On-line monitoring of hygienic raw water quality at Oset drinking water treatment plant, Oslo

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Abstract

Two new on-line instruments were installed at the Oset drinking water treatment plant (Oslo). The purpose was to evaluate their suitability for monitoring hygienic raw water quality. Real-time measurement of the UV-VIS absorption spectrum (with a spectrolyser, S::can) was useful for monitoring physicochemical water quality parameters like UV_{254} and colour, and revealed interesting trends with regard to the response of the raw water, extracted from 35 m depth in lake Maridalsvannet, to weather conditions and season/turnover period. Such information is useful for optimisation and control of the water treatment process and therefore important for the hygienic water quality. *E. coli* was, however, sometimes detected without detectable changes in the UV-VIS spectrum, and when the turnover period started (autumn and spring) the response of the physicochemical parameters seemed to be delayed compared with sporadic occurrence of *E. coli*. The sensor was therefore not useful for direct monitoring of faecal pollution. Daily monitoring of *E. coli* by the on-line Colifast ALARM instrument, with a 15 hours delayed result, gave useful additional information compared with the weekly routine samples about the hygienic raw water quality under different weather conditions and seasons.

Keywords: On-line monitoring, *E. coli*, UV-VIS spectrum, raw water, drinking water

Introduction

Traditionally, the hygienic quality of raw water used for drinking water production is monitored by weekly or monthly samples, which are analysed for faecal indicator bacteria. When results from several years are available, these routine samples give a good indication of the level of faecal contamination in the raw water and of seasonal and annual variation. Such information, combined with microbial risk assessment, is important for determining sufficient water treatment and disinfection to ensure safe drinking water. Weekly samples, however, do not necessarily reflect the deterioration of the raw water quality during acute pollution episodes, e.g. caused by heavy rainfall and wind. Such information may be important for the optimization and control of the drinking water treatment plant.

An "ideal" method for monitoring hygienic drinking water quality is simple, but also sensitive (e. g. detect 1 *E. coli* per 100 ml) and specific (does not detect non-target/harmless substances, including non-viable cells). The water quality is measured at-line (no need for manual water collection and analysis), and the measured data is available continuously without delay (in "real time" or within a timeframe that allows corrective actions to be taken). Such an "ideal" method does not exist; all methods seem to compromise one or several of the criteria above. Standard methods for detection of faecal contamination in drinking water, which are based on growth of faecal indicator bacteria on selective media, are done manually in laboratories and require 18-72 h before the result is available. Automated methods for detection of *E. coli* exist, but still need up to 14 hours for detection of 1 *E.*

coli/100 ml (James *et al*., 2011). Methods based on molecular detection are being continuously improved and are now reported to be sensitive enough for routine monitoring of drinking water quality (Maheux 2011), but the development of on-line sensors based on molecular detection is difficult, as well as the differentiation between viable and dead microbes. Measurement of surrogate parameters, like ATP, has been suggested (Hammnes 2010), but is not specific for faecal contamination.

Field instruments for continuous measurement of absorption spectrum reaching from the low UV to visible light have been shown to be promising for real time monitoring of physicochemical water quality parameters like UV_{254}, colour and TOC. Such methods are simple and generate large amounts of water quality data without use of chemicals. Since microbial pollution may be associated with rainfall and runoff that also include leaching of organic matter from the surface and soil (e. g. humic substances and other compounds that absorb UV- and visible light), the spectral absorption coefficient at 254 nm has been suggested as a real-time early warning proxy for detecting faecal pollution events (Stadler *et al*., 2010).

The purpose of this study was to obtain increased knowledge about the presence of *E. coli* in raw water extracted from lake Maridalsvannet under different weather conditions and seasons, and to investigate the feasibility of methods based on measurement of UV-VIS absorption spectrum for real-time monitoring of hygienic raw water quality. The project is still on-going, and some preliminary results are presented here.

Study area and methods

The lake Maridalsvannet is the main drinking water source for the city of Oslo. The lake has a surface area of 3.7 km^2, medium depth 19 m and maximum depth 45 m. The raw water is extracted from about 35 m depth and is treated by alkalisation, chemical precipitation, sedimentation, filtration and UV-disinfection at the Oset drinking water treatment plant (WTP). About 1500 people live in the catchment area, and their black water is collected in closed tanks and grey water is treated locally. There are about 100 horses in the catchment area, but few other farm animals. It is a popular area for recreation (including dogs), but bathing and camping are not allowed in or near the lake and tributaries. Wild birds and animals may contribute to faecal pollution.

The hygienic raw water quality at Oset WTP was monitored by the weekly routine analysis of faecal indicator bacteria and parasitic protozoa (Husebø and Kjøglum, 2013). A Colifast ALARM instrument was installed for daily monitoring of the presence-absence of *E. coli* in 100 ml raw water. The results were available 15 hours after the samples were taken and increased *E. coli* levels can generate an early warning result from 6 hours. A spectrolyser (s::can, distributed by Pemac AS, Norway) was installed for continuous (every 10 minutes) measurement of the UV-VIS absorption spectrum (220 nm-720 nm) of the raw water. After calibration the sensor was used for monitoring colour, UV_{254} and total organic carbon (TOC). The temperature of the raw water and surface water was continuously logged by the WTP. Turnover (circulation) period was defined as the period when the difference between the temperature of raw water and surface water was less than 1 °C.

Results and discussion

The winter 2013 was cold and lake Maridalsvannet was covered with ice in January and until 7th of May 2013. No *E. coli* were detected in this period, neither by the routine weekly samples taken by the WTP or with the daily samples taken by the ALARM instrument (Figure 1). The temperature measurements of raw water and surface water indicated spring turnover in the lake from 7th of May until 17th of May 2013. The ALARM instrument detected *E. coli* 16th and 18th of May, but no *E. coli* was detected by the routine samples during the spring.

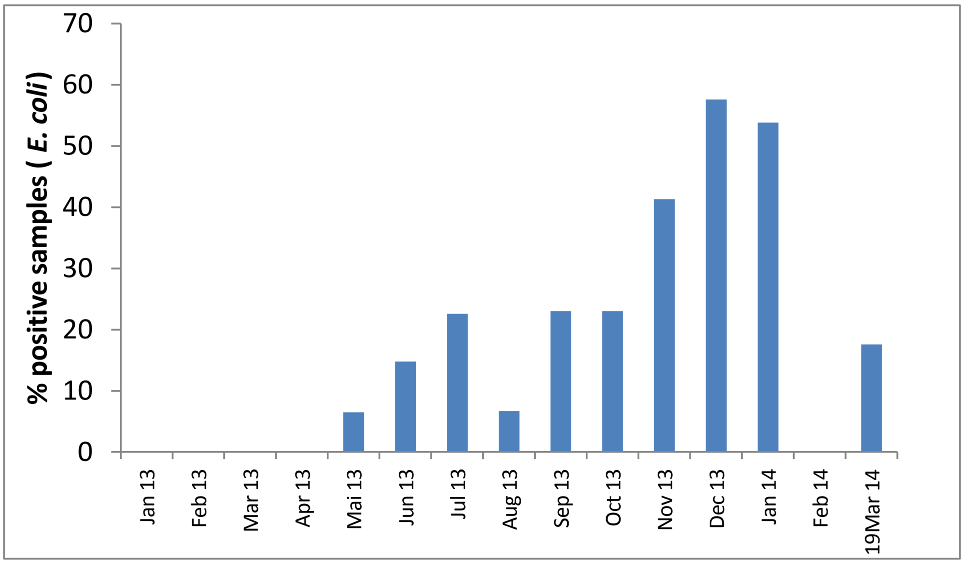

Figure 1 Detection of *E. coli* in the raw water (Oset WTP) by Colifast ALARM in the period January 2013 to March 19th 2014.

During the summer 2013, *E. coli* was detected once by the routine testing, 1 *E. coli*/100 ml on the 15th of July. The ALARM instrument confirmed that this was not an isolated incident, i.e. *E. coli* was detected 7 times during the warm and dry days in July, with stable temperature stratification in the lake. It is assumed that birds (mainly gulls, ducks and geese) located near the water intake are the sources of *E. coli* in the raw water during the dry summer days.

Temperature measurements indicated autumn turnover in the lake from about 27th of October 2013 until the lake was covered by ice 11th of January 2014. In this period ALARM detected *E. coli* in about 50% of the samples. The weekly routine testing detected *E. coli* 30th of September, 28th of October, 4th of November and 27th of December, with 2, 1, 3 and 2 *E. coli*/100 ml respectively. Also *Giardia* and *Cryptosporidium* were analysed by weekly samples in the reported period. 1 *Giardia* cyst/10 L was detected 14th of October and 2 *Giardia* cysts/10 L was detected 21st of October, i.e. 1-2 weeks before the temperature measurements indicated autumn turnover and not exactly at the same days as *E. coli* was detected.

The winter 2014 was much warmer than the winter 2013. The lake was not covered by ice before in the middle of January and the ice disappeared already 7th of March 2014, i.e. 2

months earlier than in 2013. Contrary to 2013 when no *E. coli* were detected during the first 4 months, *E. coli* was detected in >50% of the samples in January 2014 and thus far in several samples taken in March. The routine testing also detected 1 *E. coli*/100 ml in one sample in February.

Data from measurements of colour and TOC by the Spectrolyser, were available from August 2013. The measurements indicated a decrease in colour (from about 27 to 23 mg Pt/l) and TOC (from about 4.4 to 4.1 mg/l) during the summer with a minimum before the autumn turnover in the middle of October. During the autumn turnover the colour and TOC then increased again (Figure 2). Little precipitation was observed in November, which may explain the relatively low increase in colour and TOC this month. A significant increase in colour and TOC was observed from about 20th of December 2013 to 7th of January 2014, which was a wet period, i.e. about 100 mm precipitation was observed at Blindern weather station (www.yr.no). During the following period with ice cover the colour and TOC decreased, but a significant increase was again observed during the spring turnover that started the first week of March (Figure 2). The significant increase in colour and TOC during the spring turnover this year may be explained by much precipitation the first 8 days in March (about 50 mm) and more precipitation than normal in February (about 130 mm), combined with snow melting.

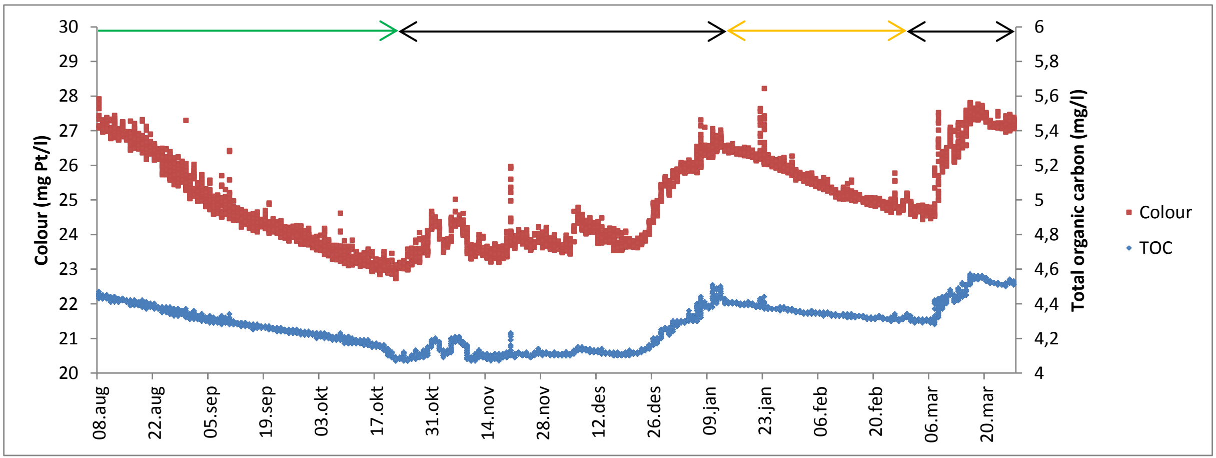

Figure 2 Colour and total organic carbon (TOC) in the raw water (Oset) measured with the spectrolyser (s::can) in the period 08.08.2013 – 27.08.2014. Black arrows show the periods when temperature measurements indicated water turnover, orange arrow show the period with ice cover and green arrow shows summer stratification.

Conclusions

On-line, real-time measurement of UV-VIS absorption spectrum was considered useful for monitoring physicochemical water quality parameters like UV_{254}, colour and TOC, but cannot be used for direct measurement of faecal pollution. Further work will be performed to evaluate whether the spectra may detect changes in the composition of the organic matter, e.g. with regard to bioavailability. Daily monitoring of *E. coli* by the on-line Colifast ALARM instrument, with a 15 hours delayed result, gave useful additional information compared with the weekly routine samples about the hygienic raw water quality under different weather conditions and seasons.

Acknowledgement

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