New method to design domestic water systems

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Introduction

In the last decades, we have gained insight in the water use of residential and non-residential buildings. However, until recently, Dutch guidelines on design of drinking water installations were based on measurements carried out between 1976 and 1980 and there were no guidelines for the hot water design. As a result, suppliers of heating systems use company specific guidelines. **Figure 1** shows an overview of the use of guidelines for the design of water systems in the Netherlands

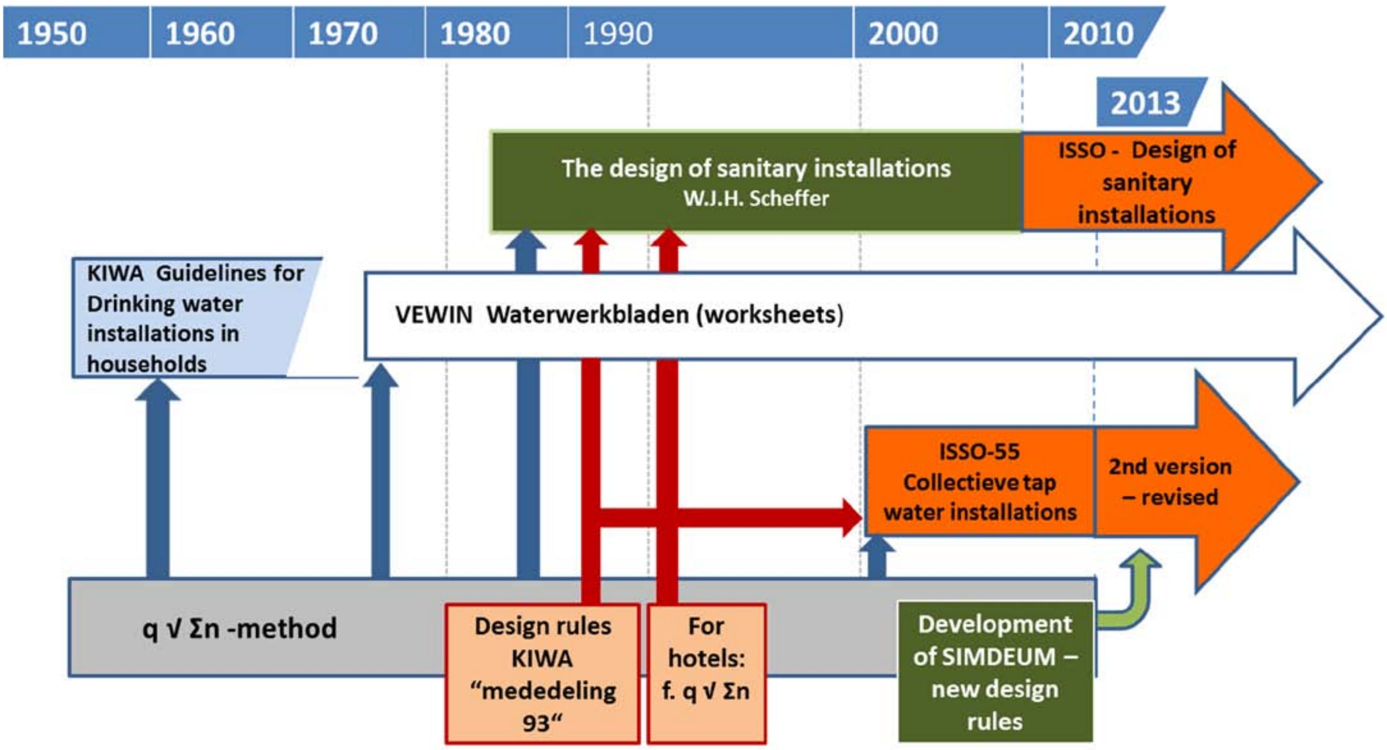

Figure 1. Overview of available methods and guidelines for the design of water systems in the Netherlands.

for residential and non-residential buildings. The old approach was no longer suitable for the current situation due to the increasing range of available appliances in the market and to changes in the behaviour of building occupants. In general, old guidelines overestimated the peak demand values. These peak values are crucial for the optimal design of the water system. Badly designed systems are not only less efficient and therefore more expensive, but can also cause stagnant water, possibly leading to increasing health risks.

Although updating the guidelines represented a major challenge, in the long run it represented a win-win-win situation for the customers, the environment and the installation sector. Since 2002 KWR Watercycle Research Institute and the Dutch installation sector (Uneto-VNI, TVVL and ISSO) worked on developing new design rules for non-residential buildings not based on measurements, but based on simulations performed with SIMDEUM.

Predicting cold and hot water use patterns with SIMDEUM

SIMDEUM stands for "**SIM**ulation of water **D**emand, an **E**nd-**U**se **M**odel." It is a stochastic model based on statistical information of water appliances and users (Blokker et al., 2010). SIMDEUM models water use based on people's behaviour, taking into account the differences in installation and water-using appliances. This means that in each building, whether it is residential or non-residential, the characteristics of the present water-using appliances and taps (i.e. flow rate, duration of use, frequency of use and the desired temperature) are considered as well as the water-using behaviour of the users who are present (i.e. presence, time of use, frequency of use), see **Figure 2**.

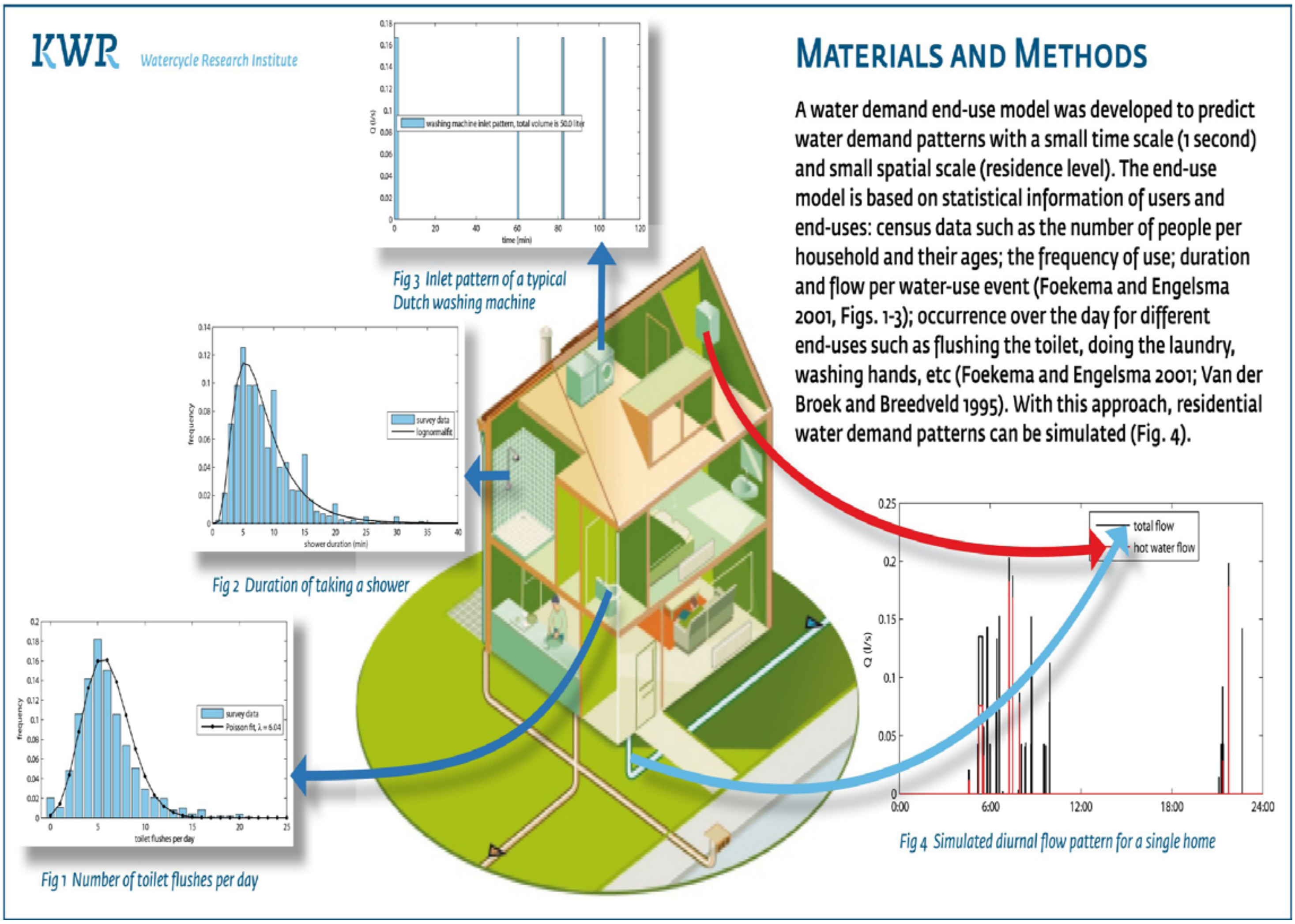

Figure 2. Schematic representation of the simulations with SIMDEUM.

SIMDEUM for non-residential water demand follows a modular approach. Each building is composed of functional rooms, characterised by their typical users and water using appliances (Blokker et al. 2011). With this approach, water demand patterns over the day for cold and hot water demand can be simulated for a specific non-residential building. From these daily water demand patterns, the characteristic peak demand values of cold and hot water during various time steps were derived. These characteristics form the basis for the new design guidelines of 2013.

Deriving new design rules using "design-demand equations"

For the design of the drinking water distribution system, the peak value of the total water demand, the instantaneous peak demand or maximum momentary flow (MMF_{cold}) is essential (Loureiro et al., 2010; Blokker and van der Schee, 2006). Additionally, the peak demand of hot water, i.e. maximum momentary flow (MMF_{hot}) and the hot water use (HWU) in different time periods is required to select the correct type of water heater as well as the design capacity of the hot water device. In 2010, a procedure was developed to derive design-demand equations for the peak demand values of both cold and hot water for various types of non-residential buildings, i.e. offices, hotels and nursing homes (Pieterse-Quirijns et al., 2010).

The aim of the design-demand equations is to predict the peak demand values (MMF_{cold}, MMF_{hot} and HWU in different time periods) for various types and sizes of buildings. The new design-demand equations predict the peak demand values as a function of the most important (dominant) variable. The dominant variable for hotels is the number of rooms, which can be occupied by 1 or 2 guests, depending on the type of hotel, for offices is the number of employees and for nursing homes de number of beds.

For a specific value of the dominant variable, a standard building was constructed, i.e. each functional room is equipped with appliances and users. For this purpose, the number of appliances and users is established as a function of the dominant variable for each type of non-residential building. From 100 stochastic demand patterns simulated with SIMDEUM at different values of the dominant variable, the peak demand values were derived, i.e. maximum momentary flows (MMF_{cold} and MMF_{hot}) and the maximum hot water use (HWU) for different time periods: 10 minutes, 1 hour, 2 hours and 1 day.

These peak demand values and the HWU for several buildings could be described by simple linear relations as a function of the dominant variable. These linear relations form the design-demand equations.

Test and validation of the "design-demand equations"

The validation of the new design rules was performed in two steps. The first step focused on validating the assumptions of how to standardize the buildings, using the functional rooms. This was done with measurements and surveys. Cold and hot water diurnal demand patterns were measured (in seconds) for three categories of small-scale non-residential buildings, viz. offices, hotels and nursing homes. The surveys gave information on the number and characteristics of users and appliances, and on the behaviour of the users, like the frequency of toilet use, or the use of coffee machine. Comparison of the surveys with the standardized buildings showed that the assumptions of the number of users and their water using behaviour as well as the number of appliances correspond with the surveyed buildings. Comparison of the simulated water demand patterns and the measured patterns showed good correlation. This good correlation indicates that the basis of the design-demand equations, the SIMDEUM simulated standardised buildings, is solid. The results for a business hotel are presented in **Figure 3**, showing the measured and simulated cold and hot water flow.

The second step focused on validating the design-demand equations by comparing the simulated and measured peak flows. For hotels, the derivation of peak demand values from the measured water demand patterns was especially difficult, due to the varying occupation of rooms. However with the proposed method, the MMF_{cold} can be predicted fairly well. **Figure 4** shows the comparison of measured and simulated peak flows and compares them with the old guideline (Scheffer, 1994) and with the original $q\sqrt{n}$ -method. The MMF_{cold} and MMF_{hot} can be predicted fairly well. The studies showed that the old guidelines overestimate the MMF_{cold} with 70–170% for hotels, resulting in too large heaters.

Consequences for design of distribution systems and heating system

The new SIMDEUM based design-demand equations lead to a better estimation of the MMF_{cold} than with the old guidelines. Moreover, the pattern of water use of different building types can be easily determined using the functional rooms.

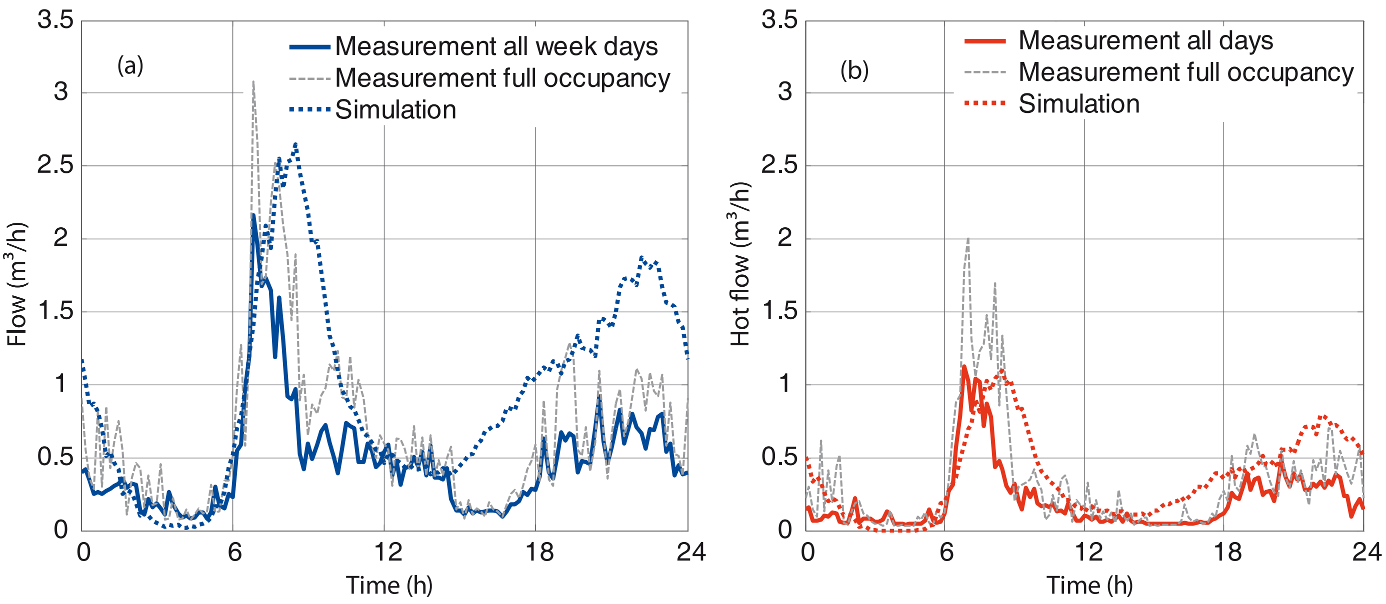

Figure 3. Comparing average measured and simulated demand of a) cold water and b) hot water of a business hotel.

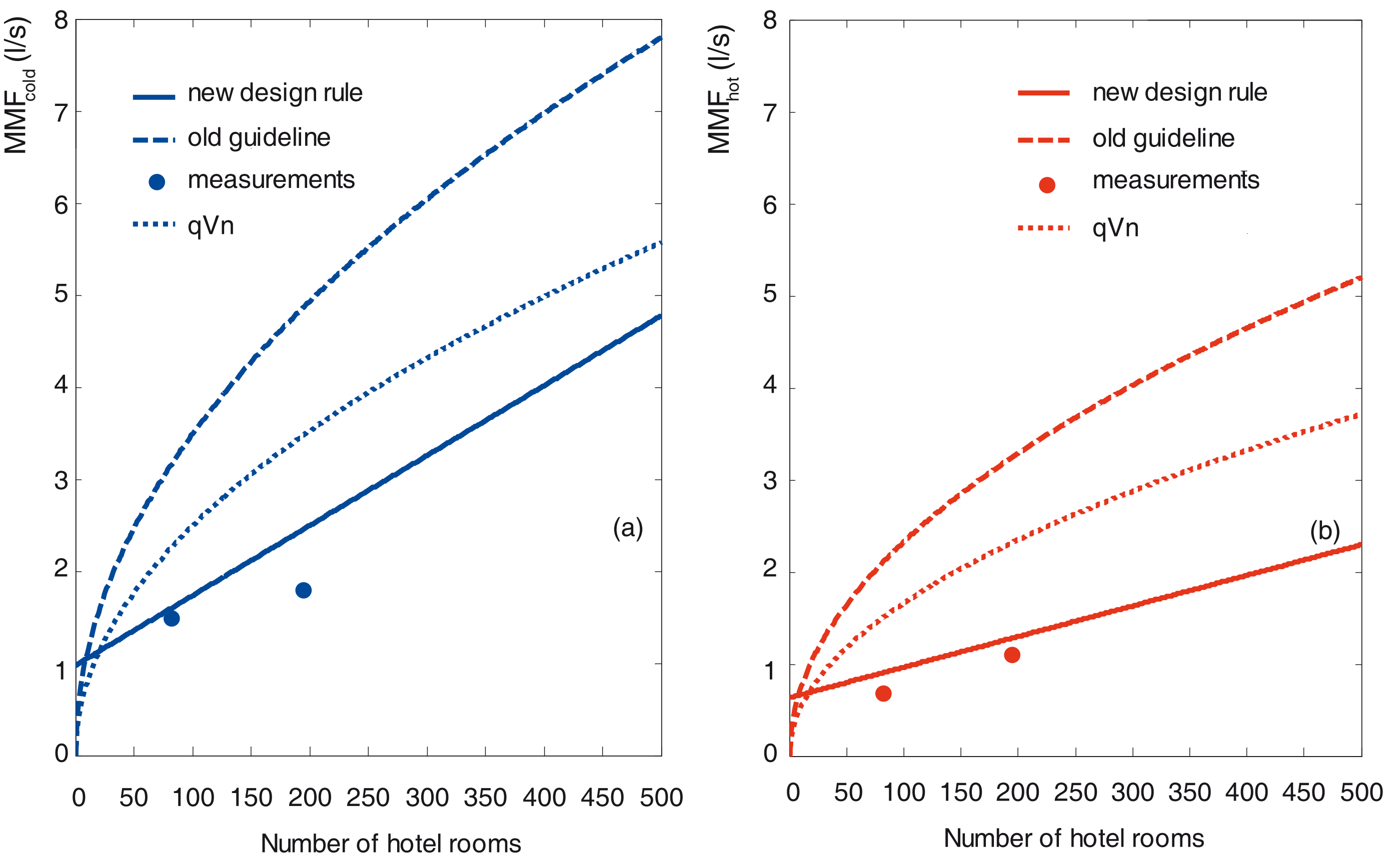

Figure 4. Comparing measured and simulated peak flows a) cold water and b) hot water of a business hotel.

SIMDEUM based design-demand equations reduce the design of heater capacity with a factor 2 to 4 compared to suppliers proposals, while still meeting the desired need and comfort. Thus, the improved insight of the new design-demand equations will lead to an energy efficient choice of the hot water systems, and thus save energy. Moreover, the smaller design of the heating system reduces the stagnancy of water, which may lead to less hygienic problems.

The selected pipe diameters are smaller than the ones used in practice and the ones predicted by the existing guidelines. This indicates that the common practice leads to oversized systems, with corresponding potential quality problems. The tendency to over dimension the system might also be present in other countries. Given the physical basis of SIMDEUM, the presented procedure is easily transferable to other countries when some specific information on users and appliances is available. Although international guidelines do not exist in the public domain, international knowledge exchange regarding design rules of residential and non-residential buildings will strongly contribute to better understanding drinking water use. Further, the knowledge exchange can support the design of more efficient and sustainable water systems. With increasing concern for sustainability, this approach can support the development of guidelines for the design of on-site water systems, such as rainwater systems or energy harvesting techniques i.e. harvesting energy from water flows.

Conclusion

The validation shows that the model predicts the cold and hot water daily demand patterns reasonably well to good. The correlation of the simulated patterns with the measured patterns indicates that the basis of the design-demand equations is solid. Due to the modular approach of SIMDEUM and its physical basis, it is possible to construct a specific building and simulate its water demand. In this way, SIMDEUM was used to develop diurnal profiles for several different buildings, like schools, shops, restaurants, sporting facilities etc. (Pieterse-Quirijns and Van de Roer, 2013).

The new design-demand equations have been adopted in a revised version of the Dutch guidelines, which were released in 2013. The Netherlands is a frontrunner, being the only country in the world with specific regulations for water use in non-residential buildings. Therefore, they are a step ahead in the transition to more sustainable buildings. ■

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