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Improving root cause analysis of bacteriological water quality failures at water treatment works.

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Abstract

Variations in spot-sampled and continuously-monitored water quality data were assessed to determine whether they could be linked to regulatory coliform failures. Data were available from raw water to the final monitoring point at water treatment works (WTW)-B and included climate, physico-chemical and bacteriological data. These were analysed using cross-correlation and self-organising maps in MATLAB®. The results highlighted rainfall and upstream coliforms and turbidity as important factors in the coliform failures. Further examination showed that failures correlated with low turbidity and low coliform loading, but relatively high rainfall. This outcome could be used to improve bacteriological compliance at WTW-B and similar sites.

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Keywords: Bacteriological water quality; data analysis; monitoring data; proactive failure prevention

1. Introduction

Water companies conduct bacteriological quality monitoring to assure the safety of drinking water for consumers and to monitor the performance of treatment processes. Water samples are routinely collected from water treatment works (WTWs), service reservoirs and customers' taps. Due to the low numbers of bacteriological

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pathogens in drinking water under normal circumstances, water samples are tested for indicator organisms. The principal bacteriological indicators are coliforms, *Escherichia coli*, Enterococci and *Clostridium perfringens* (Standing Committee of Analysts, 2002). All four parameters have prescribed values of 0 cells per 100 ml and any detections of these microorganisms is indicative of environmental or faecal contamination of treated water (Council of the European Communities, 1998). Larger sample volumes, for example 1 L, may be used for surveys.

Our previous work (Ellis et al., 2014) showed that cross-correlation and self-organising maps (SOMs) could be used to inform the root cause analysis of a coliform detection at a surface water WTW in the UK (WTW-A). Cross-correlation is a measure of the similarity of two variables as a function of a time lag between them (Bracewell, 1965). This tool could therefore give WTW operators a time period in which to amend treatment processes to prevent a bacteriological failure. SOMs enable the correlation of more than two parameters (with no specific time element) (Kangas and Kohonen, 1996) and were used to understand the broader water quality at the time of the coliform detections. The methods showed some promise for the improvement of root cause analysis, but a limitation of the case study was that data were only available from the final monitoring point. This meant that there was no practical time lag between changes in water quality and the detection of coliforms.

This work builds on the findings from WTW-A and focuses on WTW-B, which produces 160 ML d^{-1}. Both WTWs are owned and operated by Severn Trent Water Ltd. (STW), UK. It treats surface-water using the process outlined in Fig. 1. On the 14th March, 1st April and 12th April 2013 there were 1 L coliform failures from samples at WTW-B collected as part of a water quality survey. Despite extensive investigations, STW have been unable to determine the cause(s). This is the outcome for approximately two thirds of all bacteriological failure investigations (UK Water Industry Research, 2009; Ellis et al., 2013). Since no cause could be identified, these failures were selected for the data analysis in this work. The supply network for WTW-B is extensive and it is important to STW to determine the causes of these non-compliances so that they can protect their consumers. This paper analyses data from 1st January to 31st May (accounting for all three 1 L coliform detections) and for the week 9th to 15th April (focusing on the third 1 L coliform failure) to assess the utility of the analytical methods at both scales.

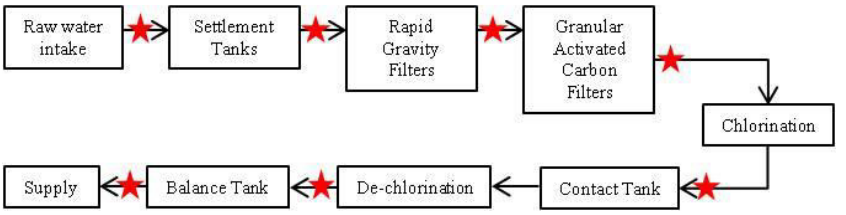

Fig. 1: Process flow diagram for WTW-B; ★ marks the location of the on-line monitors and spot-sampling points.

Data were available throughout WTW-B (Fig. 1), from raw water through to final water. The aim of this study was to see whether through-plant data could identify a time lag which enables operators to act to prevent future bacteriological failures.

Nomenclature

CFU	colony forming units
FTU	formazin turbidity units
GAC	granular activated carbon
NTU	nephelometric turbidity units
RGF	rapid gravity filter
SOM	self-organising map
STW	Severn Trent Water Ltd.
WTW	water treatment works