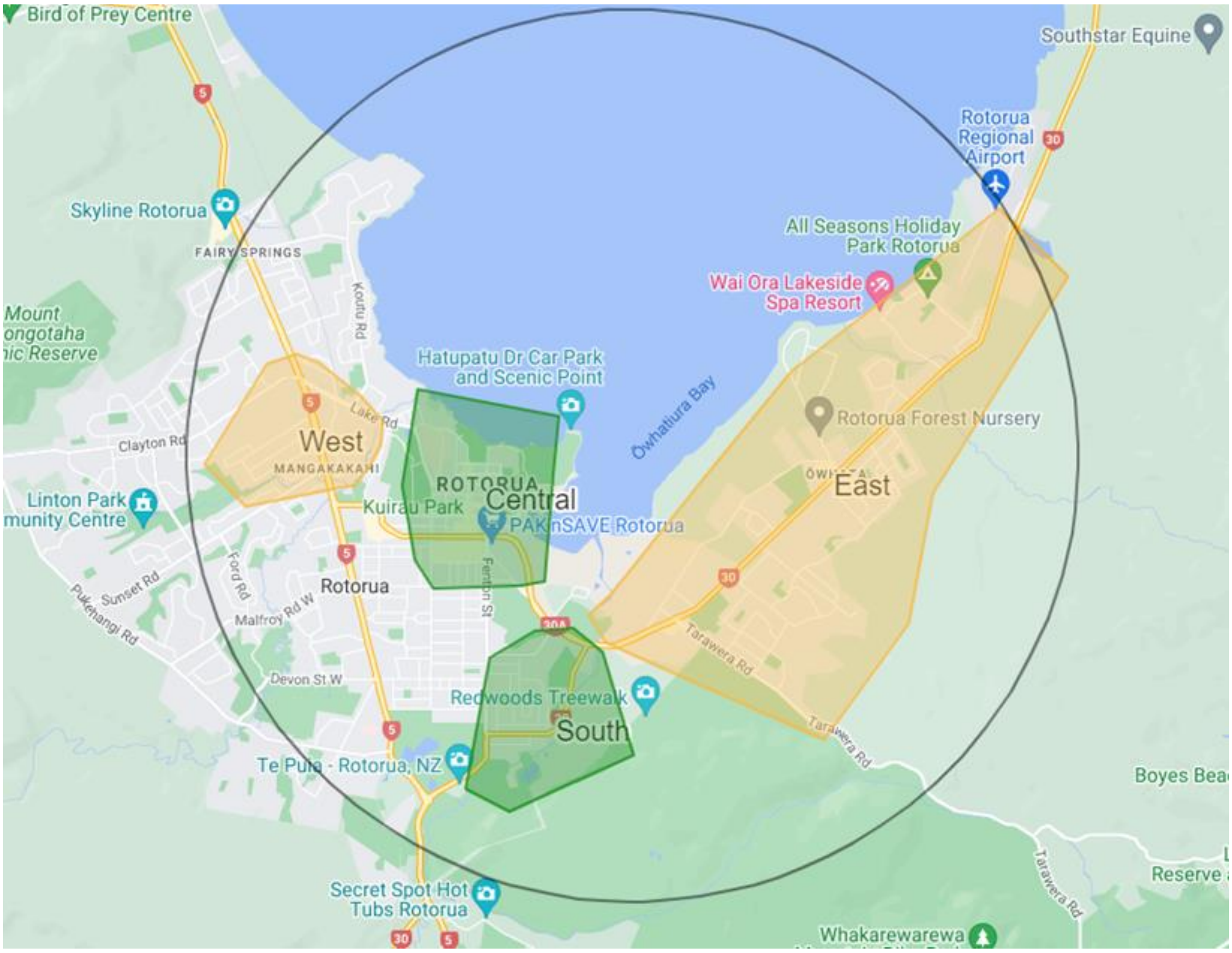

Figure 6: Kando Overview Showing Catchment Status

4.2 17TH DECEMBER 2021 INCIDENT

At 6:15 am on 17 December 2021, an extreme PE occurred, originating from Business 1. The discharge from Business 1 suddenly increased from a baseline of low EC up to 180,000µS/cm. For context, the conductivity of seawater is 30,000 – 60,000µS/cm. This discharge was, therefore, a highly concentrated saline solution.

An hour and a half later, at 7:45 am, EC began to increase in the Depot Street PS, peaking at 18,000µS/cm in this location. Further peaks, of 8,000 and 6,000µS/cm respectively, were subsequently measured at the Western Inlet to the WWTP and the Combined WWTP Inlet. This progression of the PE through the western network is shown in Figure 7. It is also evident from Figure 7 that the 6:15 am discharge from Business 1 was not an isolated discharge, with further elevated conductivity discharges detected at 8:05 am and 9:40 am on the same day, and EC from these subsequent discharges was also tracked through the network. Similar high conductivity discharges also occurred from Business 1 on other days in the first few weeks of the programme.

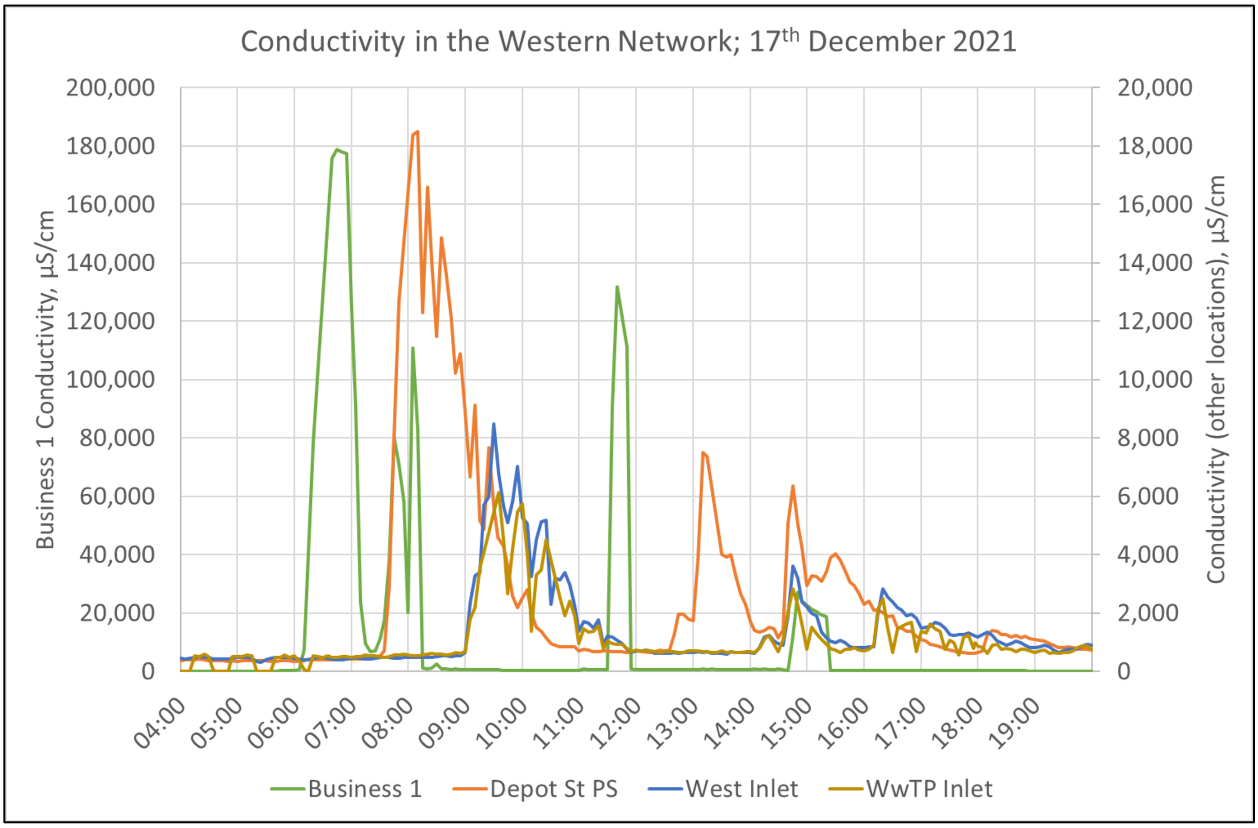

Figure 7: Progression of Pollution through the Western Network

It was not possible to undertake conventional laboratory analysis of the sample from Business 1 due to the autosampler collecting only a small volume of sample. However, RBTT, which requires only small volumes for analysis, was undertaken. Unsurprisingly given the extremely high conductivity, the sample was found to be very inhibitory. The inhibition curve for this sample is shown in Figure 8, indicating the neat sample caused virtually complete inhibition of nitrifying bacteria. Even at a 10:1 dilution, this wastewater inhibited the nitrifying biomass by 40%.

A sample was collected from the Depot Street PS at 7:15 am, as the PE moved through the network, with sufficient volume collected for both RBTT and conventional laboratory analysis. These analyses were very informative. While the conventional laboratory analysis confirmed a high conductivity and salt concentration in the sample, with sodium and chloride concentrations of 3,200g/m^3 and 5,000g/m^3 respectively, no other contaminants were measured at concentrations of potential concern. Yet, in the RBTT analysis, the neat sample collected from the

Depot Street PS inhibited nitrifying biomass by 40%. This is consistent with the level of nitrification inhibition measured on the 10:1 dilution of the sample collected directly from Business 1.

While this PE was detected right the way through the western network to the WWTP inlet, it did not have an adverse effect on the performance of the Rotorua WWTP.

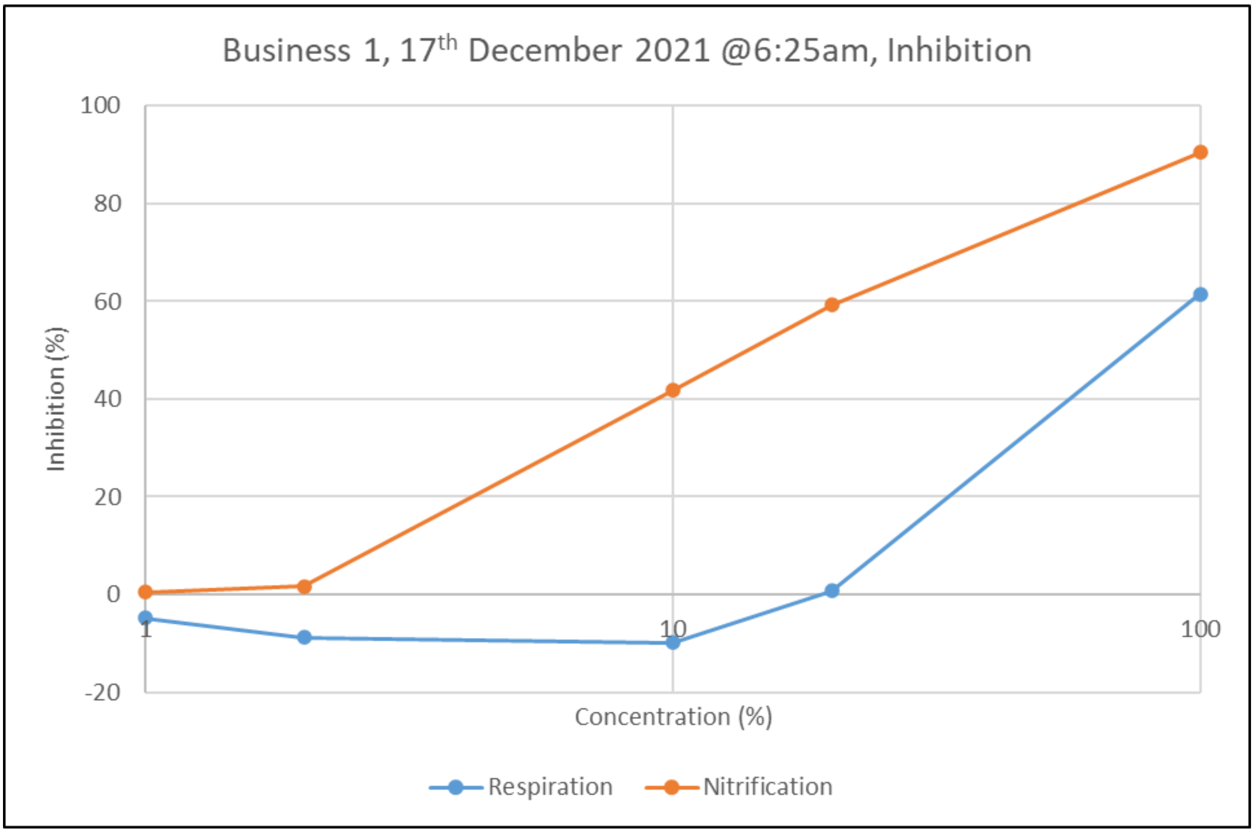

Figure 8: Inhibition Curve of Sample from Business 1

4.3 10TH JANUARY 2022 INCIDENT

The discharge from Business 4 had given no cause for alarm for the first few weeks of the monitoring programme. Then, on 10 January 2022, the nature of the discharge from Business 4 changed dramatically, as shown in Figure 9. Unfortunately, because of this business' earlier "good behaviour", the autosampler had been redeployed from this location to the Hona Road PS, so no sample was collected.

TRILITY advised Co-Lab, RLC's trade waste management provider, of this change in discharge behaviour. When Co-Lab followed this up with Business 4, they were advised that Business 4's dissolved air flotation (DAF) pre-treatment process had experienced a mechanical breakdown. Co-Lab and TRILITY would not have been aware of this incident until much later without the Kando technology.

This PE was not detected at any of the downstream monitoring locations in the eastern network, and did not have an adverse effect on the performance of the Rotorua WWTP.

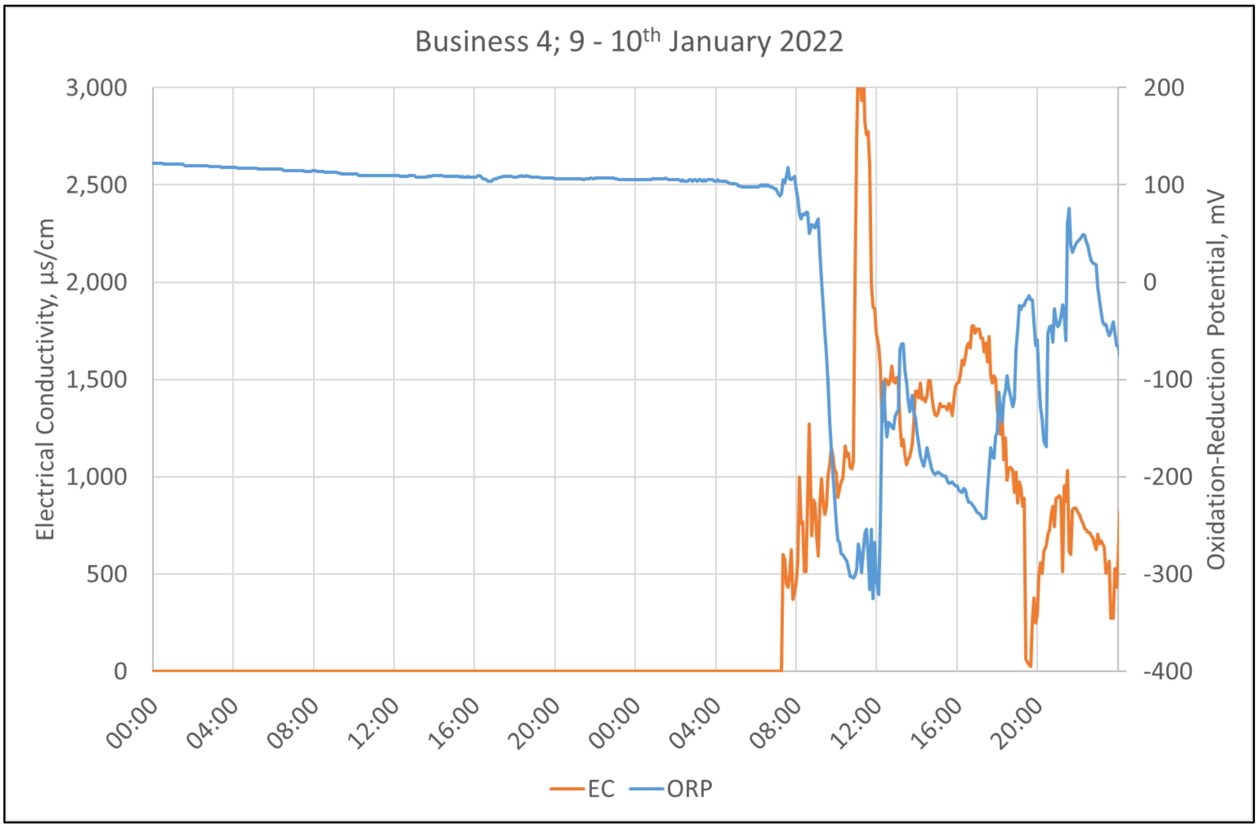

Figure 9: Pollution Event from Business 4 Resulting from Mechanical Failure

4.4 UNIDENTIFIED EVENTS AT HONA ROAD PS

During the three-month pilot monitoring programme, unexpected PEs were identified at the Hona Road PS. These PEs were not linked to Business 4, which was the only trade waste discharger in the eastern part of the network that was directly monitored during the three-month programme. An autosampler was not initially located at the Hona Road PS. However, the autosampler from Business 4 was redeployed to Hona Road PS partway through the monitoring period to capture later PEs.

One unexplained PE was measured in the Hona Road PS on 17 February 2022, with an EC of almost 2,000µS/cm measured at 13:20. A sample was collected and analysed by RBTT. The inhibition curve for this sample is shown in Figure 10, indicating the neat sample caused complete inhibition of nitrifying bacteria. Even at a 10:1 dilution, a measurable impact on nitrifying biomass was detected in this sample. However, this PE did not have an adverse effect on the performance of the Rotorua WWTP.

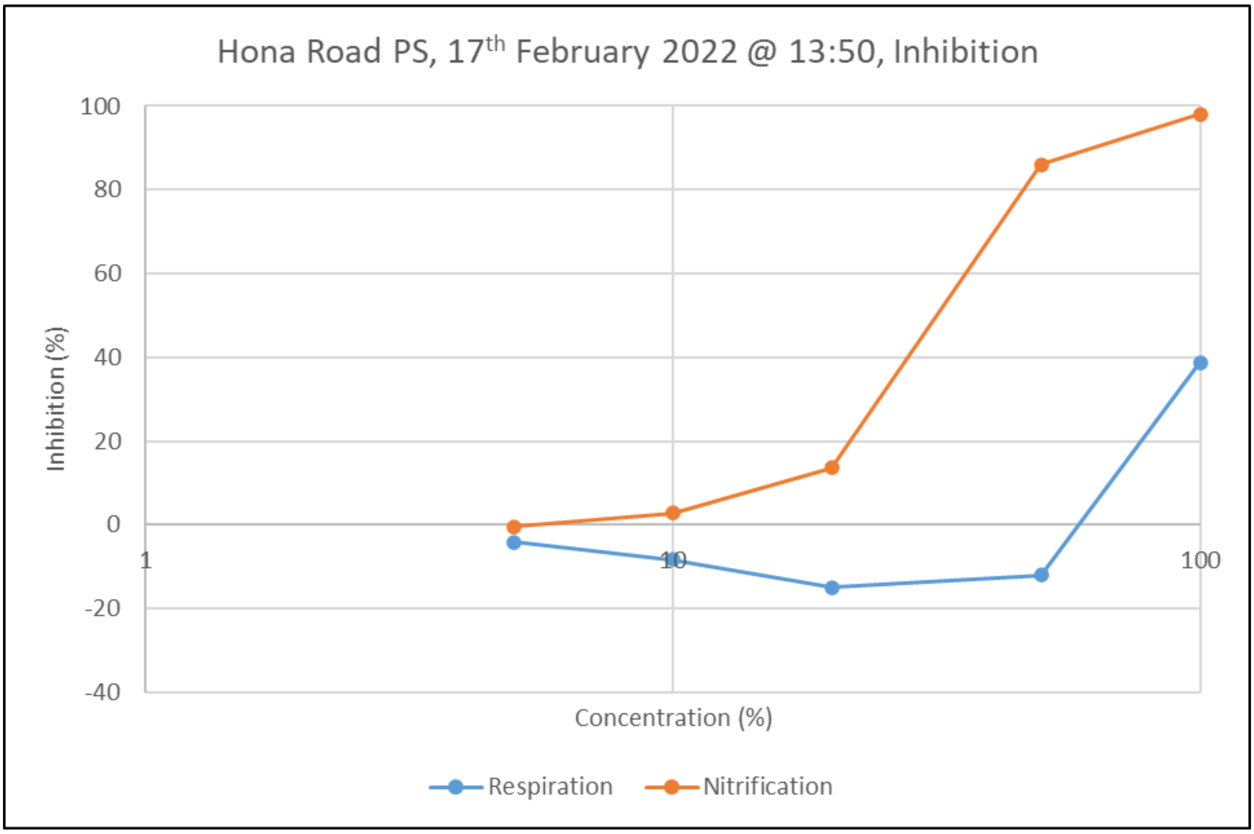

Figure 10: Inhibition Curve of Sample from Hona Road PS

4.5 COMBINED BUSINESSES 2 & 3

As well as identifying PEs, Kando's system also identified some businesses which behaved as expected given the nature of their activities. For example, the combined discharge from Business 2, the meat processing plant, and Business 3, the commercial laundry, showed diurnal and weekly trends in discharge quality, an example of which is shown in Figure 11. During weekdays, the temperature of the combined discharge typically increased around 8:00am, before dropping back to a baseline at 17:00. During weekends, no such temperature increase occurred. Similarly, diurnal patterns in pH and EC were evident.

Therefore, as well as identifying the rats discharging into the Rotorua sewer network, the Kando system also showed where some dischargers were operating as expected.

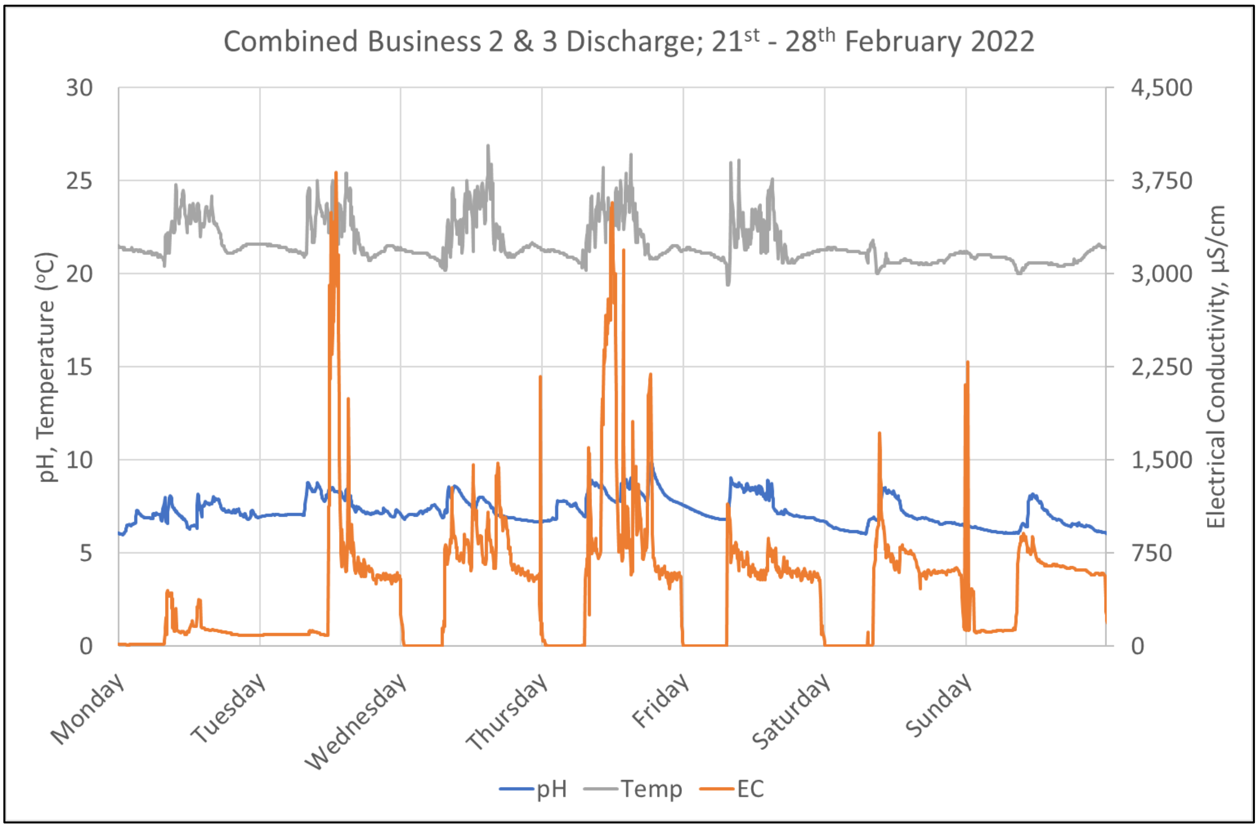

Figure 11: Diurnal and Weekly Variations in Combined Business 2 & 3 Discharge

5 DISCUSSION

Much was learned regarding trade waste discharger behaviour through the three-month monitoring period and, by working closely with Co-Lab, significant improvements in discharger behaviour were achieved. Instantaneous notification of PEs, combined with real-time on-line gathering of data, enabled TRILITY to provide Co-Lab with accurate and rapid evidence of discharger misdemeanours. In turn, Co-Lab was able to quickly pass this information on to the dischargers in question. For Business 1, this enabled off-site Managers to better understand on-site activities and drive improvements.

Over the programme period, from 23 November 2021 to 28 February 2022, the quality of the wastewater received at the Rotorua WWTP from Business 1 and the Depot Street PS improved significantly, as shown in Figure 12. This figure shows a dramatic decline in exceptionally high EC discharges and, as a result, biomass health and WWTP performance improved.

While, in an ideal world, trade waste dischargers would have full understanding and control of their activities, the reality is that wastewater is a by-product of any business and is often seen as being less important than their core activities. Therefore, businesses often do not give trade waste discharges the attention it deserves.

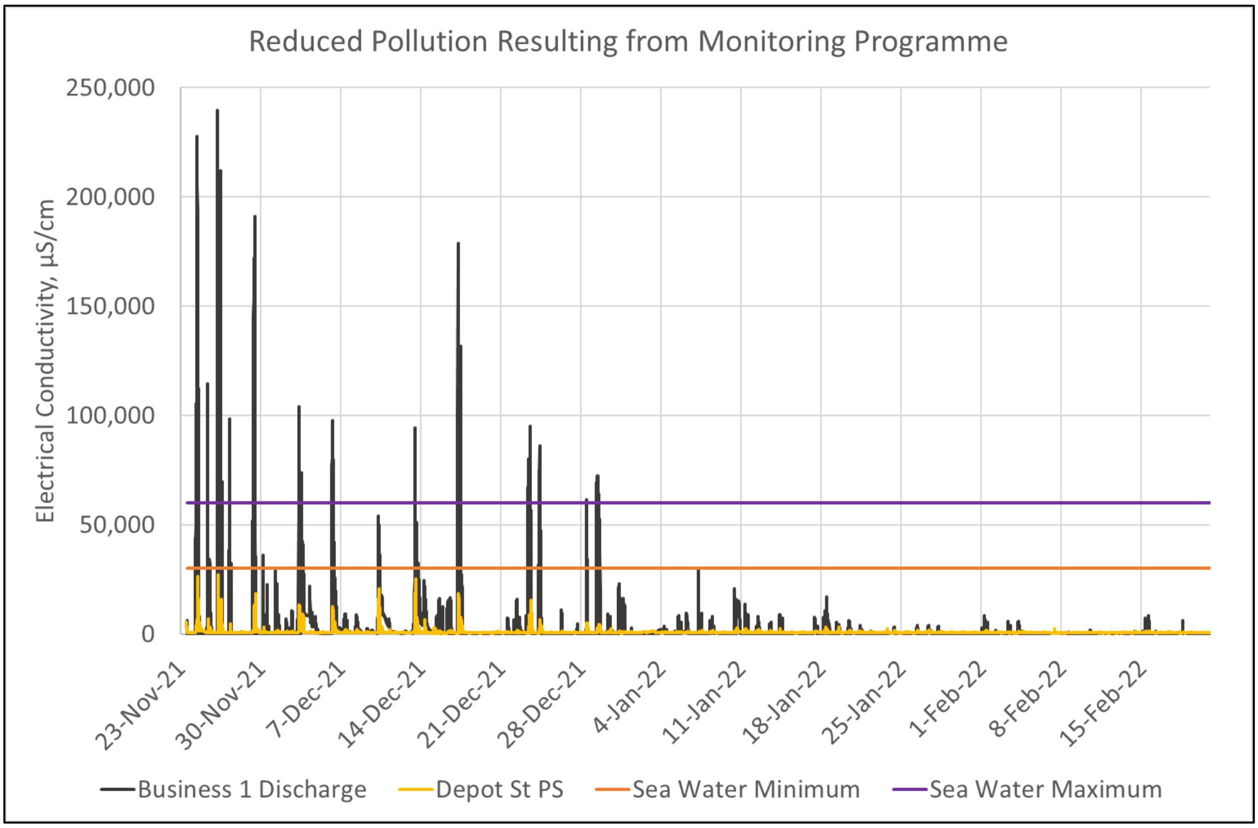

Figure 12: Improvement in Business 1 Behaviour through Monitoring Period

The most significant outcome of the pilot programme, apart from the immediate behavioural improvements of the known dischargers, was the detection of a number of unidentified PEs that occurred in the eastern part of the Rotorua sewer network. During the pilot programme, only two data gathering units and autosamplers were installed in this region because the area was designated as non-industrial. One of the autosamplers was located at Business 4, directly from their discharge point into the reticulation system, and another at the Hona Road PS. While the samples from Business 4 were site-specific, the Hona Road PS is the last point of collection for the eastern part of the network. Monitoring at the Hona Road PS indicated there was significant medium to high pollution events not attributed to the only consented discharger (Business 4) on the eastern side. This raised a high level of concern regarding the multiple other businesses located in the area.

As a result, a full-scale, 12-month, project using Kando's wastewater intelligence platform will be used to identify problem discharges and further improve the quality of wastewater delivered to the Rotorua WWTP. This second programme will enable TRILITY, working with Co-Lab, to identify discharges of concern in the eastern network, potentially implement trade waste consents where none existed before, reduce operational risk, and most of all, steer the governance of the bylaws and consent to a robust position that ensures the future operation of the Rotorua WWTP is not compromised by the actions of others.

Determining the exact nature of the material discharged into the reticulation system can be difficult. However, the parameters measured by the remote Kando data gathering units and data analytics were sufficiently broad indicators that any identified PE was likely to have the potential to be detrimental to the health of the receiving WWTP. Combining these on-line measurements with sample collection and smart analysis enabled the team to confirm which discharges were likely to be inhibitory to the WWTP. In this regard, RBTT was found to be a much more useful tool for identifying discharges of concern than conventional laboratory analysis, with RBTT directly measuring the inhibitory effect of wastewater on WWTP biomass. Apart from verifying on-line conductivity and pH measurements, while conventional laboratory analysis identified the concentration of measured determinands in the samples, it did little to identify the potential toxicity of discharges to the WWTP. For most chemical constituents potentially present in wastewater, the concentration which inhibits nitrifying bacteria is poorly understood. Furthermore, even where inhibiting concentrations of an individual substance are known, these don't take into account synergistic or antagonistic interactions between different compounds or elements.

The Rotorua WWTP provided a good level of treatment through the three-month monitoring period, maintaining full nitrification. This is despite many PEs being identified through the trial period, with some of the PEs being severe. This demonstrates how robust activated sludge-based WWTPs can be, but also shows how extreme the pollution events must have been in December 2020 and January 2021 to have caused such devastation to the Rotorua WWTP.

While the three-month trial was successful, lessons were learned that must be considered in future programmes. First, the rate of sample collection was poor. In total, autosamplers were triggered on 43 occasions, but these 43 activations resulted in a sufficient sample being collected for RBTT analysis on only 25 occasions. The successful collection of the larger volume of samples required for full laboratory analysis was lower still. Causes of sample collection failure were attributed to several factors, including inadequate flow from smaller reticulation gravity mains, blocking of the sample hose by cotton materials, the nemesis of the Wastewater Operator, Baby Wipes, and initial positioning of the sampler. Kando, Detection Services, and TRILITY worked through these issues and improved the sample collection rate; however, sample collection was still seen as a significant issue because critical sampling opportunities were lost. With the implementation of a further 12-month programme due to commence in November 2022, this will be one of the performance issues that will be top of the agenda in project kick-off meetings.

During the three-month pilot programme, maintenance of the on-line data gathering units and autosamplers was reactive. For example, where on-line trends "flatlined", or autosamplers failed to collect a sample, the maintenance team would visit the site to check on the installation. It is considered likely that a more proactive maintenance programme would result in a higher sample collection success rate.

6 CONCLUSIONS

To guarantee the smooth operation of the Rotorua WWTP and its network, now and into the future, it is essential to focus on the incoming wastewater. Neglecting the feed source's quality will only lead to problems and much operational inconvenience. The incoming waste quality is as important to the plant as the assets, routine operations and maintenance, and the overall process management.

In Rotorua, historical trade waste monitoring, based on composite or spot samples, did not provide RLC with a sufficiently robust understanding of trade waste discharges or the risk these discharges posed to the Rotorua WWTP. The three-month trial of Kando technology provided TRILITY and Co-Lab with sound evidence that known trade waste dischargers were contravening their trade waste agreements, and using this evidence to work with dischargers resulted in a tangible reduction in PEs from these known dischargers. In addition, the three-month pilot programme determined that other inhibitory wastewaters were entering the eastern part of the sewer network. While these additional discharges are from unidentified sources, the three-month pilot programme has identified where future investigations should focus in the network.

When coupled with on-line monitoring and PE-triggered sample collection, RBTT allows the risk posed by trade waste discharges on WWTP health and performance to be better understood. In addition, RBTT is regarded as a more useful tool than conventional laboratory analysis for understanding the inhibitory nature of wastewater.

Real-time data gathering at strategic locations throughout a sewer network, coupled with sample collection and AI, provides a powerful trade waste management and WWTP risk mitigation tool. Such monitoring programmes shouldn't be seen as "Gold Standard", but as an essential part of WWTP risk management. As resource consent conditions continue to be tightened to meet the objectives of the National Policy Statement – Freshwater Management (NPS-FM), so we will need our WWTPs to consistently provide high levels of treatment. Without robust trade waste management, WWTPs will constantly be fighting an uphill battle. It's time to identify, and control, the rats in your sewer.

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ACRONYMS

BoPRC	Bay of Plenty Regional Council
EC	Electrical Conductivity
IoT	Internet of Things
MBR	Membrane Bioreactor
ORP	Oxidation-Reduction Potential
PE	Pollution Event
PI	Pollution Index
RBTT	Respiration-Based Toxicity Testing
RLC	Rotorua Lakes Council
SBI	Sludge Biotic Index
TN	Total Nitrogen
WWTP	Waste Water Treatment Plant