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Reinterpretation of Water Temperature Measurements †

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Abstract: Drinking water temperatures above 25 °C have been measured more often since Dutch drinking water companies are required to take Random Day Time (RDT) samples. The objective of this study was to obtain more information from the required temperature measurements. A total of 34,595 drinking water temperature measurements between 2012 and 2021 were analyzed and compared with the temperature prediction from a soil temperature model (STM), developed by Blokker and Pieterse-Quirijns (2013) and Agudelo-Vera et al. (2015). More than 300 exceedances of the modeled urban soil temperature were found (ca. 1%). While there were only four measurements with temperatures higher than 25 °C. By looking at the locations of the temperature exceedances, drinking water companies can further investigate whether there are other heat sources near these locations. Using the STM calculations as a reference for the measured drinking water temperature has provided more options for locating hotspots.

Keywords: drinking water; temperature; soil temperature model

1. Introduction

In the Netherlands, chlorine as a residual disinfectant is not used in drinking water. Therefore, the water temperature is an important indicator of water quality, and the Dutch drinking water decree sets the maximum temperature of drinking water at the tap to 25 °C. With increasing extreme weather events and urbanization and the urban heat island effect, temperature exceedances are expected to increase [1]. Drinking water above 25 °C has been measured more often than before, and drinking water companies are required to take Random Day Time (RDT) samples. However, the number of exceedances from the dataset being analyzed in this study, four exceedances since 2012, is too limited to locate risk areas. In this study, temperature measurements from one of the drinking water companies in the Netherlands were analyzed and compared with the temperature prediction according to the soil temperature model (STM) [1,2]. The aim of this study is to have better insight on how the RDT temperature measurements can be better interpreted, given the environmental factors of the measurement locations.

2. The Soil Temperature Model

Blokker and Pieterse-Quirijns [1] developed a micrometeorological model to predict soil temperature at different soil depths based on weather and environmental conditions. Agudelo-Vera et al. [2] then expanded this micrometeorological model by including urban evaporation, anthropogenic heat emissions, and the heat storage capacity of buildings. The soil temperature has been simulated under different conditions, based on shade condition, type of paved surface, and soil type.

The weather conditions data from KNMI [3] constitute important information for modeling the soil temperature. The following data from the nearest weather station were

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used for the soil temperature model: date and time; temperature (in °C) at a height of 1.50 m during the observation (T_{atm}); hourly average wind speed (in 0.1 m/s); cloud coverage during the observation (0–1; 9 = upper sky invisible); global radiation (in J/cm^2) per hour (R_g); wind direction (in degrees) averaged over the last 10 min of the past hour (360 = north, 90 = east, 180 = south, 270 = west, 0 = calm, 990 = variable); relative humidity (in %) at a height of 1.50 m during the observation (R_H); and hourly sum of precipitation (in mm) (−0.1 for <0.05 mm) (P_p).

The soil temperature is calculated under various urban types, pavement types, and shade conditions. The urban type influences the anthropocentric heat source from buildings, Q_F. The type of pavement influences the heat storage coefficient, a_3. The shade condition influences the percentage of the global radiation (R_g) reaching the ground surface. Some of the parameters used in this study are as follows; Peri urban, $Q_F = 50$, $a_3 = -50$, grass = 1; Urban grass, $Q_F = 100$, $a_3 = -100$, grass = 1; Urban $Q_F = 100$, $a_3 = -100$, grass = 0; Hotspot, $Q_F = 150$, $a_3 = -150$, grass = 0; No shade = 100% R_g; partial shade = 50% R_g; and full shade = 0% R_g.

3. Analysis of Measured Drinking Water Temperature and Predicted Soil Temperature

34,595 temperature measurements from the water utility, measured between 2012 and 2021, were analyzed and compared to the soil temperature prediction according to the soil temperature model, calculated based on the weather data from the closest weather station. Figure 1 shows the measured temperature and the result of the soil temperature prediction based on the STM and data from the nearest weather station.

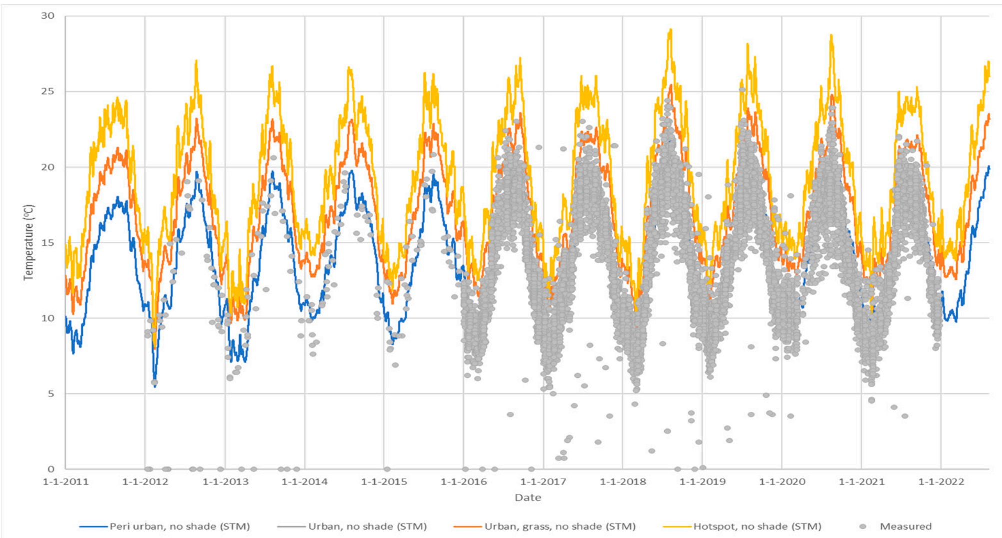

Figure 1. Measured temperature vs. prediction according to soil temperature model (STM) for the influence area of the nearest weather station.

Figure 1 shows that the measured temperature is the closest to the prediction of the STM scenario 'peri urban'. The average Mean Absolute Error (MAE) between the measured temperature and the prediction of the STM scenario 'peri urban' is 1.3 °C (Table 1). 55 temperature measurements (0.16%) are higher than the temperature prediction according to scenario 'urban'. 361 temperature measurements (1.04%) are higher than the temperature prediction according to scenario 'urban'.

Table 1. Mean Absolute Error (MAE) between measured temperature and the soil temperature prediction according to the soil temperature model (STM).

Influence Area Weather Station	MAE Peri Urban	MAE Urban	MAE Hotspot
A	1.2	3.5	5.6
B	1.4	3.6	5.6
C	1.4	3.9	6.0
D	1.2	3.7	5.8
E	1.4	3.9	6.0
Average	1.3	3.7	5.8

Figure 2 shows that the number of temperature measurements that are higher than the 'urban' scenario is highest in the summer months (May–September). The temperature measurements in the summer months that are higher than the 'urban' scenario show the effect of high atmospheric temperatures on drinking water temperature.

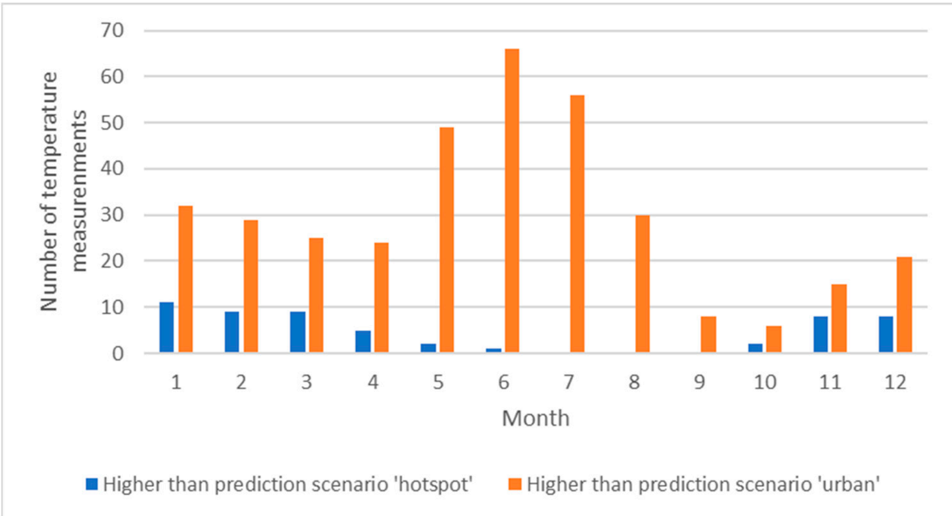

Figure 2. Number of temperature measurements higher than the prediction according to STM.

For the 'hotspot' scenario, the exceedances are highest during the winter months (November–April), and absent during the summer months (July–September). High temperatures (>20 °C) were measured, while the maximum temperature according to STM scenario 'hotspot' is approximately 15–17 °C. Temperature measurements in the winter months that are much higher than the 'hotspot' scenario suggest that there is a factor other than the weather that influences the temperature of the drinking water.

Based on this information, the drinking water companies can further investigate whether there is indeed another heat source (hotspot) near the drinking water pipe. The locations of the temperature exceedances were then checked by the water utility. Some factors that might be the reasons for the higher temperature are: the location of temperature measurement is in the industrial area; high water residence time; and the presence of another heat source in the environment.

4. Conclusions

More than 300 exceedances with respect to the expected temperatures, based on the soil temperature model were found in 34,595 measurements between 2012 and 2021. Temperature measurements in the winter months that are much higher than the 'hotspot' scenario suggest that there is a factor other than the weather that influences the temperature of the drinking water. The comparison of the measured drinking water temperatures to the results of the soil temperature model has provided a method for locating potential hotspot locations and other deviations.

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