Real-time monitoring technologies for indicator bacteria, pathogens and viruses in critical buildings like hospitals.

The integrity of well managed distribution systems in water companies and critical buildings is one of the most important barriers that protect drinking-water from contamination and spreading of diseases. However, management of distribution systems often receives too little attention. There is extensive evidence that inadequate management of drinking-water distribution systems has led to outbreaks of illness. The causes of these outbreaks and the range of chemical and microbial hazards involved are diverse. The most common causes of illness were enteric pathogens, including bacteria (Salmonella, Escherichia coli O157), protozoa (Cryptosporidium, Giardia) and viruses (Norovirus) (Fig. 1)

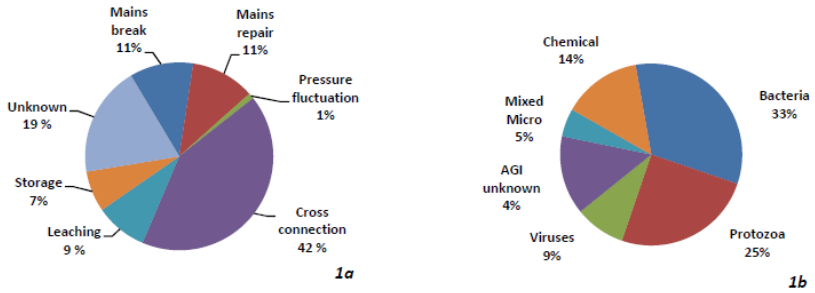

Fig.1 Waterborne outbreaks associated with distribution systems in the USA, 1981–2010, by (a) system fault and (b) causative agent. Water Safety Distribution Systems 2014-WHO.

The presence of faecal pathogens is assessed by monitoring for indicator bacteria. The WHO (World Health Organization) Guidelines for Drinking-water Quality (WHO, 2011) recognizes E. coli as the indicator of choice, although thermotolerant coliforms or enterococci can be used as an alternative.

The counting of bacteria in water has been a critical element in protecting public health in the last century. In the early part of the previous century scientists were able to grow many species of bacteria and differentiate them from each other using biochemical tests. They also had observed that certain bacteria were always found in the faeces of humans and other warm-blooded animals and that significant disease was also associated with faecal wastes. This association was recognized early on by the scientists who were the fore-runners of our present-day public health scientists.

The common factor to counting bacteria is the requirement for cell multiplication to occur over a sufficient period of time, so they can be easily observed. Standard methods like quantifying colonies takes three days after sampling and is far too slow to be applicable as a warning system for possible incidents. Online detection of such incidents by high frequency monitoring, e.g. the (enzymatic) activity of bacteria, is cause for further action, including fast (inline) sampling to assess the exact nature of the incident.

It is frequently important to know if the pathogens being measured are viable and therefore able to cause infections. Enzymatic methods, like which is used in the BACTcontrol (see Fig.2) on the other hand, do measure viable microbes. Therefore, the estimates of bacterial densities in water samples by this methods is more likely to be comparable to those obtained with cultural methods.

Fig.2 BACTcontrol in operation

Water Safety Plans for water companies and highly critical buildings like hospitals

Water safety and quality should primarily depend on the protection of sources, operation and continuous microbiological monitoring, the structural integrity of treatment and distribution systems, and hygiene during manual operations. The design and control of all parts of the system

(infrastructure, automation and manual operations) should be validated by applying scientific methods and critical control monitoring. The WHO has described the outlines of a safety system – Water Safety Plans – which drinking water companies and critical buildings can apply. Continuous and online testing the provided quality is considered a verification step which can protect consumers. By the time standard laboratory tests are completed and results indicate the water is not safe to drink; people may have already consumed the water, get infected, develop illness or worse. The WHO guideline Water Safety in Buildings (Fig.3), provides guidance for those responsible for managing water supply systems in buildings on applying the WSP approach to improve risk management and ensure water safety is maintained within the buildings like hospitals.

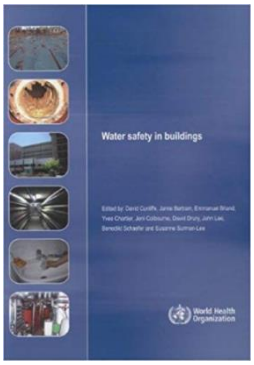

Fig.3 WHO 2011

The time between sampling and the result of a standard analysis is too long (>24 h to days) for 'off-line' analysis to be an effective safety system. Problems also occur due to sample transport, storage and pre-treatment. When online monitors like the BACTcontrol are applied, the consumers, patients and hospital personal is still not fully protected (the product has already been consumed), but the time between contamination and response can be limited considerably. Furthermore, these online systems provide a powerful tool for evaluating the effectiveness of processes in water treatment and distribution throughout the critical buildings like hospitals.

Using the BACTcontrol to monitor and maintain the microbiological quality

Online bacterial enzymatic monitoring can be used as a meaningful process variable that may improve and speed-up the detectability of incidents which impair microbiological water quality and safety. The BACTcontrol can rapidly detect *E.coli,* total coliforms, enterococci or the total microbial activity in a continuous or laboratory setup to increase protection as early warning of contaminations.

Examples where the BACTcontrol was used to protect people for diseases like viruses:

- A capital city in Eastern Europe suffered from a norovirus contamination. The BACTcontrol was use to quickly detect the source of the contamination in the distribution network
- A big utility in Southern Europe uses the BACTcontrol to monitor the effect of the final disinfection to protect users of their supply water
- It was used by the UN army to protect the water for soldiers against microbiological contaminations during a peace keeping mission in Africa.

In the international press the Corona virus has already been related to faecal pollution:

- 2019-nCoV has been reported elsewhere in the faeces of patients with atypical abdominal symptoms, similar to SARS which was also shed in urine, suggesting a faecal transmission route which is highly transmissible
- In the recent findings from Shenzhen third people's hospitals raise the possibility of faecal-oral transmission after researchers found genetic traces of coronavirus in patient's stool samples.

Some conclusions for using the BACTcontrol, it offers:

- Flexibility: the system can be used for both important faecal indicators (e.g. E. coli, coliform and enterococci) as well as process parameters (total bacteria contamination)
- Added value: this method can be used to create a fingerprint to show the log-removal of different disinfection steps and also after a contamination happened.
- Automation: fully automated online monitoring offers unique perspectives with respect to increased security and protection of the public.
- Water Safety: it can detect episodes of operational stops and switching procedures between water and treatment types
- Microbial Monitoring & Protection: its measures the enzyme activity only of living and active cells.

Overall it can be said that the BACTcontrol can be used as an early warning monitor when upstream disinfection steps show failures and in this way, can contribute to the microbiological quality of the treated water and the safety and protection of the patients, visitors and hospital employees.