Disinfection Process Optimization in Wastewater Treatment Plants Using VeloCens

Alberta Innovates Project #232403596

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ROSHAN WATER SOLUTIONS

Clear Water, Bright Future

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B. EXECUTIVE SUMMARY

The main objective of this project was to add Roshan Water's rapid bacteria testing capability to wastewater treatment plants' operations and optimize the disinfection process. Through the collaboration with ARROW Utilities, rapid E.coli test results were used to characterize the UV disinfection system and optimize the process. At the end of this project, it was determined that the treatment plant can reduce its UV dosage by as much as 50%. Today, the treatment plant is using 30% UV dosage which in turns reduces the power consumption of the UV system and the associated GHG emissions by 30% annually.

C. INTRODUCTION

Disinfection processes in wastewater treatment plants make up to 25% of annual plants O&M cost. Moreover, they generate up to 4000 tons of GHG per year per plant (in case of plants using UV disinfection) or significant load of disinfection by-products (in case of plants using chlorination) that are highly carcinogenic. This high annual O&M cost and environmental impact of disinfection processes is simply because these processes almost always are operated at the overdosage state. Wastewater treatment plants knowingly over-disinfect because while the role of disinfection processes is to inactivate microbes, plant operators do not have access to a tool to test samples onsite and rapidly for bacteria to verify the efficiency of the process and adjust accordingly if needed. Rather they send samples to their lab where it takes at least 24 hours to generate the results. Consequently, conservative approach is taken to inactivate as much microbes as possible to stay as far away as possible from the compliance levels. The high O&M cost of disinfection processes has been the reason why some wastewater treatment plants started evaluating the potentials of adding other treatment processes such as MBR to reduce the workload of the disinfection processes. However, retrofitting current treatment process with new processes such as MBR requires a significant Capex and time. To solve the problem of over-disinfection at wastewater treatment plants, a tool is needed so operation and engineering teams at wastewater treatment plants can perform microbiological tests on their effluent whenever they need to, receive the results rapidly, and optimize disinfectant dosage. VeloCens by Roshan Water provides these benefits. It is a portable device with an easy-to-operate protocol that allows the operation and engineering teams to perform the tests at any point they want and receive the results in only 1 hour.

VeloCens paints a picture of drinking water, wastewater and raw water sanitary conditions in a given jurisdiction in real-time, enabling data based decision making. This project was designed to deploy VeloCens in a wastewater treatment plant in Alberta with one main goal: optimizing the disinfection process using rapid E.coli tests. The main outcome for this project was to quantify the cost saving and environmental impact reductions when rapid E.coli results by VeloCens are used to optimize disinfection processes.

According to their operational license, wastewater treatment plants are required to perform E.coli tests on their effluent with a pre-determined frequency. These tests are normally done at the laboratory and the test process is slow by nature. It usually takes at least 36 hours to obtain the final E.coli counts. While these tests are suitable for reporting purpose to the government agency, the delay in getting the results often does not offer any operational insights. As a result, wastewater treatment plants normally opt to overdose their disinfection system to stay far below their regulatory limit. A tool that can test samples for E.coli rapidly can provide significant information on the spot and can allow wastewater treatment plants to characterize and optimize their disinfection process.

D. PROJECT DESCRIPTION

VeloCens allows wastewater treatment plants to test their effluent for E.coli easily and in only 1 hour. Today wastewater treatment plants use standard laboratory test methods that are lengthy and provide results a day later. That is why these test results are only used for reporting to the government and they are never used to understand the disinfection process and optimize it.

In this project, the original plan was to deploy VeloCens within two wastewater treatment plants and create dose response curves (DRCs) for their disinfection process. A dose response curve fundamentally shows the log reduction of E.coli as the disinfectant dose is increased. However, today, DRCs can only be created by sending samples to labs that have collimated beams and subject a small amount of sample to varying doses. DRC obtained in this way provides valuable information about the degree of ease that a particular sample can be disinfected; however, it does not represent the disinfection process of the wastewater treatment plant. In this project, using VeloCens, for the first time we allowed the wastewater treatment plant partner of this project to develop DRCs for their whole treatment system. Using these system DRCs, the project partner was able to optimize its UV dosage.

The original plan was to deploy VeloCens in another WWTP and repeat the DRC process. The second deployment was originally planned with ACWA in Calgary. The main goal of this second deployment was to generate more data for the VeloCens AI training, as well as to repeat the process. However, the plan changed since the first project partner, ARROW Utilities, after optimizing its UV system, requested to continue the collaboration and continue monitoring the UV system at the lowered dosage for an extended period of time. This change did not affect the product development for Roshan Water since 1) ACWA utilizes UV disinfection, similar to ARROW Utilities. As a result, from DRC development perspective, ACWA's system would not have provided additional insight, whereas if there was a chlorination disinfection system, that could have been useful. Worth mentioning that almost all major WWTPs in AB use UV disinfection. 2) Additional data planned originally to be generated from ACWA's pilot was achieved during the whole work with ARROW Utilities.

The main two metrics used in this project were:

- How much can the UV dosage be reduced? By virtue of that dosage reduction, metrics were developed to estimate the electricity cost saving as well as GHG emission reductions.
- At the new lowered dosage, how many subsequent tests will fail/exceed the regulatory limit?

E. METHODOLOGY

ARROW Utilities has two UV treatment systems (UV1 and UV2) that are controlled and operated separately. Each treatment system consists of two treatment channels. In this pilot study, work was done on Channel 1 at the UV1 system. Based on the discussions with the ARROW Utilities operators, the following procedure was developed:

- UV dosage on Channel 1 of UV1 was set at the following values: 85, 75, 65, 55, 45 and 35 mJ/cm2.
    - Note that 85mJ/cm2 represents the dose setpoint that is currently used at the treatment plant continuously.
- At each dose setpoint, 5 minutes was given for the system to reach equilibrium, after the dose reaches the desired setpoint.
- Calculations of the wait time based on the system HRT is given below.
- Although the PLC controls both channels in UV1, samples were only taken from a single channel to eliminate potential channel variabilities.
- After the wait time, a 200 ml sample was taken with the Roshan Water sampling bottle.
- A duplicate sample was also taken for ARROW laboratory test.
- Roshan Water also obtained another sample at each dosage for submission to its laboratory partner, Element in Calgary.

HRT Calculations

These calculations are done based on the spec and calculations provided by the ARROW Utilities staff.

HRT = Volume of the disinfection system/flow rate

To obtain the most conservative HRT (longest wait time), we used the highest volume in the system and the lowest flow rate ever recorded in the UV1. Here are the channel specs:

- Length (from beginning of bank 1 to the end of bank 2): 6 m
- Width: 1.43 m
- Depth: 1.05 m (the physical depth of the channel is 1.465 m, however, as instructed by the operator, wastewater level is normally at 1.05 m as set and controlled by the PLC)
- Vchannel= 6 x 1.43 x 1.05 = 9.009 m3 or 9009 L
- The lowest ever recorded flow in the channel was around 15 MLD
- HRT = 9009 L/15 MLD = 0.0006006 day or ~52 seconds
- Industry standards consider 5xHRT for the UV disinfection system to reach steady state. As a result, the wait time of 5 min proposed here was more than enough after each dose setpoint change.
- As mentioned in the work plan, the 5-min wait time started from the time when the dose reaches its desired setpoint.

F. PROJECT RESULTS

The following graph shows the data obtained from VeloCens as well as the data provided by Element Lab. Standard membrane filtration was used by Element Lab.

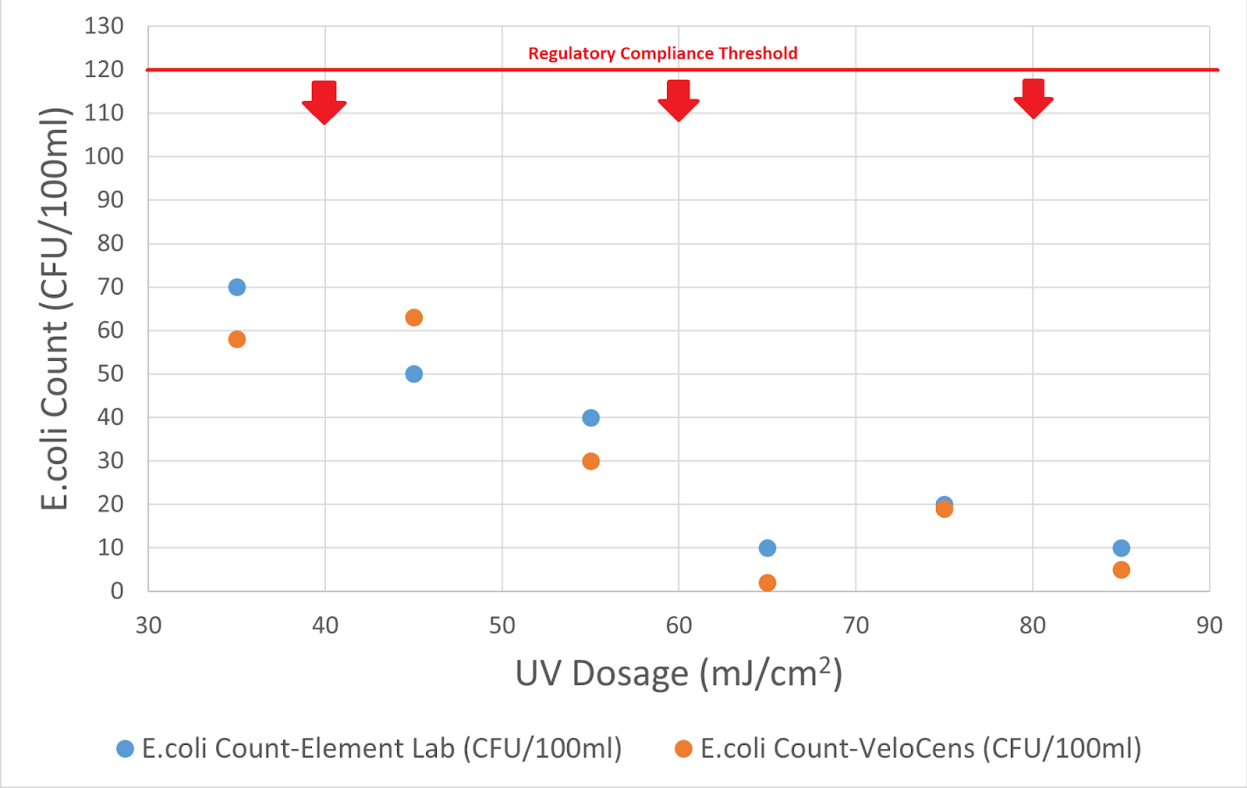

Figure 1. Dose response curve obtained for the UV1 system at ARROW Utilities

Two main conclusions can be drawn:

1. The data generated by VeloCens is in close agreement with the data generated by Element lab, both from an absolute E.coli count perspective as well as the trend.
2. According to the data and considering ARROW's regulatory limit of 120 CFU/100ml, there is significant room for optimizing the UV dosage. Although even the lowest dosage of 35 mJ/cm2 corresponding to E.coli count of 60-70 CFU/100ml is less than the regulatory limit, it is understood that wastewater treatment plants prefer to maintain a larger safety margin to account for unpredictable events. Nevertheless, even at UV dosage of 55 mJ/cm2 (corresponding to E.coli count of 30-40 CFU/100ml), there is an opportunity to lower the UV dose and hence power consumption and electricity cost (as well as GHG emission) by at least 35%, conservatively.

At the start of the project, based on the calculations performed, it was hypothesized that wastewater treatment plants could reduce their dosage by up to 50%. According to the results obtained in this project, that hypothesis has been confirmed. As shown in the DRC above (Figure 1), a 50% reduction in UV dosage represent a UV dose of around 42.5 mJ/cm2. According to the DRC, this dose corresponds to E.coli count of 60-70 CFU/100ml which is still lower than regulatory threshold of 120 CFU/100ml.

After completion of this work, ARROW Utilities decided to lower the UV1 dose to 60 mJ/cm2 and monitor the system on a daily basis for a month. The goal of this work was to observe if the lower dose can be reliably used by assessing the number of the tests that exceed that regulatory limit of 120 CFU/100ml. This subsequent bonus project showed that at the lower dosage, the system can disinfect the wastewater reliably and keep the E.coli count reliably below the regulatory limit with E.coli count range of 10-30 CFU/100ml obtained during the 30-day trial period.

ARROW Utilities benefited from using VeloCens during this project. At the moment, the treatment plant is in the process of bringing a new treatment process online and wishes to continue the conversation about future usages for VeloCens in near future when the new treatment process is up and running.

The learnings and data obtained during this project has significantly helped Roshan Water's position in this market segment. During the Singapore International Water Week (SIWW) in June of 2024, the results of this work attracted significant attention to the technology. Currently, as a result of this work and SIWW2024, conversations with several key partners in different geographies to conduct similar type of projects are ongoing. Working in partnership with other wastewater treatment plants in other jurisdictions will have a significant impact on the credibility of Roshan Water and VeloCens, as well as increasing the confidence of Alberta municipalities to deploy and benefit from rapid E.coli testing on a continuous basis.

G. KEY LEARNINGS

This project resulted in several impacts and learning both for the company and the technology as well as for the industry in general. These include:

- Technological:
    - Results generated during this project have helped with increasing the accuracy of the AI/ML model of VeloCens predictions.
    - A shift in the electrical signal happened during this project due to the change in the supplier of one of the components inside test cartridges. This unexpected event had a significant positive impact on the data processing algorithm and required Roshan to rework and unify the algorithm to account for such sudden changes.

    - Invaluable insights and feedback were obtained during this project because of direct interactions with operations staff at ARROW Utilities.
- Impacts on the industry:
    - The main impact of this project on the industry is the fact that for the first time, wastewater treatment plants can use E.coli measurements as a tool for optimizing operations, and not only as a data that needs to be reported to the government.
    - Any disinfection process is always governed by a Dose Response Curve that fundamentally shows the bacteria count as a function of the disinfectant dose. However, before this project, the only dose response curve that the industry could develop was based on tests done in a small petri dish, in a laboratory environment. These laboratory generated dose response curves (DRC) are great water quality information; they show how easy or difficult it is to disinfect a particular wastewater sample, obtained at a particular time. However, they do not represent the disinfection process at a wastewater treatment plant where wastewater is flowing through huge channels at a very high speed. In other words, laboratory DRCs do not take operational parameters into account. In this project, using rapid bacteria testing, for the first time a DRC for the disinfection system was generated, providing a valuable decision-making tool.

This project also provided another general key learning. In any industry, if there is a process that is designed for eliminating microbes, rapid test results are required to have the most optimized process. Without using rapid tests and only relying on standard tests in the lab with test results often days later, the treatment process is either under-disinfecting (which means significant environmental or operational risks) or it is over-disinfecting (which means significant unnecessary costs). This learning has been used to apply VeloCens technology for other industries. The technology is currently being adapted to develop tests for the oil and gas industry (sulfate-reducing bacteria, acid producing bacteria, etc.) that have to deal with significant consequences of corrosion caused by these bacteria.

H. OUTCOMES AND IMPACTS

Project Outcomes and Impacts:

This project helped Roshan Water to validate its hypothesis regarding the over-disinfection of streams in wastewater treatment plants and how a rapid easy to use E.coli test can help in creating the disinfection process optimization dialogue in this industry. Moreover, through this project, supporting the core staff of Roshan Water, alongside creating the opportunity to obtain more test data, the prediction of the AI model in VeloCens has become more accurate by 35%.

ARROW Utilities decided to reduce their UV disinfection dosage from 85 to 60 mJ/cm2 permanently. This almost 30% dose reduction simply means 30% reduction in ARROW Utilities' annual UV electricity cost (~$60,000 saving) as well as GHG reduction by ~1500 tons per year.

Clean Resources Metrics:

- TRL advancement: With implementation of the technology at ARROW Utilities and achieving the goal of disinfection process optimization, TRL advancement from 8 to 9 has been achieved.
- Future Capital Investment: The goal was to raise $1M in capital during this project. However, the process of getting investors onboard, especially with the conservative nature of the industry, proved to be very lengthy. As a result, Roshan decided to primarily allocate time to work with potential customers and leads. As a result, no capital was raised during the project.
- Clients selling goods or services domestically: Goal was $300k revenue at the completion of project. However, projected revenue now is $85,000. The revenue project was not met mostly due to the conservative approach of utilities in AB. This is being rectified through geographical as well as product line expansion.
- Field pilots/demonstrations: Goal was 2 pilots, however as mentioned in the report, only work with ARROW Utilities (formerly ACRWC) was necessary to achieve the objectives of this project.
- Publications: The report from this work was used in both SIWW2024 in Singapore, as well as a case study in the Solar Impulse Foundation platform.
- Sector HQP Trained: The goal was to onboard two new members for a) QA Automation and b) Manufacturing and Assembly. Current team members developed the skills needed to perform the tasks of QA automation as well as assembly of test kits. The manufacturing & assembly of the hardware is being contracted to Karma Manufacturing.
- Existing Sector HQP Jobs Retained: All 4 HQPs were retained.
- Actual GHG emissions reduction from project: With 30% reduction in the UV dosage, ARROW Utilities is on its way to reduce its GHG emission related to the UV disinfection process by 2000 tons annually, meeting the projection of this project.
- Projected GHG emissions reductions from future deployment (to 2030): Projection is GHG reduction of 100,000 tons by 2030 which is attainable by deployment of VeloCens globally.

Program Specific Metrics:

This project proved that disinfection processes at wastewater treatment plants can be optimized by up to 50% which means up to 50% reduction in disinfectant cost, GHG emission and disinfectant by-products formation. This optimization potential means:

- If a treatment plant uses UV disinfection process, it can lower its UV dosage up to 50%. This in turn reduces the electricity bill for the UV process by up to 50% and reduces the associated GHG emissions from lower electricity usage.
- If a treatment plant uses chlorination disinfection, this up to 50% optimization means lower costs of chlorination and de-chlorination chemicals. On the other hand, one of the major concerns with chlorination of wastewater streams is formation of disinfection by-products (DBPs) that can be highly toxic, entering drinking water sources as well as the environment. The

concept of optimizing disinfection process shown could have the potential to reduce the chances of formation of DPBs by up to 50% as well.

Project Outputs:

- During this project, the patent covering how VeloCens can perform bacteria tests in 1 hour was granted in 18 European countries (Austria, Belgium, Bulgaria, Denmark, Estonia, Finland, France, Germany, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Portugal, Romania, Slovenia, and Sweden).
- Findings of this project and the report developed based on the work with ARROW Utilities was the main talking point during 22 one-to-one B2B meetings during the Singapore International Water Week (SIWW2024).
- Findings of this project and the report developed based on the work with ARROW Utilities was used in email campaigns and communications to other wastewater treatment plants in Canada, which has led to the project currently being planned with a wastewater treatment plant in Toronto.

Project Success Metrics:

- The goal was to optimize disinfection techniques by up to 50% at wastewater treatment plants, resulting in reduction of overall:
    - UV power consumption
    - Chlorine chemical consumption
    - GHG emissions
    - Disinfection by-products formation
- ARROW Utilities reduced its UV dosage by 30% which is directly related to the GHG emission the process causes. If a treatment plant uses chlorination disinfection, this up to 50% optimization means lower costs of chlorination and de-chlorination chemicals. On the other hand, one of the major concerns with chlorination of wastewater streams is formation of disinfection by-products (DBPs) that can be highly toxic, entering drinking water sources as well as environment. The concept of optimizing disinfection process shown has the potential to reduce the chances of formation of DPBs by up to 50% as well.
- # Datasets added to AI/ML models: Target was adding 150 data points, and 200 were added through this project as well as internal tests.
- # test kit components reused: Target was reusing 500 components from the test kits, and 800 test kit components were cleaned and reused during the 200 tests mentioned above.

I. BENEFITS

Economic Benefits:

The learnings and data obtained during this project have significantly helped Roshan Water's position in this market segment. During the Singapore International Water Week in June of 2024, the results of this work attracted significant attention to the technology. Currently, as a result of this work and SIWW2024, conversations are ongoing with several key partners in different geographies to conduct similar type of projects. These interactions will enhance the export potential of Roshan Water and augment its position in the international market. One of the main objectives of this project was to establish whether the concept of disinfection process optimization at WWTPs is a viable business case, both from technological as well as market demand perspectives. From the technological standpoint, this project and the work with ARROW Utilities generated conclusive data that most disinfection processes at WWTPs are not optimized and a WWTP such as ARROW Utilities was able to use findings of this project and reduce its UV dosage by 30%.

From the market demand perspective, during this project, Roshan has engaged with all of the large WWTPs in Alberta. ARROW Utilities has benefited from using VeloCens during this project. At the moment, the treatment plant is in the process of bringing a new treatment process online and wishes to continue the conversation about future usages for VeloCens in near future when the new treatment process is up and running. Other large wastewater treatment plants in Alberta were also approached during this project. However various challenges such as ranging from internal restructuring to resistance to change procedures have hindered deployment of VeloCens in these plants. We strongly believe that working in partnership with other wastewater treatment plants in other jurisdictions will have a significant impact on the credibility of Roshan Water and VeloCens, as well as increasing the confidence of Alberta municipalities to deploy and benefit from rapid E.coli testing on a continuous basis.

Continued commercialization within the WWTPs in Alberta (especially EPCOR and Calgary) is contingent on future successes of VeloCens in this sector in other regions. A recent development as a result of this project is discussions with a WWTP in Toronto which is one of the largest and oldest WWTPs in North America. They are converting their chlorination system into a UV disinfection system and after reviewing the results of this project, they are interested to deploy VeloCens for a trial before their UV system is online. Roshan is confident that current discussions with this treatment plant in Toronto and potential deployment in this WWTP can bring some success in future within the Alberta Market. At the moment, the team at the Toronto WWTP is reviewing a Demonstration Project Agreement and the Quote from Roshan. The start time is expected to be mid- to end of October 2024.

The conservative approach mentioned above was one of the main reasons Roshan started looking into the international market. The Canadian Technology Accelerator with the focus on the water and wastewater sector in east Asia alongside its included SIWW2024 provided the perfect opportunity for us to evaluate the market desire for our product and findings of this project internationally. As mentioned

above, one of the objectives of this project was to validate the disinfection process optimization business case through the lens of market demand. The successful conversations in Singapore and current project plannings in Philippines and Pakistan allowed Roshan to validate and reach that objective. These two projects by themselves represent massive revenue generation for the company and the economic impacts for Alberta. Moreover, continuation of this path guarantees hiring more HQPs for the company to fulfill these projects.

Building Innovation Capacity:

This project supported 4 core staff of the company, 2 in Alberta and 2 in BC. Through this support:

- VeloCens was successfully deployed and improved.
- Interactions with the treatment plant staff helped augment overall understanding of the decision-making process.
- Data processing and underlying OS of the product improved significantly.

Environmental Benefits:

This project directly contributed to GHG emission reduction at ARROW Utilities by 30% through reduction of their UV dosage. Depending on the type of the disinfection process, the concept developed in this project can contribute to GHG emission reduction or chance of DBPs formation by up to 50%.

J. RECOMMENDATIONS AND NEXT STEPS

The knowledge generated during this project has formed the basis for attracting other wastewater treatment plants into this conversation. Unfortunately, wastewater treatment plants in Canada are more conservative, as a result, Roshan has pivoted to the international market. Various challenges such as ranging from internal restructuring to resistance to change procedures have hindered deployment of VeloCens in WWTPs in Alberta. However, Roshan expects that working in partnership with other wastewater treatment plants in other jurisdictions will have a significant impact on the credibility of the company and VeloCens, as well as increasing the confidence of Alberta municipalities to deploy and benefit from rapid E.coli testing on a continuous basis. Roshan is already in the process of deploying VeloCens in a WWTP in Toronto. Successful deployment in this project will assist significantly as this wastewater treatment plant is one of the largest and operationally complex WWTPs in Canada. Relationships with engineering firms and suppliers in the Philippines, Pakistan, France and Belgium have also been established to use the report generated in this project and attract customers in these regions. The main strategy behind these partnerships is to work with water management and engineering firms that are already serving the water and wastewater market in each region.

The core of the learning obtained in this project was: if actual bacteria counts are not used to monitor and optimize the efficiency of the disinfection system, the disinfection process is either under-

disinfecting, or it is over-disinfecting. Both of these outcomes result in unnecessary costs and significant environmental impacts. Starting earlier in 2024, Roshan has explored this line of thinking and looked at different industries that are dealing with similar issues. As a result of this project and the learnings it created, they have identified a new application and market for their technology. In the oil and gas industry, significant amounts of biocides are used annually to remove Sulfate-reducing bacteria (SRB) and Acid-producing bacteria (APB) from pipelines and equipment. These groups of bacteria are main culprits in Microbiologically Influenced Corrosion (MIC) that is responsible for over $500B cost to the industry annually. One of the main challenges with these bacteria is that the current test in the lab can take up to 28 days to generate results. Hence, the biocide treatment is either overkilling or under killing the bacteria. The R&D work to use VeloCens for rapid detection of these bacteria started in April of 2024 and already with initial successful results, Roshan is working with Pathways Alliance and their members (Imperial Oil and Cenovus) that have shown interest in deploying and piloting VeloCens in their systems.

K. KNOWLEDGE DISSEMINATION

The methodology and results obtained from this project have been boiled down into a 6-page report. This report has been used in trade shows as well as through email campaigns. As mentioned before, this report has created a tremendous amount of interest in this subject and overall the benefits that the technology can offer.

As mentioned before, in this project and for the first time, Roshan's VeloCens technology enabled a wastewater treatment plant to develop a system wide DRC for its disinfection process. As opposed to traditional DRCs that are good water quality tools only, the DRC concept developed in this project can serve as a significant decision making and characterization tool for the whole water and wastewater treatment industry. The impact that this potentially can have on government and industry is simple. Now the industry can use rapid E.coli tests as an operational aid and decision making tool, and not only as a reporting tool.

L. CONCLUSIONS

The main objectives of this project were to validate and quantify how much disinfection processes at wastewater treatment plants can be optimized through the use of rapid E.coli testing. The bonus objective that was added by the project partner was to evaluate the disinfection process over a longer period of time when a reduced disinfectant dosage was used. The main goal was to evaluate whether the system shows non-compliance with provincial regulations or not.

Key components of the project included ARROW Utilities as the site for deploying VeloCens. Roshan Water staff for execution and management of project, Roshan Water advisors and Element lab as the

lab partner of the project. The main result of this project was the UV dosage at ARROW Utilities were lowered by 30%. This means that the wastewater treatment plant can expect to have 30% less in power consumption and electricity bill. Moreover, lowered electricity consumption can be connected to the lower GHG emission as well. For this first time, through this project, a UV disinfection Dose Response Curve was developed for the whole system at ARROW Utilities.

Technologically speaking, the data generated in this project helped the AI/ML processes used in VeloCens significantly, increasing the accuracy of its predictions. The next step for the concept developed in this project is to deploy VeloCens at other major WWTPs in Canada and internationally, starting with the WWTP in Toronto.