Demonstration of water deterioration model in distribution network in Eindhoven

Demonstration Report

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COLOPHON

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Contents

1 INTRODUCTION

Current drinking water distribution systems (DWDS) will encounter higher temperatures as a result of climate change (IPCC, 2013). This will influence the the composition of the bacteria population in the drinking water. A shift will take place in the species that are present in the drinking water and in the biofilm. Moreover, opportunistic or pathogenic organisms can develop in the drinking water at higher temperature, causing potential health risks (van der Kooij and van der Wielen, 2013). These issues are also relevant in countries that use disinfectants to control microbiological water quality, since the biofilm protects organisms from chlorine and chlorine decay increases with temperature. Therefore an increased need is observed globally to monitor water quality at the right locations and time in distribution systems to ensure safe drinking water. As part of the PREPARED project a model was developed to predict weather impact on water quality and the effect on microbial growth in the distribution system that allows to model the impact of changing weather patterns due to climate change. The model was demonstrated in the city of Eindhoven, the Netherlands together with the Brabant Water water supply utility. Brabant Water provided the distribution network model and general demand patterns. KWR provided the water quality modelling using simulated detailed water demand, GIS data on land use and predicted weather patterns under climate change. The Brabant Water performed water quality testing and provided historical water quality data.

The demonstration in Eindhoven consisted of a virtual simulation of predicted growth of three types of bacteria with different growth rates under increasing temperature conditions and comparing predictions for the current situation to measurements of *Aeromonas* as an indicator of microbial growth.

2 FINDINGS

2.1 Model description

The model combines the EPANET hydraulic flow model with the SIMDEUM water demand model, GIS models to predict the soil temperature around the distribution system based on weather data and soil conditions and a temperature model in EPANET MSX (Blokker and Pieterse-Quirijns, 2013). The bacterial growth model of Rubulis et al.(2007) considers all relevant processes including free bacteria in the bulk water, attached bacteria (biofilm) on the inner surface of the pipe wall, transformation between free and attached bacteria and bacterial growth rate based on biodegradable organic carbon concentration and temperature (Figure 2-1). Testing showed that this model was too complex and contained many unknown variables to be used for predictions (Blokker et al. 2014).

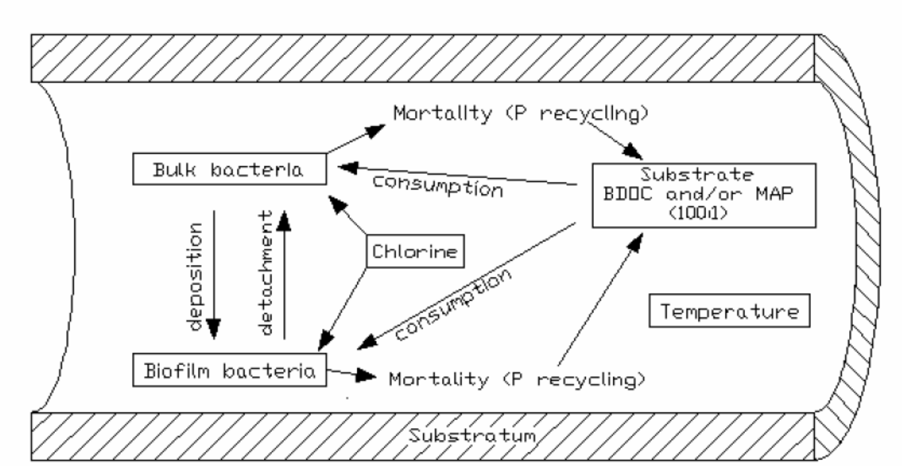

Figure 2-1: Schematic presentation of processes in the microbial growth model (Rubulis et al., 2007).

A simplified growth model was applied for microorganisms, for which growth is only dependent on temperature using three different growth curves (Figure 2-2). The model provides a qualitative prediction of the rate of microbial growth in the network (Blokker et al. 2014).

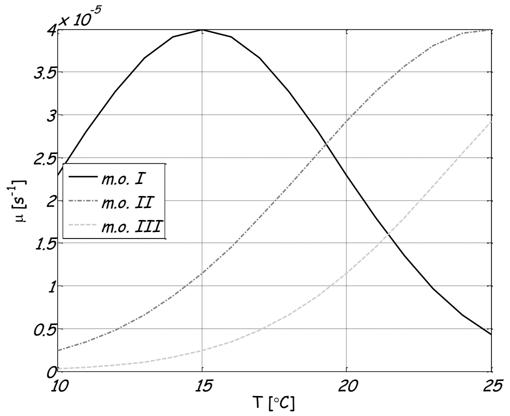

Figure 2-2: Bacterial growth rate for the 3 virtual microorganisms over the assumed temperature range

2.2 Results

As an illustration, the predicted evolution of the drinking water temperature and the three virtual microorganisms are shown in Figure 2-3 at one node in district A and one node in district B. The figure shows that in district B the amount of microorganisms is higher than in district A. Due to the higher residence time of the drinking water at comparable temperatures, the microorganisms had more time to develop. The development of the microorganisms also varies with the temperature dependent growth characteristics of each bacteria. Moreover, the figure shows that both drinking water temperature and number of microorganisms depend on demand. The drinking water temperature varies with demand: after the morning peak demand the temperature of the drinking water decreases. The amount of microorganisms appears also to decrease. During the afternoon, at lower demands, the predicted number of microorganisms is higher.

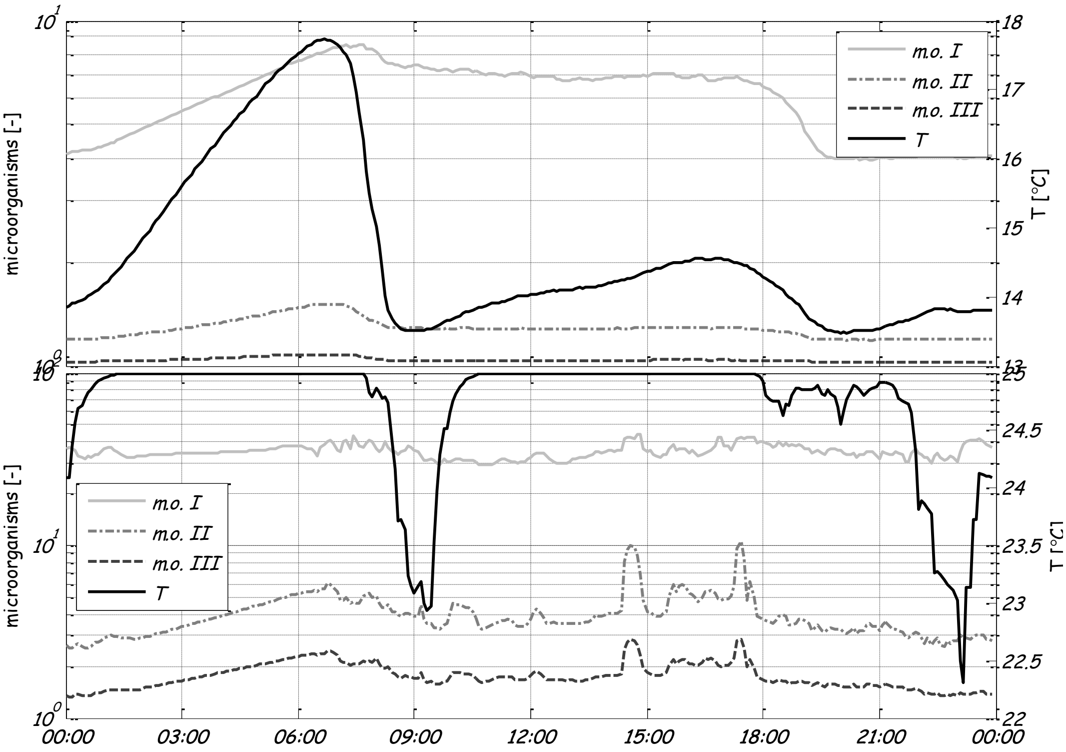

Figure 2-3: Model results: number of virtual microorganisms I-III and temperature in one measurement location in district A (top) and one in district B (bottom).

At five locations in district A and B of Eindhoven, the number of *Aeromonas* as well as the temperature of the drinking water were measured. The model gave a good qualitative prediction of the *Aeromonas* activity in district A and B. In district B a higher number of *Aeromonas* was predicted and measured, in district A barely any bacteria were predicted and measured. The predicted drinking water temperature deviated less than 1°C in average from the measured values. This is less than the variation in temperature over the day. There is also a large variation in predicted drinking water temperature, depending on the location in the network and on the demand. A higher drinking water temperature did not automatically mean a higher number of microorganisms. Moreover, large variations in temperature on a location did not correspond with large variations in predicted number of bacteria.

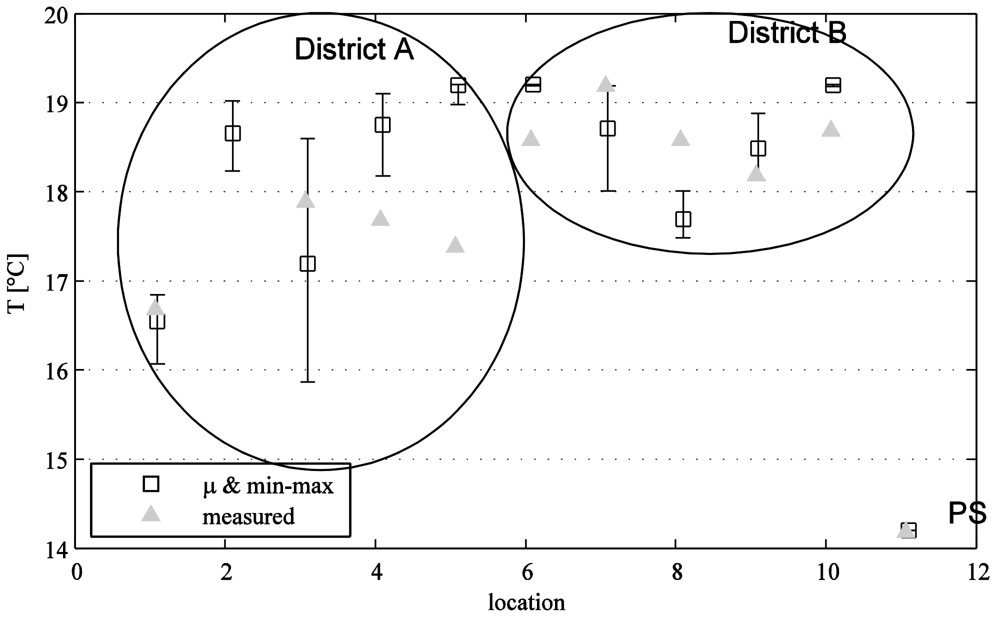

Figure 4 Measured and predicted drinking water temperature at five locations in district A and five locations in district B (between 9:00 and 12:00 am).

3 CONCLUSIONS AND RECOMMENDATIONS

The model results show that the predicted temperature and number of microorganisms at each location in the DWDS is highly dependent on the customer's demand. The modelling of residence time on detailed level, using the stochastic demand patterns on connection level is necessary to get a realistic insight in residence times. The predictions vary during the day and between different days. Therefore, a qualitative prediction of the microbial activity at each node is the highest possible accuracy that can be achieved with a model .

Temperature of the soil is dependent on the ambient temperature. With good weather forecasts the temperature model is also applicable in present daily practice. With an accurate weather forecast of 7-14 days, hot spots can be anticipated on the same timescale. This enables pro-active measuring campaigns and consequential actions like local booster chlorination. The results illustrate that conclusions based on measurements of bacteria, like *Aeromonas*, might be highly unreliable due to the high variations. This information is essential in developing and testing of measurement programmes. Current sampling programmes should be reconsidered. With the new measuring methodology of Continuous Biomass Monitoring (CBM) the criticality of combinations of residence times and temperature can be explored.

The model for microbial water quality in drinking water networks developed within PREPARED can be used by water companies as an early warning system to anticipate the effect of the changes in temperature due to climate change and changes in future water demand on the microbial water quality and to identify hot spots in the network. The model is applied by Brabant Water to further explore the potential hot spots in the network and to support decisions in extra steps in treatment as a remedial action to prevent hot spots. With a better quality at the treatment, the criticality of combinations of residence time and temperature will be extended. Booster chlorination is not considered as a remedial action by Brabant Water since chlorination isn't applied in the first place.

4 REFERENCES

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