Drinking Water Contamination Detection by On-line Monitoring: Pilot Scale Studies

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INTRODUCTION

Drinking water (DW) supply systems are vulnerable to deliberate and accidental water contamination events. Modern drinking water DW quality monitoring methods and accessibility to them have indicated that DW quality contamination events are still an issue all over the world. According to the data, in average 1906 accidents per year, related to DW contamination, occurred in China (Liu et al., 2015). Contamination events with high impact on society were detected in the USA, e.g., the spill containing crude 4-methykcyckihecabenethanol in 2014 contaminated the Elk River and influenced water supply to 300 000 consumers (Liu et al., 2016). Moreover, at least 400 000 people were affected from distribution of pathogens (Corso et al., 2003) during the outbreak reported in Milwaukee in 1993, which led to hundreds of hospitalizations and even deaths. Serious chemical contamination have been reported in Europe, for instance ammonia spillage in Tel Aviv (Israel) in 2001 (Winston et al., 2003) and contamination of aluminium sulphate in Camelford (UK) in 1988 (Clayton, 1989). A diversity of contamination events, their origin, and a need of reliable contamination detection systems were shown. On-line DW quality monitoring and early warning systems have been designed in order to warn the water utilities and consumers about the contamination events in DW supply system, and therefore to prevent possible contaminant exposure (Storey et al., 2011). The aim of this study was to evaluate the ability to detect various DW contamination events by on-line DW quality monitoring system.

MATERIALS AND METHODS

To evaluate the operation of on-line monitoring system, the pilot scale DW distribution network (PSDN) was constructed. PSDN is located in Riga Technical University (RTU) Water Research Laboratory at RTU campus. Water source – public DW supply system, water outlet – public sewer system. The PSDN consists of 200 m pipeline: material – PVC, inner diameter – 25 mm, total volume – 98.2 l. Hydraulic conditions: flow – 0.20 m^3/h, velocity – 0.1 m/s. The PSDN has 2 on-line DW quality monitoring points, one is installed after 100 m from connection to public DW supply system, the other one after 200 m (100 m after point 1). Each of monitoring points is equipped with temperature (T), electrical conductivity (EC), total organic carbon (TOC), chlorine ion (Cl-), oxidation-reduction potential (ORP) and pH sensors. Selection of the monitored parameters was described in the previous study (Dejus et.al 2015). On-line monitoring data period was 1 min. Adenosine triphosphate (ATP) and flow cytometry measurements (FCM) of total and intact cell counts were conducted with a time step of 5 and 10 min (depending on the phase of experiment) to monitor biological parameters. Five contamination scenarios were imitated – failure in DW treatment plant, groundwater intrusion in supply pipeline, DW supply and sewer system cross connection, deliberate contamination (artificial sample with initial *E.coli* total cell count 6.8 x 10^8 cells/ml), and prolonged DW retention time (simulated water stagnation events). 6.15 l of contaminants were added to the PSDN during each event in a way it resulted in 10 % (v/v) dilution in DW. Addition of contaminant lasted for 15 min and was repeated 3 times.

RESULTS

The results showed that both the on-line monitoring system and microbial analyses detected the contamination events. Reaction to contamination events are summarized in Table 1. From 7 measured parameters, 5 or 6 of them were able to detect changes of DW quality due to simulated contamination. During deliberate contamination event, it was detected by 4 methods (TOC was not recorded), where neither pH nor Cl^- showed any changes. Strong correlations were obtained between physico-chemical parameters and total and intact cell count: Pearson coefficient was 0,85 during groundwater intrusion simulation.

Table 1. Evaluation of contaminant detection by the set of sensors (A – monitoring station after 100 m, B – monitoring station after 200 m, 1 – contamination is detected, 0 – contamination is not detected, - sensor out of service

Scenario indicator	On-line monitoring					Analysis		Total
	TOC	pH	Cl	ORP	EVS	ATP	FCM	
Prolonged retention (B)	0	1	1	1	1	1	1	6/7
Prolonged retention (A)	0	1	1	1	1	1	1	6/7
Untreated water (B)	1	1	0	1	0	1	1	5/7
Untreated water (A)	1	1	0	1	0	1	1	5/7
Ground water (B)	1	1	0	1	1	1	1	6/7
Ground water (A)	1	1	0	1	1	1	1	6/7
Wastewater (B)	1	0	0	1	1	1	1	5/7
Wastewater (A)	1	0	1	1	1	1	1	6/7
Deliberate contamination (B)	-	0	0	1	1	1	1	4/6
Deliberate contamination (A)	-	0	0	1	1	1	1	4/6

CONCLUSIONS

- Strong correlations between physico-chemical and biological parameters during contamination events were obtained.
- Current set of sensors was able to detect various contamination scenarios, and could be used a tool for early warning system.
- Further studies are necessary to develop physico-chemical measurement system, which could substitute manual biological methods for contamination detection.

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