DEVELOPMENT OF A LOW-COST SEWER SAMPLING SYSTEM

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ABSTRACT (500 WORDS MAXIMUM)

Sewer sampling is useful for monitoring a range of environmental parameters, trade waste parameters and indicators of public health such as the prevalence of SARS-CoV-2 genetic material. To obtain indicative samples of the sewage from a defined catchment, composite samples are optimal as they provide multiple snap shots of the sewage at different time points. Composite sampling currently requires the use of a large auto-sampling device. This device needs to be installed in a safe, secure, and accessible site. When monitoring specific sewage catchments, finding a suitable site for an autosampler can be challenging. While pump stations are safe and secure, they are not always in the best location for a desired catchment. Manholes across the network are predominantly the best way to divide a catchment for sampling purposes. However, modern manholes are increasingly installed with safety grates to minimize the risk of falls into the sewer of the public and staff. There are currently no composite auto-samplers on the market that can be fitted to the safety grates in these manholes.

To overcome these challenges, a low-cost sewer sampling system was designed able to be deployed into a manhole fitted with a safety grate. The device is intrinsically safe, uses low-cost materials and is reusable. A composite can be generated of up to 1.5L of sample. Additional benefits include less need for a series of grab samples, samples that are more representative, ability to deploy anywhere across the network and the possibility of use in remote locations such as dams, other suitable freshwater locations and sites without power.

The prototype sampler was deployed in stagnant and flowing water in March 2021 with great success and was originally developed to assist capturing SARS-CoV-2 genetic material in specific catchments. Sewer trials are planned for late March/April to prepare for same day setup of sampling sites in locations of interest across the network if community transmission is suspected. This may also be a suitable low-cost option for a range of alternate applications especially where an intrinsically safe device is required.

KEYWORDS

Sewer sampling, composite sampling, intrinsically safe, low-cost, safety grate

PRESENTER PROFILE

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1. INTRODUCTION

There are many challenges associated with sampling from sewer networks and composing representative samples of a wastewater catchment. These challenges need to be addressed to meet the needs of emerging wastewater epidemiology projects and provide options for monitoring trade waste within wastewater catchments. Discreet grab samples only give a small snapshot of the sewer content from a single point in time. Most parameters of interest in sewage are highly diluted and enter the sewer during discreet events. Therefore, these parameters are unlikely to be detected in a grab sample.

In the example of sampling for and monitoring possible community transmission of SARS-CoV-2, a grab sample would not likely provide a representative sample and may not detect SARS-CoV-2 RNA from the bodily excretions of a small number of infected individuals shedding into a large, diluted network. The grab sample would most likely miss a shedding/excretion event of a possibly infected member of the community. New solutions need to be investigated that can provide a low cost, battery operated, intrinsically safe solution that can safely be deployed by staff across complex networks.

When considering sewer networks in Aotearoa, many networks around cities and towns gravity feed and/or are pumped into wastewater treatment plants (WWTP) for nutrient removal and sludge treatment. For wastewater epidemiology and SARS-CoV-2 monitoring, wastewater catchments of around 100 000 people or less are optimal for detecting diluted RNA excreted from a possible infectious individual in the community. One large centralised WWTP in Auckland (Mangere) services up to 1.6 million people and is fed by three main large interceptors with many complex branches. Of all the plants in New Zealand recorded in Water New Zealand's latest inventory (2019-20), Mangere treated 28.2% of all New Zealand's wastewater influent (Water New Zealand, 2021).

Of three large interceptors feeding into the Mangere WWTP, each interceptor is fed from smaller interceptor branches with the ability to divert flow between interceptors if there is an operational need due to maintenance or repairs. This adds another level of complexity when attempting to divide these catchments into regions containing sewage from around 100 000 people for wastewater epidemiology applications.

There are currently four main options in New Zealand for sampling different parameters from wastewater across a network:

- Composite samplers setup on a secure WWTP site
- Composite samplers setup at secure pump stations
- Manholes in public spaces across the network (see Figure 1)
- Passive samplers across the network (emerging field with limited options)

This paper will discuss the current options for sampling from networks and propose a new solution for manhole sampling that can provide composite samples, pose minimal spark risk (intrinsically safe), is robust and is low cost. The device consumables can also reduce the cost of freight when shipping of samples is needed. Further development and commercialization of the device will allow for a low-cost sampling solution for the water industry here in New Zealand and abroad. This device will especially provide composite sampling options for remote locations where composite sampling has previously been limited.

2. COMPOSITE SAMPLERS

Composite samplers take a known amount of sample at regular intervals to enable a representative sample to be generated. Composite samplers are an industry standard and are used at many WWTPs for the monitoring of influent quality and process control. Many composite samplers rely on lead acid batteries or a power supply for operation that may cause a spark risk in enclosed high methane environments (such as a sewage network) and are often bulky so fail to fit within manhole systems in the network. These systems are useful when a safe and secure site can be used such as a pump station or WWTP and require ongoing maintenance to ensure the collection bucket is kept free of algal growth and the influent hose is free from blockage.

There are many suppliers of these composite samplers that use a peristaltic pump to dose wastewater into a collection bucket (ISCO, Hach, Global Water). The ISCO systems (Figure 2) are the main composite samplers used within Watercare Services Limited for monitoring of WWTP influent and wastewater process. These devices are unsuitable for deployment inside a public network manhole as the main unit needs to sit externally to the manhole in a non-secure public space. The gaps around where the samplers hosing enter through the manhole and into the sewer can increase the occurrence of nuisance odours around these sites. Therefore, these devices are limited for use within pump stations and at WWTPs where a secure site can be assured and accessed by the sampling team. These samplers are also between $6000 and $10000 per sampler so cost is prohibitive when many sampling sites are required for a single project.

Composite samplers are currently used at all large WWTP sites across Watercare. The autosamplers are used to routinely sample the influent to the plant and monitor a range of nutrients and contaminants. The autosamplers collect more than is required for routine analysis and routine samples are collected on a regular basis as per a predictable schedule. These existing sampling setups provide a quick way to fulfil new sample requests for these catchments. Health and safety paperwork and approvals are already in place for these sites so samples can be provided quickly for new projects as all aspects of the sampling system are currently operational and scheduled.

In the case of Mangere WWTP, there are composite samplers for the Eastern, Southwestern and Western interceptors. Each interceptor delivers sewage from large portions of the community with a combined coverage of 1.6 million people plus industrial waste. The influent is heavily diluted through such a large system and detection of specific parameters that are highly dilute and localised can be challenging.

Across the network, however, pump stations can provide a safe a lockable location for setup of these composite sampling systems. However, wet well access often requires hours of ventilation prior to access and entry only by competent personnel with confined space training.

Ventilation is needed as methane and hydrogen sulphide can build up in the wet well space from anaerobic activity within the sewage. All hazardous gas needs to be removed from the wet well prior to entry. To use these pump stations, holes need to be drilled through the thick concrete walls of the wet well to allow for the inlet hose to be delivered to the dry well for the sampler installation. Due to the many different designs and sizes of pump stations across the networks, many are not suitable for these types of installations. In addition, if the inlet hose were to clog on the wet well side due to solids from toilet paper or baby wipes, the entry process to the wet well by trained staff needs to be repeated to address the issue.

3. MANHOLE SAMPLING

Manholes across the network were installed over many years by many different councils using different contractors. Hence, there are several different types of manholes present across these main interceptors. Most, however, are a standard sizing and contain a standard safety grille design (Figure 3). The safety grille is a safety device designed as a fall arrest system if a person were to fall into an open manhole. It is mandatory for manholes to be fitted with a safety grilles.

Manholes are located throughout the entire interceptor and allow for access to discreet wastewater catchment areas. This is important for targeted wastewater epidemiology especially when tracking infectious disease where locations of interest are linked to specific cases in the community. The main limitation of manhole sampling is the ability to install auto-sampling devices safely and securely in these locations with the safety grille still in place. Therefore, sampling from manholes is currently limited to grab samples. Hence, only discreet grab samples can be taken and the probability of detecting an event in dilute wastewater is minimized.

Figure 1 Grab sampling from a manhole across the Watercare network.

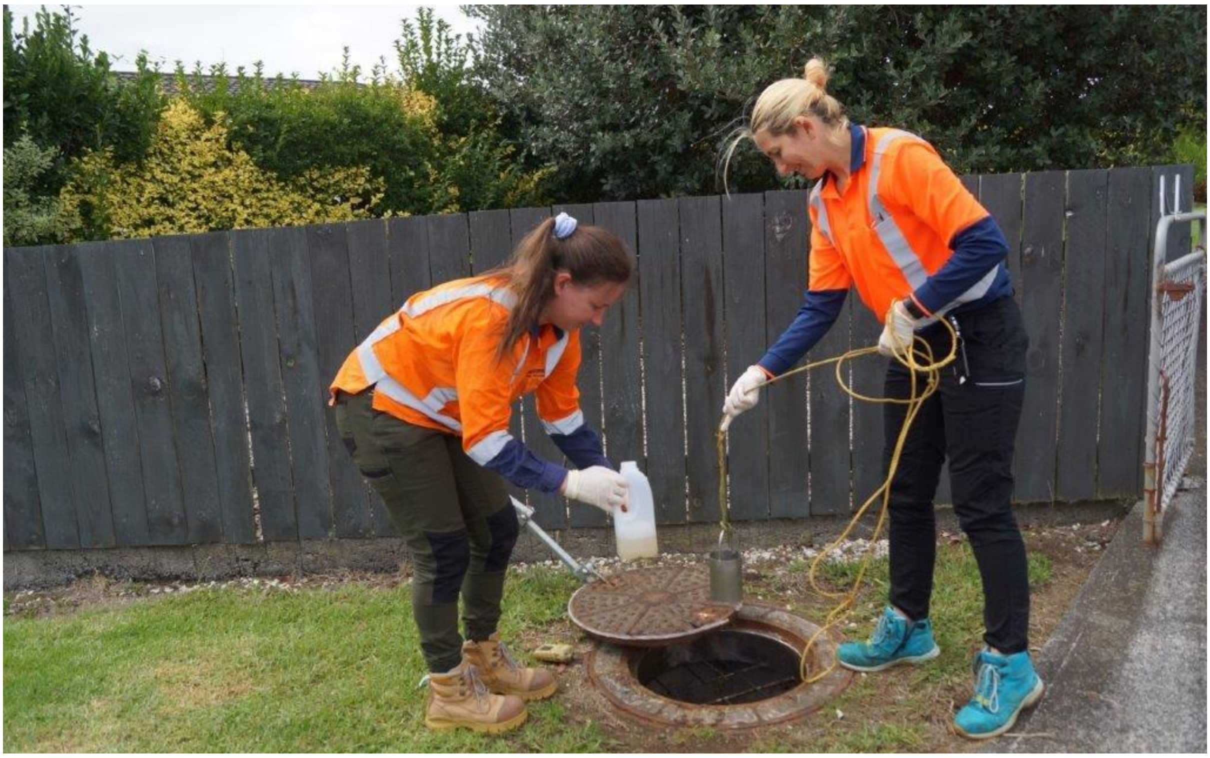


Figure 2 ISCO 3700 composite sampler setup in the drywell at a pumpstation. The inlet hosing threads through the floor and into the wetwell of the pump station. The autosampler is located in the safe location for ease of access.

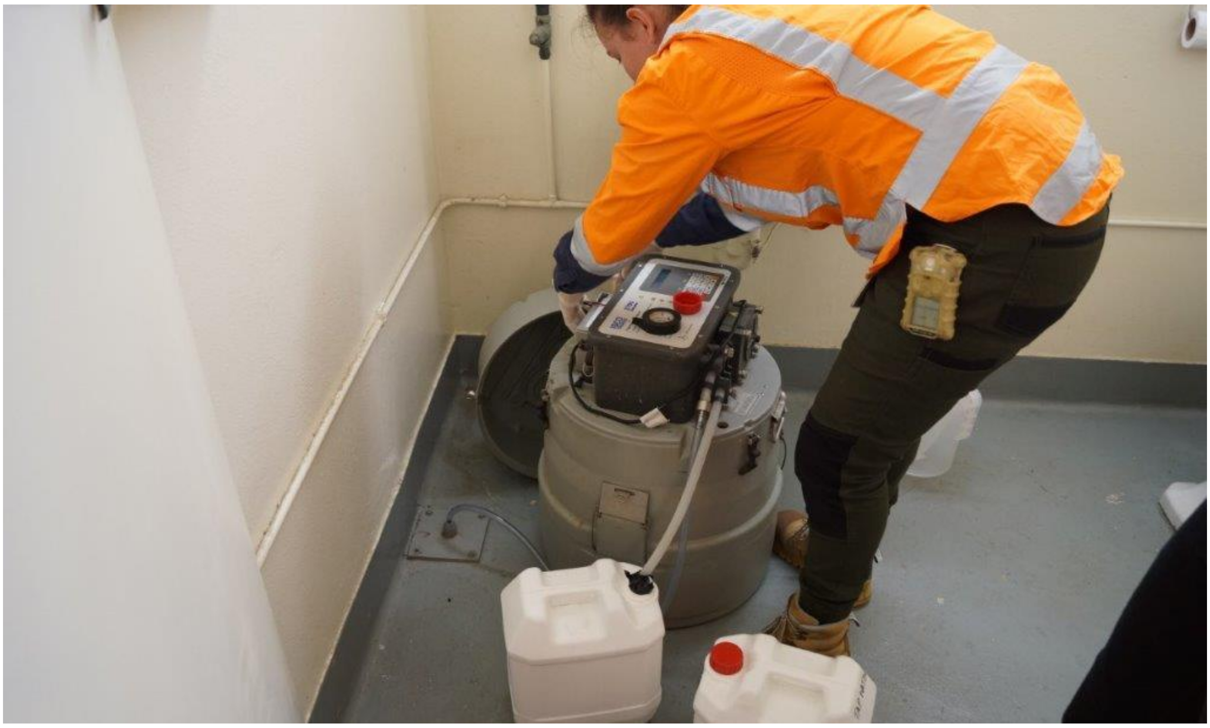
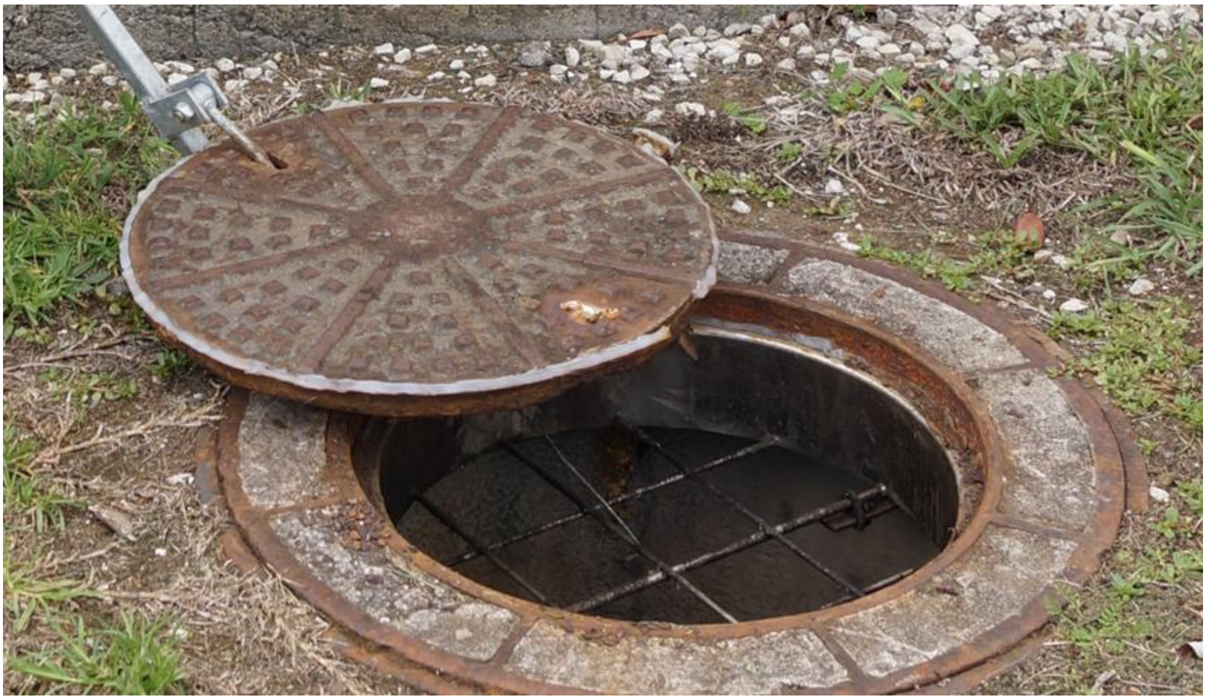


Figure 3 Representative manhole on the Southern interceptor (feeds into the Eastern interceptor) complete with safety grille. Some manholes are sealed to reduce odour nuisance in the community.



4. PASSIVE SAMPLERS

The use of passive samplers for detection of a range of parameters is an emerging field and full validation of each parameter is being reported from several research groups across the globe. The Civil Engineering department at Monash University in Melbourne developed an open-sourced passive sampler for deployment into sewer systems for monitoring SARS-CoV-2 RNA levels in wastewater (Schang, et al., 2020, Donner, et al., 2021). Of the different styles tested, the torpedo style was the most effective at capturing SARS-CoV-2 RNA and avoiding fouling and clogging by wet wipes and other solids present in the sewer (Figure 4). The technology is a simple casing containing a Moore swab (gauze tied to a stick and exposed to a flowing liquid (Liu, et al., 2020)) and negatively charged filters for non-specific binding to SARS-CoV-2 RNA (Schang, et al., 2020). However, there is limited published data comparing composite samples to these devices and establishing a good correlation.

Passive samplers have been used successfully in wastewater for the capture and quantification of a range of organic contaminants including hormones, personal care products and drugs (Cristovao, *et al.*, 2021; Ahrens *et al.,* 2015; Skodova*, et al.*, 2016; McKay, et al., 2020). Most passive systems have challenges when determining actual concentrations of a chemical target in the catchment due to the target compound binding at different rates under different conditions (eg flow, pH, temperature), elution of bound target during the sampling period due to these changing conditions and large amounts of non-specific binding to other compounds.

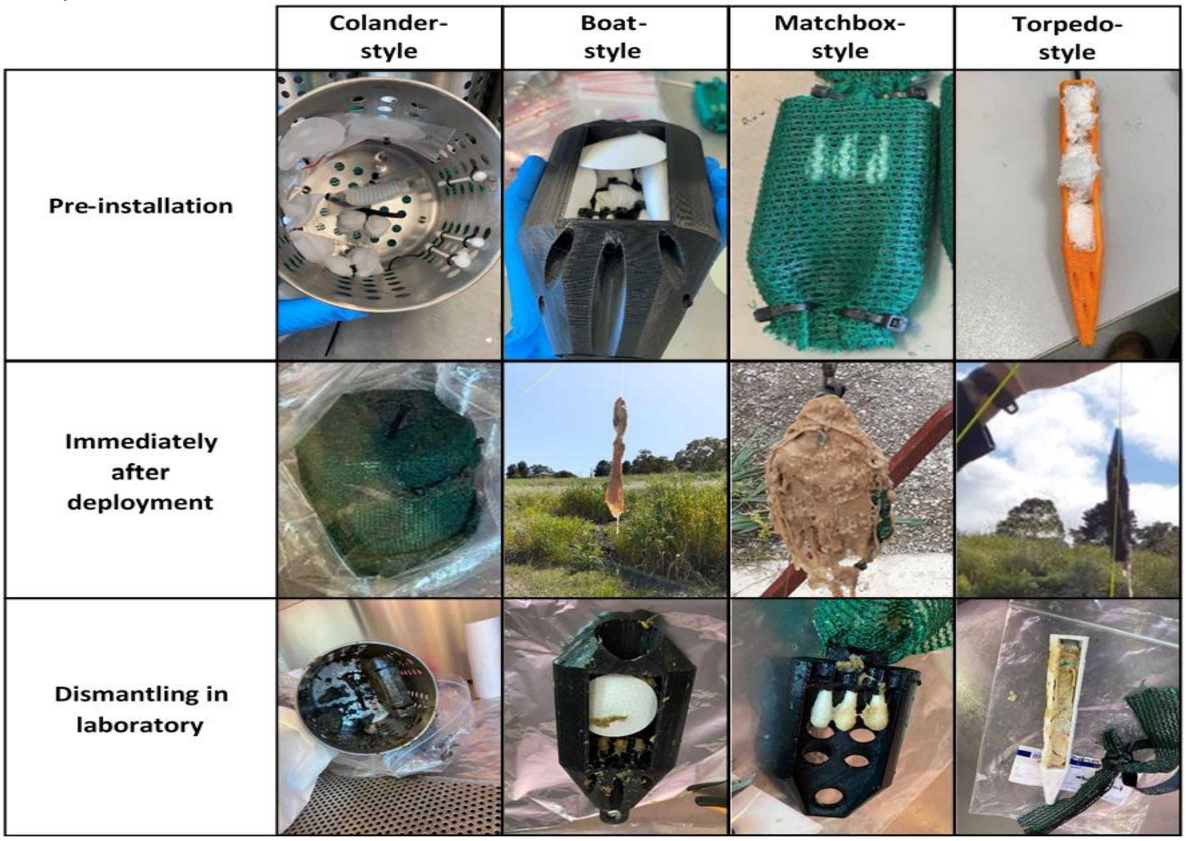


Figure 4 Passive samplers developed by Monash University for detecting SARS-CoV-2. Figure taken from Schang, et al., 2020.

In addition to these challenges, there is a high chance of fouling around the sampler and/or obstruction from solids such as wet wipes or other foreign materials. The concentration obtained from analysis must then be compared to flow through that sewer point or another reference of sewage volume. This can be difficult to calculate without flow monitoring equipment in these locations. Another concern is the binding of the target molecule to fats in the sewer or other solids such as cellulose fibres. These large solids masses may not be passing by the passive sampler and may be limiting the amount of target compound detected.

Due to these challenges, passive samplers have promise for use in some wastewater epidemiology applications. They provide a low-cost comparison of compound concentration at different sites within a network as the conditional variables mentioned above may be similar across the studied network. Whilst they may be low cost, they are also limited to the analysis of the specific group of targeted compounds. Further development is required to provide a solution that covers a broader range of target compounds and to better understand the target binding mechanisms/dynamics in a variable wastewater matrix.

5. A NEW TYPE OF SAMPLER

From the current options on the market, none provided a composite sample from a device that was small enough to fit through the safety grille and sample from sewers with differing lift heights (up to 15 m). The device needs to be a low spark risk to ensure it would not be an explosive hazard if methane were to build up in that part of the network. These basic needs are important to address when designing a low cost device suitable for use in wastewater epidemiology projects that can provide composite samples across a complex network.

To achieve these requirements the device must be:
- Able to fit within 108 mm square safety grate gaps
- Be intrinsically safe (high chance of methane)
- Be able to provide a 24-hr composite
- Be easy to use
- Safe to deploy
- Not clog with sewer materials
- Not cause harm to the network
- Survive in a high sulphide environment
- Self-powered for at least 1 week

To achieve this, a low-cost system was designed that has minimal moving parts, simple operation and is small enough to be deployed through the safety grille system. The consumables for the system will also provide savings for sample logistics as more samples will be able to be transported in an ice box compared to traditional plastic sampling bottles. A prototype was manufactured at Watercare Services Limited using off-the-shelf materials and deployed into flowing wastewater environments to test the design. Initial tests were successful and showed promise for the design to be developed further into a commercial product.

After the initial success of the device and with Watercare's permission, ESR commissioned InFact to assist with upscaling the number of prototypes produced and preparing the design for mass production. An initial half day workshop was held in Christchurch in June 2021 with Watercare, ESR and InFact to determine critical design requirements for the mass produced, low-cost prototypes. These prototypes are currently under development and production.

There are many applications for this device that will provide value for the water industry throughout New Zealand and abroad. Some of these applications include:
- Sewer network sampling for trade waste and wastewater epidemiology studies
- Stormwater sampling for contaminants
- Environmental sampling for contaminants and nutrients (lakes, dams, streams, rivers)
- Small wastewater treatment plants for monitoring influent or process changes
- Monitoring of sewage at large events or specific sites such as prisons or hospitals (drugs, SARS-CoV-2 etc)
- Identifying sources of contaminants in different areas of a landfill when contaminants are detected in the leachate
- Simple sampling system for monitoring specific processes at a wastewater treatment plant or manufacturing facility (manufacturing, potable water plant, stormwater runoff on a site with contamination risk)
- Low-cost sampling options for remote locations. Examples of projects include monitoring the quality of water sources in the Pacific Islands for

improved drinking water safety and assessing/optimising wastewater treatment processes in these countries.

After the next round of prototypes are manufactured and tested in the field, the product is planned to be refined, manufactured large scale and made available for the industry to purchase. The main aim of the project is to provide low-cost sampling options for the greater good of the water industry here in New Zealand and abroad. The product will allow access to affordable, field deployable composite sampling for use in current studies of community health, water health, environmental health and wastewater process performance.

CONCLUSIONS

Sampling from sewer systems to capture discreet sections of the community can be challenging especially where large networks are concerned. Setting up bulky and costly composite auto-sampling equipment can be time consuming, requires a safe and secure site and limits the regions in which samples can be collected. To overcome these challenges, a low-cost composite sampling solution was developed to enable sampling from most points across a sewer network. The device has minimal spark risk and provides shipping savings when samples are required to be transported via freight. The device can also be used in several other fields within the water industry and beyond as an alternative to traditional composite devices that require large batteries and secure sites for deployment.

ACKNOWLEDGEMENTS

Thank you to Watercare Services Limited, Watercare Laboratory Services and ESR. Through a collaborative project, the needs for the sampler were well defined to allow for the design of the resulting product. Collaboration between the three entities will guide a pathway for the sampler to be available for the broader water community in future.

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