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Methodology for the development of temporally high-resolved and spatially accurate tapping profiles

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Abstract. Within the framework of a current research project, different types of drinking water installations in flats are analysed and compared in a simulation study with regard to drinking water hygiene criteria. The planned modelling of the temperature, stagnation and flow behaviour of individual pipe sections requires the development of particularly detailed tapping profiles. The paper at hand shows a methodology to derive tapping profiles in the required level of detail. A spatially accurate resolution requires that each of the selected draw-off points - washbasin, kitchen sink, shower, bathtub, WC, dishwasher and washing machine - receives its own tapping profile, separated into hot and cold water. The high temporal resolution is the prerequisite for an adequate recording of short tappings lasting only seconds. The basis of the tapping profiles is a statistical database of tapping quantities and frequencies for three different types of residents (couple, family, retirees). In the next step, the DHWcalc tapping profile generator is configured and used to create spatially accurate tapping profiles. Subsequently, an Excel VBA tool refines the time step from 1 min to 5 s and shortens the tapping time for small tapping quantities. By means of simulations with the software TRNSYS an exemplary compact T-piece installation is set up to account for transient effects, like temperature adjustment processes at the shower. With the presented methodology, tapping profiles can be created for different installations that clearly exceed the level of detail of DWHcalc and are suitable for detailed simulative analyses.

Keywords. Tapping profile, drinking water hygiene, simulation, DHWcalc, TRNSYS
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1. Introduction

The high temperature in central domestic hot water heaters in multi-family houses (MFH) is an obstacle for the use of heat pumps. The aim of the research project "Trans2NT-TWW" is to reduce this temperature in a hygienically safe way. With regard to hygienical requirements in drinking water installations, the cold water temperature and the frequency of water exchange also needs to be addressed beneath the hot water temperature. There are different types of drinking water installations available on the market (e.g. T-piece, loop and ring installation), which will be evaluated in future system simulations. As a basis for the planned work, this paper presents a method that enables to generate tapping profiles for hot and cold water that are accurate in terms of draw-off location and highly resolved in terms of time. A high level of detail is necessary to determine the exact flow and stagnation behaviour, as well as the temperature changes of individual pipe sections. This allows conclusions to be derived regarding the quality of the drinking water. Existing tapping profile generators, such as DHWcalc (v.2.02) [1], do not meet the detailed requirements because there is insufficient temporal resolution or it is not possible to separate hot and cold water demands or individual draw-off points. Chapter 2 introduces statistical basics of typical water demand, which are implemented in the DHWcalc (v.2.02) tool in chapter 3. This tapping profile generator is used to generate precise profiles for three different types of residents with different water demands. In the next step, the obtained time increment of 1 min is refined to 5 s and at the same time small tapping quantities are temporally compressed to a shorter tapping period. The final step in chapter 4 requires the simulation software TRNSYS to account for installation-specific effects. This separates hot and cold water flows, due to mixing processes at the tapping and increases the demand due to stagnation effects.

2. Statistical basics

2.1 Selection of the draw-off points

The selection of the draw-off points is based on the floor plans of a statistically representative apartment building that was investigated in the project "MFH-re-Net" carried out at the ISFH [1]. The floor plan section in Fig. 1 shows the arrangement of the draw-off points used. In addition to the kitchen sink, a dishwasher and a washing machine are installed in the kitchen. The bathroom has a washbasin, WC and bathtub with shower fittings (shower tray).

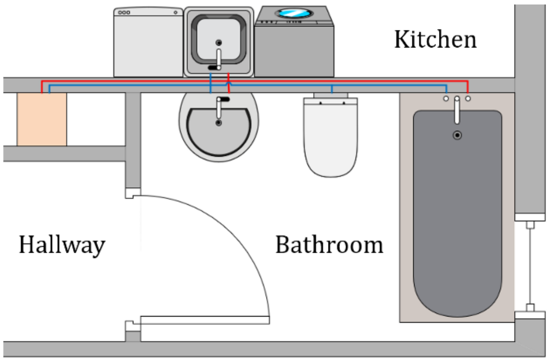

Fig. 1 - Arrangement of the draw-off points.

2.2 Resident types

The definition of three resident types allows the consideration of different tapping behaviour with regard to the daily tapping quantity and the temporal distribution of the tappings. Resident type “couple” is a childless young couple working full-time. Both are absent a lot and use the drinking water installation relatively little. Resident type “family” is a family of three with a school-age child. One parent works full time, the other parent works part time. Resident type “retirees” is a retired couple who have no regular absences. The drinking water installation is used evenly throughout the day.

2.3 Presence profiles

Part of the daily tapping does not take place in one's own household, but for example at work or at school. With the help of presence profiles, it is possible to calculate the share of the daytime the resident types spend outside their own household. The corresponding absence times serve as a factor for reducing the tapping frequencies and quantities at the washbasin, WC and kitchen sink. It is assumed that the shower and bathtub are used exclusively in the household. The presence profiles are drawn up on the basis of the time use survey of the Federal Statistical Office of Germany [2].

Tab. 1 shows the times when tapping is likely and unlikely on working days. The category "likely" means that 95 % of all tappings fall into these periods. The remaining tappings occur evenly at unlikely times of the day and night. No regular or prolonged absences are assumed at weekends in this study. However, there is a shift of 30 min of the night's rest into the evening.

Tab. 1 - Presence profiles of resident types and percentage of absence on weekdays.

	Couple	Family			Retirees
		Parent 1	Parent 2	Schoolchild	
Likely	06:30-08:00	06:00-08:00	06:00-08:00	06:00-07:30	06:30-21:30
Unlikely	08:00-17:30	08:00-17:30	08:00-13:00	07:30-13:30	-
Likely	17:30-22:30	17:30-22:30	13:00-22:30	13:30-21:30	-
Night’s rest	22:30-06:30	22:30-06:00	22:30-06:00	21:30-06:00	21:30-06:30
Absence time	39.6 %	Ø 28.5 %			0.0 %

2.4 Water demand at the draw-off points

In 2018, the average water consumption in private households in Germany was 115.5 l per person and per day (p·day) [3]. Fig. 2 shows the differentiation of water use in households. It is assumend that the categories "cleaning, gardening, etc." and "eating, drinking" occur at the kitchen sink. The categories "washing dishes" and "laundry" are completely assigned to the household appliances dishwasher and washing machine. The category "personal hygiene" can be subdivided into tappings at the shower, the bathtub and the washbasin. The division is based on further literature data ([4], [5], [6]). From this, a consumption of 32.9 l (28.5 %) for the shower, 5.8 l (5.0 %) for the bathtub and 7 l (6.1 %) for the washbasin per person and day can be determined.

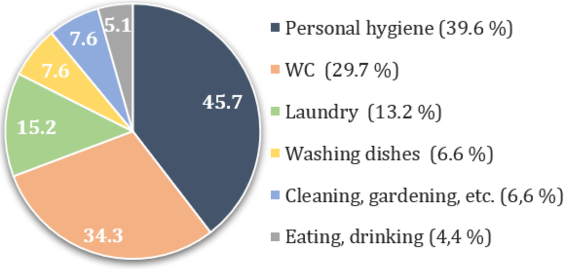

Fig. 2 - Water usage in the household in l/(p·day); own illustration based on [3].

2.5 Tapping frequencies

Tab. 2 lists the tapping quantities and frequencies of the individual draw-off points. The lower part of the table shows the reductions determined according to Tab. 1 due to the absence times, as well as the predefined target mixing temperatures.

Following the default settings of DHWcalc, the tapping frequencies and quantities of the kitchen sink and washbasin given in Tab. 2 are based on a representative survey by Dichter (1999) [7], [8]. However, adjustments are made to the statistical average values determined in Fig. 2, as well as increases with regard to frequency, since three tappings at the kitchen sink or seven tappings at the washbasin per p·day seems to be unreasonably low. According to DIN 1385:1988-05, a WC cistern holds between six and nine litres of water [9]. Based on this, five flushes of 7.5 litres per p·day are assumed, which correlates with the statistical demand quantities according to Fig. 2.

Tab. 2 - Average tapping quantities, frequencies and duration, as well as reductions due to absences.

	Kitchen sink	WC	Shower	Bathtub	Washbasin
Ø Water demand/tapping	3.0 l	7.5 l	48 l	140 l	0.7 l
Ø Water demand /(p·day)	12.7 l	35 l	32.9 l	5.8 l	7.0 l
Ø Tappings/(p·day)	4.22	5	0.6857	0.0415	10
Tapping duration	≤ 1 min	1 min	6 min	14 min	≤ 1 min
Ø Water demand after reduction due to absences [l/(p·day)]					
Couple (39.6 %)	7.7	21.1	-	-	4.2
Family (28.5 %)	9.1	25.0	-	-	5.0
Retirees (0.0 %)	12.7	35.0	-	-	7.0
Target mixing temperature	42 °C	-	39 °C	42 °C	35 °C

2.6 Dishwasher and washing machine: cleaning sequences

The underlying cleaning programme of a dishwasher consumes an average of 11 l of water [10] within 120 min. During this time, there are three tappings: The pre-rinse cycle requires 4 l of water at the beginning. After 45 minutes, the dirty water is pumped out and fresh water is poured in for the intermediate rinse cycle. After 90 minutes, the water is changed again for the clear rinse cycle with 3 litres of fresh water. The washing machine consumes 48 l of water within the standard programme of 150 min. During this time, there are a total of five rinse cycles with evenly distributed fresh water tappings of 9.6 l each (based on [11], cf. Tab. 3).

Tab. 3 - Statistical database for generating a dishwasher and washing machine sequence.

	Dishwasher	Washing machine
Water consumption per cleaning cycle	11 l	48 l
Cleaning cycles per year (couple; family; retirees)	209; 313; 261	140; 175; 140
Duration of the cleaning programme	120 min	150 min
Number of tappings per cleaning cycle	3	5
Timing of tappings	0; 45; 90 min	0; 30; 60; 90; 120 min
Tapping quantity per tapping	4; 4; 3 l	9.6 l each
Tapping duration per tapping	1 min	1 min

3. Generation of the tapping profiles

3.1 Tapping profile generation with DHWcalc

With the exception of the dishwasher and the washing machine, two tapping profiles are initially created with DHWcalc for each resident type and for each draw-off point (30 in total): one tapping profile for the weekdays and one tapping profile for the weekends. The separation is necessary because the daily tapping quantities differ due to the presence profiles. The tapping profiles for weekdays cover 261 days and consider the tapping volume reductions due to the presence profiles (cf. Tab. 1 and Tab. 2). The daily tapping quantity, the volume flow and the tapping duration are set in DHWcalc to match the values displayed in Tab. 2. The settings for the probability distribution of the tappings correspond to the presence profiles according to Tab. 1. The tapping profiles for the weekends cover 104 days accordingly and do not take absences into account. Generally, the smallest possible time step setting of 1 min is selected in DHWcalc [12]. Holiday periods are not considered in this step, since they can be inserted individually afterwards (e.g. in the resulting text file or in TRNSYS).

3.2 Merging the tapping profiles

A tool implemented in Microsoft Excel - Visual Basic for Applications (VBA) merges the separate tapping profiles according to working days and weekends. The sorting is done by the VBA tool periodically creating a gap in the weekday tapping profile after 7,200 time steps of 1 min (5 days) and then copying in 2,880 time steps (2 days) from the weekend profile. Fig. 3 visualises the sorting process. A total of 15 tapping profiles remain (5 per resident type), each covering a year.

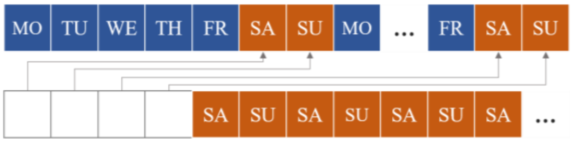

Fig. 3 - Principle of merging weekday and weekend tapping profiles.

3.3 Refinement of the time step and temporal compression of small tapping quantities

In everyday life, very short tappings, lasting only a few seconds, often occur at the kitchen sink and washbasin. Examples include filling a kettle or wetting a toothbrush. With a time step of 1 min, these tappings cannot be represented realistically by DHWcalc, as even the smallest tappings, e.g. 0.1 l, are always assumed to last 60 s. From the point of view of drinking water hygiene, it can be assumed that pipes and their surroundings heat up more the longer a hot water tapping lasts.

A tool, also realised with Excel-VBA, refines the time step width of the tapping profiles from 1 min to 5 s (the desired simulation time step) and compresses tappings at the kitchen sink and the washbasin in terms of time. Tab. 4 shows the categories for compressing small tappings. Based on the default settings in DHWcalc, the assumed maximum flow rate is 7.2 l/min.

Tab. 4 - Categories for compressing small tappings.

Category	Volume [l]	Duration [s]
1; 2	> 0.0 - 0.6; > 0.6 - 1.2	5; 10
3; 4	> 1.2 – 1.8; > 1.8 - 2.4	15; 20
5; 6	> 2.4 - 3.0; > 3.0 - 3.6	25; 30
7; 8	> 3.6 - 4.2; > 4.2 - 4.8	35; 40
9; 10	> 4.8 - 5.4; > 5.4 - 6.0	45; 50
11; 12	> 6.0 - 6.6; > 6.6	55; 60

Fig. 4 shows the principle of time step refinement and the compression in terms of time according to small tapping quantities by the VBA tool. Each time step value of the tapping profiles created with DHWcalc is read in successively, converted to 5 s values in terms of quantity and the resulting array of 12 is written to a new text file. If, for example, a time step in the tapping profile for the shower has the value 8 (l/min), the tool transforms this entry into 12 new time steps of 0.67 (l/5 s) each. If, for example, a time step has the value 2.5 (l/min), this results in the following transformation: The first 5 entries contain the value 0.5 (l/5 s), the remaining 7 entries receive the value 0.0. With this method, the tapping volume of 2.5 l is compressed from 60 s to 25 s, increasing the flow rate from 2.5 l/min to 6 l/min.

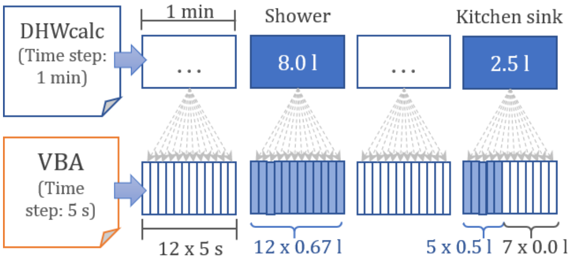

Fig. 4 - Principle of time step refinement and temporal compression of small tapping quantities.

3.4 Tapping profile generation for dishwasher and washing machine

The generation of the tapping profiles for the dishwasher and the washing machine is done in the same way and requires two steps. In the first step, markers are set in an empty tapping profile defining the start of a dishwasher or washing machine sequence. This step is done with the help of the random function in Excel. In the random distribution, absence times and night rest are left out according to Tab. 1. The number of markers depends on the resident types (cf. Tab. 3). Using the example of the dishwasher for resident type couple, 209 randomly selected markers are set in the course of the year (family: 313, retirees: 261).

The second step involves the actual tapping profile generation with a tool implemented in Excel VBA. It reads in the previously formed marker profiles and generates new profiles with a time step resolution of 5 s. A marker triggers a cleaning sequence. As described in chapter 2.6, this consists of 3 or 5 tappings of 1 min each at defined intervals. The volume flow is 0 l/min during the periods before, after and between the tappings. Fig. 5 illustrates how the washing machine and dishwasher sequences are integrated into the tapping profile. With the dishwasher and washing machine cold water tapping profiles created, each resident type receives a total of 7 tapping profiles.

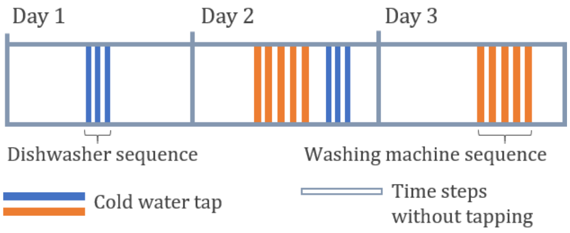

Fig. 5 - Exemplary integration of dishwasher and washing machine sequences.

4. Optimisations in TRNSYS

The water consumption in households determined in chapter 2.4 does not distinguish between hot and cold water demand. However, simulative detailed analyses of drinking water installations require this distinction in order to be able to model the flow, stagnation and temperature behaviour of individual pipe sections. Therefore, the simulation tool TRNSYS (v17.01.0028) is used to create a model for a drinking water installation in order to separate the hot and cold water flow streams (cf. chapter 4.1). Based on the chosen draw-off points in Fig.1, Fig. 6 shows the structure and pipe lengths of the T-piece installation which is implemented in the TRNSYS model.

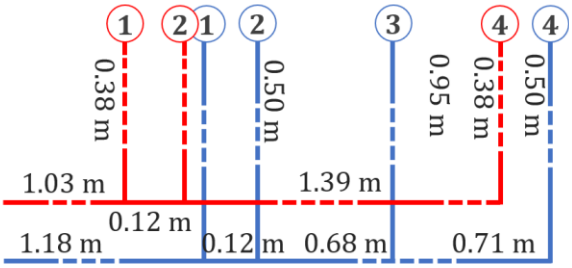

Fig. 6 - Structure of the T-piece installation implemented in TRNSYS; 1: washbasin, 2: kitchen sink, dishwasher, washing machine, 3: WC, 4: shower tray

The selected simulation parameters are listed in Tab. 5. In the framework of the TRNSYS model, flow extensions due to temperature adjustment processes are added (cf. chapter 4.2).

Tab. 5 - Simulation parameters regarding to pipes and temperatures used in the TRNSYS model

Pipe diameter (inner; outer)	16; 18 mm
Pipe material	Copper
Insulation thickness (PWH; PWC)	4; 4 mm*
Pipe total length (PWH; PWC)	3.68; 5.14 m
Total volume	1.773 l
Temperature input (PWH; PWC)	Ø 48; 15 °C
Ambient room temperature	Ø 23.5 °C
*λ = 0.04 W/(m·K); c.f DIN 1988-200 [13]	

DIN 1988-200:2012-5 recommends the insulation of PWH pipes to avoid corrosion and to provide for mechanical protection [13]. The temperatures are implemented as sinus functions, which show a range of 0.8 °C (PWH), 1.8 °C (PWC) and 4.1 °C (ambient room temperature) around the temperatures given in Tab. 5. The time intervals are 6 h, 18 h and 4.380 h. The sinus function of the ambient room temperature is widely stretched and shifted on the time axis. The maximum temperature is reached in the summer, the minimum temperature is reached in the winter.

4.1 Separation of hot and cold water

The required hot and cold water volume flows to achieve the target mixing temperatures specified in Tab. 2 can be determined according to formula (1) and (2). Constant heat capacitances are assumed.

$$\dot{V}_{PWC} = \frac{\vartheta_{PWH} - \vartheta_M}{\vartheta_{PWH} - \vartheta_{PWC}} \cdot \dot{V}_{SUM} \tag{1}$$

$$\dot{V}_{PWH} = \left(1 - \frac{\vartheta_{PWH} - \vartheta_M}{\vartheta_{PWH} - \vartheta_{PWC}}\right) \cdot \dot{V}_{SUM} \tag{2}$$

ϑ_M, ϑ_{PWH}, ϑ_{PWC}: Target mixing temperature [°C], Warm- and cold water temperature[°C]

$\dot{V}_{PWH}$, $\dot{V}_{PWC}$, $\dot{V}_{SUM}$: Volume flow[l/min] of warm- and cold water, Total volume flow [l/min]

Fig. 7 illustrates exemplarily the implementation of the mixing rule in TRNSYS for one of the warm water draw-off points: kitchen sink, washbasin, shower and bathtub. In the central element, the equation, the formulas (1) and (2), as well as the target mixing temperature ϑ_M of the respective draw-off point are stored. The tapping profiles are read in with a data reader and provide the total volume flow $\dot{V}_{GES}$ as input for the mixing rule. The hot and cold water connections of the draw-off points are implemented as pipe types. These calculate the time-varying discharge temperatures $\vartheta_{PWH}(t)$ and $\vartheta_{PWC}(t)$. In each simulation time step (à 5 s), the required mixing ratio of $\dot{V}_{PWH}$ and $\dot{V}_{PWC}$ is determined from these data. Both volume flows are fed back as input to the pipe types in order to map the respective flow of the pipe sections. The Delay (Type 661) is only present at the shower tap and is used to implement the temperature adjustment process described in chapter 4.2.

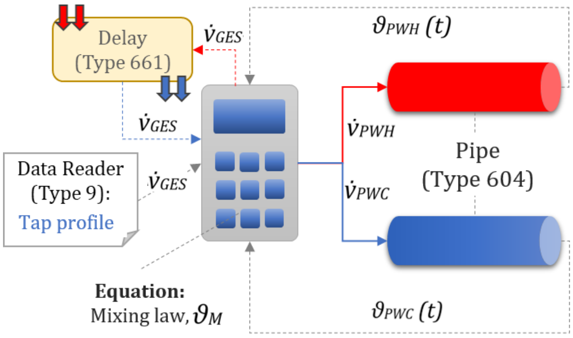

Fig. 7 - Implementation of the mixing rule in TRNSYS.

4.2 Temperature adjustment process

The water temperature in the pipes approaches the ambient room temperature during a stagnation period. In this case, the maximum PWH supply temperature is available with a delay after the start of tapping, as the stagnant water must first drain off. In this context, the temperature adjustment process means the process of adjusting the target mixing temperature using the mixer tap at the beginning of a tapping. The process typically proceeds in such a way that initially only hot water is requested by using the lever position of the mixer tap until an increasing heating of the outflowing water is perceived. The subsequent step-by-step adjustment of the lever position leads to an admixture of cold water until the target mixing temperature is reached. The water flowing out during this process flows unused into the drain. This must be distinguished from the volume flows defined in the tapping profiles, which refer exclusively to tappings when the target mixing temperature is reached. The temperature adjustment process takes place before the actual tapping and leads to an increase in the tapping duration and volume compared to the data from the tapping profiles. Superimposing the original tapping profiles with the tapping volume that has flowed off unused during the temperature adjustment process results in new, so-called "extended tapping profiles" (cf. Fig. 8).

The consideration of the temperature adjustment process in TRNSYS including the tapping extension is limited to the shower tap. For reasons of comfort, the desired water temperature is typically adjusted before entering the shower. For short tappings at the washbasin and kitchen sink (e.g. for washing hands or filling a kettle), the significance of the water temperature reached at the start of the tapping is negligible. The same applies when filling a bath.

The implementation of the temperature adjustment process in TRNSYS is realised with the help of the equation shown in Fig. 7 in connection with the Type 661 ("Delayed Output Device"; in this version called "delay-type"). A test condition is stored in the equation which passes on the volume flow from the tapping profile to the delay type if the mixing temperature at the outlet of the pipes is below the target mixing temperature during a tapping (ϑ_M, shower = 39 °C). The delay-type stores the volume flow for the duration of the shower tapping (72 time steps of 5 s each) and then returns it to the equation. Fig. 8 shows the volume flows from the tapping profile and the delay-type that enters the equation. The superimposition results in a summed volume flow (extended tapping profile) from which the required mixing ratio ($\dot{V}_{PWH}$ and $\dot{V}_{PWC}$) is calculated and transferred to the pipes. Thus, on the one hand, the original tapping profile is extended by the time required for the temperature adjustment process. On the other hand, the tapping volume is increased by the amount of water that previously flowed off unused.

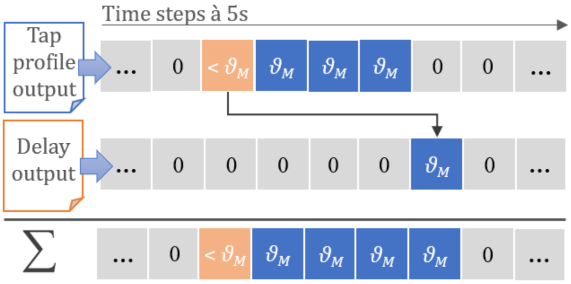

Fig. 8 - Volume flow superimposition: Extended tapping profiles.

5. Results

5.1 Exemplary tapping profile cut-outs

Fig. 9 and Fig. 10 each show an exemplary daily course (working day) of the extended tapping profiles for the resident types couple and retirees. In the time interval of the night's rest (cf. Tab. 1), tapping takes place only in exceptional cases (e.g. 3:00 AM). The direct comparison of the two resident types clearly shows the influence of the presence profiles. In the case of the couple, there is an accumulation of tappings in the morning and a subsequent stagnation until 4 PM. In the case of the retirees, the tappings are distributed quite evenly throughout the day without longer stagnation periods.

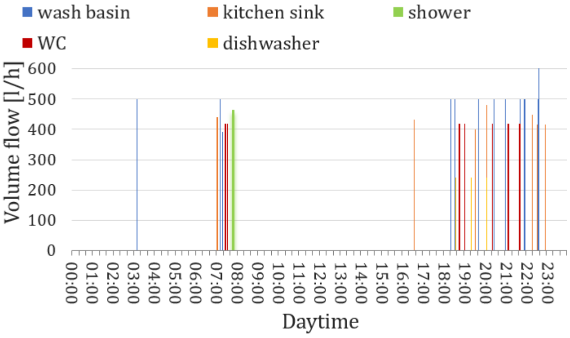

Fig. 9 - Tapping profile cut-out; resident type couple.

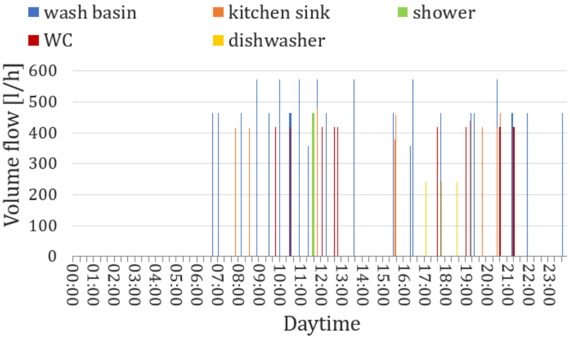

Fig. 10 - Tapping profile cut-out; resident type retirees.

Fig. 11 shows an example of the implementation of the dishwasher and washing machine sequences in the tapping profile for the resident type family. The night and absence times do not contain any tappings.

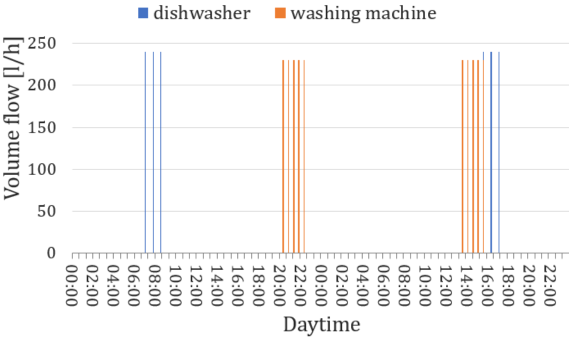

Fig. 11 - Dishwasher and washing machine sequences; resident type family.

5.2 Mixing rule, temperature adjustment process and tapping extension

Fig. 12 shows the flow rate and temperature curve of two exemplary shower tappings at intervals of around 20 min. At the beginning of the first shower tapping, a clear spike in the volume flow of the hot water pipe ($\dot{V}_{PWH}$) can be seen as long as the target mixing temperature of 39 °C is not reached. At the same time, the temperature (ϑ_{PWH}) at the outlet of the PWH-pipe rises up to a flow temperature of 48 °C (instantaneous water heater). The cold water volume flow ($\dot{V}_{PWC}$) is added with a slight time delay after the PWH setpoint temperature has been reached. The dashed line of the cold water temperature (ϑ_{PWC}) shows, that stagnant water that is close to the ambient room temperature (approx. 22 °C), initially flows out until fresh cold water with a temperature of 14 °C follows. The water that flows off during this temperature adjustment process does not count as part of the actual shower tapping and leads to an extension of the tapping time. The volume flow from the original tapping profile ends approx. with the vertical, green dotted line. The tapping extension takes place via the delay type and corresponds to the temperature adjustment process in terms of duration and quantity.

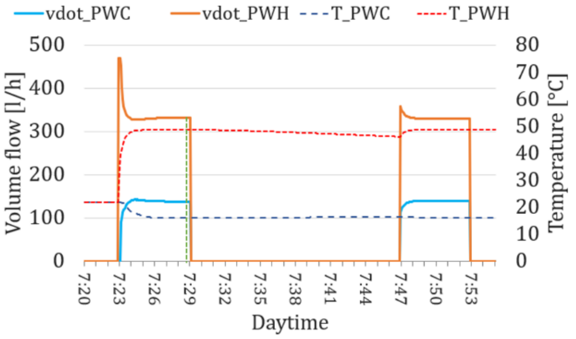

Fig. 12 - Shower tappings with temperature adjustment process.

Between the first and second shower tapping, the water temperatures in the pipes change only slightly. There is no need for an initial temperature adjustment process at the beginning of the second shower tapping, because a sufficiently high PWH temperature is already available to reach the target mixing temperature. That is why there is only a small peak in the $\dot{V}_{PWH}$-line. In contrast to the first shower tapping, the cold water volume flow is added immediately.

Simulations were performed for each resident type to determine the additional consumption at the shower due to the temperature adjustment process. Tab. 6 shows the original and extended annual tapping quantities at the shower (lines 1 and 2), as well as the relative additional consumption (line 3). Line 4 shows the relative additional consumption in relation to the respective total consumption of the resident types.

Tab. 6 - Additional consumption due to the temperature adjustment process at the shower tap

Resident type	Unit	A	B	C
Original shower profile	l/a	24,000	36,000	24,000
Extended shower profile	l/a	24,410	36,632	24,472
Add. consumption (shower tap)	%	1.7	1.8	2.0
Add. consumption (annual total)	%	0.67	0.92	0.61

6. Discussion

The high time resolution compared to DHWcalc enables a realistic consideration of short-term tappings. In the context of drinking water hygiene, this is particularly relevant in a simulation model when depicting pipe heating. With the definition of three different types of residents, individual consumption quantities and times are included. In the following studies, the influence of usage behaviour on drinking water hygiene can be analysed. The overall effort is relatively high due to the research of statistical data, as well as the implementation of the three consecutive steps with different software (DHWcalc, VBA-Tools, TRNSYS). Changes, for example with regard to draw-off points or resident types, require the repetition of at least some steps.

The additional consumption at the shower during temperature adjustment (cf. Tab. 6) increases the statistical demand quantity of the resident types by less than 1 % each. The relatively small additional demand is due to the compact drinking water installation with low pipe volume. In addition, the PWH flow temperature is immediately available at the inlet of the pipe structure in the TRNSYS model. Therefore, the cooled stagnation water drains off quickly and hot water follows without delay. Although the additional consumption is small, it may still have an impact on drinking water hygiene due to prolonged flushing and heating of the PWH pipe.

The used demand quantity refers to average values of the total German population (cf. Fig. 2). Individual tapping behaviour deviates from this. Looking at the developed extended tapping profiles, the reference to reality is still given. A general reduction of the tapping quantity in the original tapping profile should be avoided, as not every shower tapping involves a temperature adjustment process (cf. Fig. 12).

7. Conclusions

The described methodology enables the generation of suitable, spatially accurate and temporally highly resolved tapping profiles for detailed simulation analyses. For each individual hot and cold water pipe to the selected draw-off points, individually suitable volume flows are available. Due to the lack of available software solutions, the degree of automation is low. However, the tapping profiles created in this work already cover various typical tapping behaviours and can be used e.g. for detailed analyses or as summed tapping profiles for entire apartments or buildings. For the optimisation of the tapping profiles with regard to an adequate separation of hot and cold water proportions, as well as the temperature adjustment process, the use of simulation software such as TRNSYS is indispensable. For these calculations, time-step accurate state variables of the system are necessary (e.g. current temperature of the hot and cold water pipes). Looking at the planned simulative hygiene analyses, the temperature adjustment process plays an important role. The prolonged flushing of the hot water pipe leads to stronger pipe heating, which surely effects on a nearby cold water pipe, for example. This could sometimes make it difficult to maintain important hygienic temperature limits and reveal weak points in the drinking water installation types. Further extensions of the tapping profiles within TRNSYS are conceivable. This includes, for example, the addition of holiday periods or the variation of the supply temperatures in order to analyse the effects on the temperature adjustment processes.

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The datasets generated during and/or analysed during the current study are not available because because the study is currently still being carried out and will be extended and possible changes may occur but the authors will make every reasonable effort to publish them in near future.