Application Note

Adopting BactoSense for the microbial monitoring of groundwater during extreme weather events

Abstract

Intergovernmental Panel on Climate Change (IPCC) experts are firm: the frequency of extreme weather events has increased and will keep doing so [1]. High precipitation, snow melt and floods can lead, among others, to surface runoff and contamination of aquifers. As groundwater provides drinking water to at least 50% of the world's population [2], ensuring a safe and continuous supply of this vital resource is of paramount importance. In 2018, severe floods in South-West Iceland led to contamination of some water production wells. Veitur Water Utilities, which is the largest provider in the region, implemented BactoSense to respond to the threat and ensure consumers safety.

Keywords
Groundwater, drinking water distribution system, DWDS, water utility, self monitoring at the source, online microbiology, flow cytometry, water characterisation

Cover picture: BactoSense installed at a borehole in the protected production area

A protected production area with many wells

Veitur Water Utilities provides water to approximately 150'000 people in South-West Iceland from four water production areas (Figure 1). The production capacity is about 2'400 L/s, but the annual production amounts to about 720 L/s, allowing flexibility in the selection of different wells at different times.

Figure 1: Veitur Water Utilities extracts from several boreholes spread across protected areas situated either in low areas LPA (85 m a.s.l.) or in high areas HPA (140 m a.s.l.). Each area has its own maximum capacity. The blue dots indicate the positions where BactoSense is installed.

Some extraction wells in the production areas are prone to environmental microbial contamination, especially during violent weather events. These "red" wells are seasonally considered at risk and not used from October to April. During the winter of 2018, severe floods led to the first-ever recorded contamination of other wells. Consequently, the required capacity of sufficient quality could not be supplied.

Following this event three additional stable quality wells were commissioned, increasing the production capacity in extreme weather up to 1165 L/s (Table 1).

	Summer	Winter	Extreme weather
Operational wells	18	12	7
Potential capacity (L/s)	2'320	1'475	1'165

Table 1: Veitur Water Utilities production in summer, winter (when "red" wells are not used) and during the extreme event of winter 2018 (wells additionally off, reducing the permitted capacity).

A new approach with online microbial monitoring

The 2018 event incited Veitur Water Utilities to look for new ways to monitor the microbial parameters of water to ensure production while guaranteeing consumers' safety. The usual method relies on cultures and requires substantial handling and time. It is therefore not adapted to fast and sensitive surveillance.

Veitur Water Utilities decided to use the BactoSense online flow cytometer, which allows for a quick on-site determination (about 30 minutes per analysis) of microbiological concentration (Figure 2).

Figure 2: Installation of BactoSense

Adopting BactoSense online to watch over sources and help making the exploitation decision

The Total Cell Count per mL (TCC) was the parameter selected to evaluate the complete microbial landscape. TCC was monitored, first in one well (V5) in 2019, then in four wells (V5, V12+V13, V19) in 2020. V5 and V19 are considered as "red" wells, while V12 and V13 were used all year long.

Initial results showed the robustness and sensitivity of BactoSense compared to usual methods and how continuous measurement of the instrument expands the incomplete view from plating (Figure 3). The non-uniform relationship between TCC/mL and plating of microbes at 22°C might arise from the complexity of the microbial community [3]. Nonetheless, a TCC value strongly surpassing its baseline indicates a clear microbial risk, and can be used as an aid in identifying the stable or problematic sources.

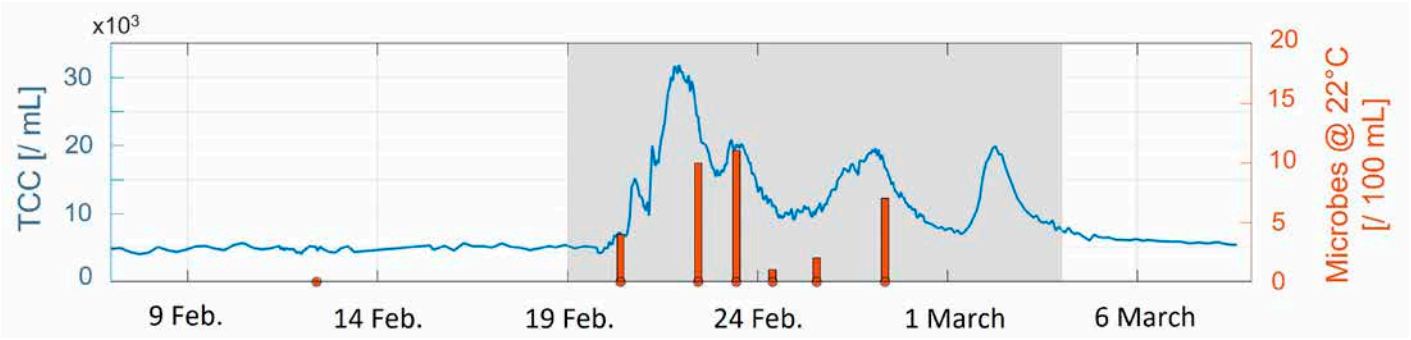

Figure 3: Evolution of the Total Cell Count (TCC) per mL, as given continuously by the BactoSense (blue curve), and the number of microbes plated at 22°C with time (orange histograms).

Monitoring TCC also allowed setting criteria to decide whether the groundwater could be utilized or not. In a first cautious approach, three water qualities were defined:

High: TCC within a 99% confidence interval of its baseline value ($TCC_{baseline}$)

Intermediate: $TCC_{baseline} < TCC < 2 \times TCC_{baseline}$

Poor: High risk of contamination with fast rising TCC values > $2 \times TCC_{baseline}$

Figure 4 presents the continuous analysis of the groundwater from well V5 in 2019. Regarded as a "red" well, V5 would normally be shut down from October to April. However, BactoSense shows that most of the time, its TCC value is in the green zone. During those periods, the well provides high-quality water, proper for consumption.
By using BactoSense to determine the water quality, the yearly exploitation window is significantly extended.

The monitoring was extended to more wells in 2020. The results shown in Table 2 present the significant increase in production capacity per well. Veitur Water Utilities had the visibility and the confidence to decide which wells were stable, but also to decide to extract less on wells that could be more problematic. It brought an increased production capacity and helped to ensure that the demand for water was met throughout the year, with increased.

BactoSense allowed the safe distribution of water from extraction wells in South-West Iceland that were usually considered as too prone to contamination.

	V5 well optimized with BactoSense monitoring (% of time in winter compared to usual use)	**Consequence / Benefit**
V5	↑ +75% in 2019 ↑ +85% in 2020	√ Production capacity increased √ Relief for other wells √ Optimize well choice
V19	↑ +90% in 2020	
V12 + V13	↓ -2% in 2020	√ Increased consumers protection

Table 2: Table presenting the potential gain in production capacity for each studied well

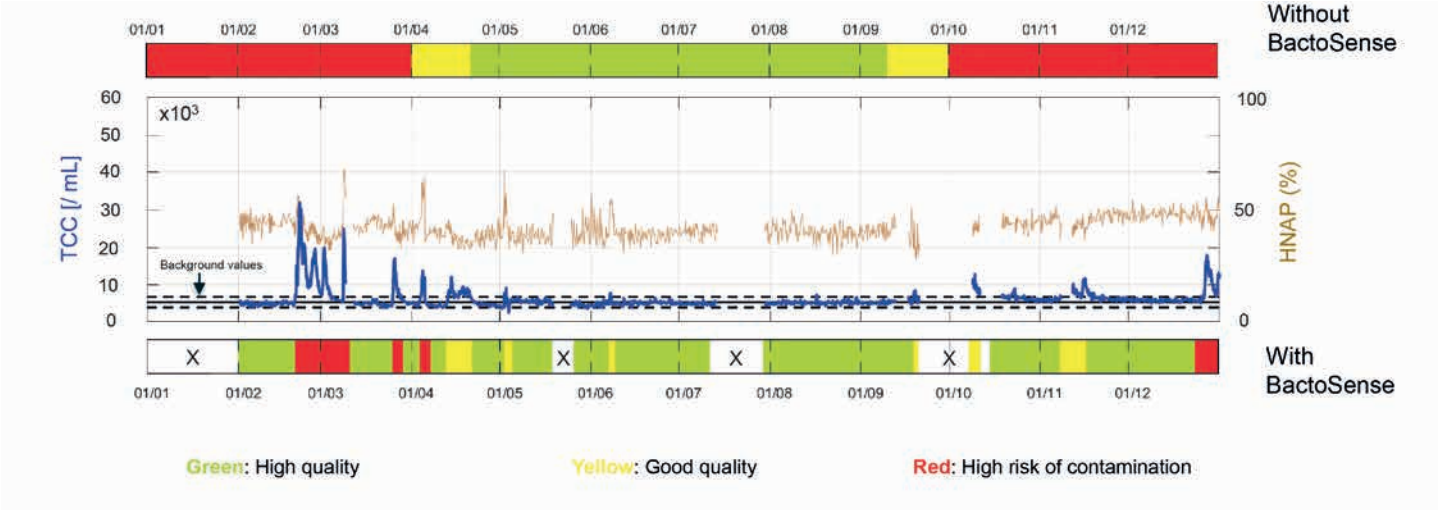

Figure 4: Evolution of TCC/mL (blue continuous line) and its background confidence interval at 99% (black dashed lines) for well V5 in 2019. The bar above the graphs represents the standard well operation without BactoSense. The bar below the graphs represents the water qualities according to the quality criteria with BactoSense (green = high, yellow = intermediate, red = poor).

Conclusion

The implementation of BactoSense by Veitur Water Utilities enhanced the quality control and safe distribution of water from extraction wells that were usually considered as too prone to contamination, limiting the overuse of other aquifers. They could increase their production capacity of high-quality water, better assess risks, and reject wells when water quality was not high, ensuring consumers' safety.

On the whole, BactoSense brings an increased knowledge of the seasonal variability and dynamics of raw water. It can be implemented to monitor microbial quality of groundwater wells in real time, particularly during extreme weather events. This leads to a safer, more optimal and sustainable use of water resources.

Benefits

- Enhanced quality control and safe distribution of water from extraction wells that were usually considered prone to contamination, limiting the overuse of other aquifers
- Increased production capacity of high-quality water
- Better risk assessment
- Increased knowledge of the raw water seasonal variability and dynamics

References

[1] IPCC, 2022: Climate Change 2022: Impacts, Adaptation, and Vulnerability, IPCC, 2022
[2] The United Nations world water development report 2015: water for a sustainable world, World Water Assessment Program, 2015
[3] Microbial intrusion and seasonal dynamics in the groundwater microbiome of a porous basaltic rock aquifer used as municipal water reservoir, Knobloch, S. et al., 2021

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