water

MDPI

Supplementary Materials

Supplementary Material 2 - Summary of equations

This document summarizes all 33 equations that are developed in the paper. With no additional explanations, direct understanding and comparisons may be easier.

Water consumption in rooms

General water demand in rooms:

$$WD_R(L/room/day) = N_G\left[\sum_i (Q_i \cdot t_i) + \sum_j (V_j \cdot n_j)\right] \quad (1)$$

where:

WD_R is the average water demand per room (L/room/day);

N_G is the average number of occupants per occupied room in the hotel. It is calculated by dividing the total number of hotel guests by the total number of occupied rooms. In general, it can also be considered as a characteristic parameter of the hotel. For example, in urban business hotels, N_G might range between 1 and 1.5, while in holiday resorts, it can be as high as 2.5 or 3;

i stands for each appliance of flow rate-based type;

Q_i is the average flowrate for each appliance i (L/min);

t_i is the average time each appliance i is used per day (min/guest/room/day);

j stands for each appliance of volume-based type;

V_j is the average volume per use for each appliance j (L/use);

n_j is the average number of uses per day for each appliance j (uses/guest/room/day).

Assessed minimum water demand in rooms:

$$WD_{R_{Min}}(L/room/day) = N_G\left[(5.68 \cdot 4.5 + 7.57 \cdot 8) + (4.85 \cdot 4)\right] = N_G \cdot 105.5 \quad (2)$$

Minimum consumption benchmark for hotel rooms:

$$MCB_R(m^3/year) = 38.5 \cdot N_G \cdot N_R \cdot Occ_{Hotel} \quad (3)$$

where:

N_R is total number of hotel rooms;

Occ_{Hotel} is the occupancy rate of hotel rooms;

Water consumption in kitchens/restaurants

General water demand in kitchens/restaurants:

$$WD_K(L/restaurant/day) = C_{meal} \cdot N_{meals} \quad (4)$$

where:

WD_K is the average water demand per restaurant (L/restaurant/day);

C_{meal} is the average water consumption per meal served (L/meal);

N_{meals} is the total number of meals served (meals/restaurant/day).

Assessed minimum water demand in kitchens/restaurants:

$$WD_{K_{Min}}(L/restaurant/day) = 12 \cdot N_{meals} \quad (5)$$

Assuming that there is (only) one kitchen/restaurant in the hotel:

$$N_{meals}(meals/day) = N_G \cdot N_R \cdot Occ_{Hotel} \cdot (K_{break} + K_{lunch} + K_{dinner}) \quad (6)$$

where:

K_{break}, K_{lunch}, and K_{dinner} are the coefficients for breakfast, lunch, and dinner, respectively.

Therefore:

$$WD_{K_{Min}}(L/day) = 12 \cdot N_G \cdot N_R \cdot Occ_{Hotel} \cdot (K_{break} + K_{lunch} + K_{dinner}) \quad (7)$$

Minimum consumption benchmark in kitchens/restaurants:

$$MCB_K(m^3/year) = 4.38 \cdot N_G \cdot N_R \cdot Occ_{Hotel} \cdot (K_{break} + K_{lunch} + K_{dinner}) \quad (8)$$

Water consumption in outdoor irrigation

General water demand in outdoor irrigation:

$$WD_I(L/garden/year) = ET_0 \cdot A \cdot PF \cdot \frac{1}{K_r} \cdot K_t \quad (9)$$

where:

WD_I is the irrigation water demand in a garden area (L/garden/year);

ET_0 is the evapotranspiration reference value at the geographical hotel location (mm/year);

A is the garden area (m^2);

PF is the plant factor for plant type;

Kt is the efficiency of gardening techniques;

Kr is the efficiency of the irrigation system.

Assessed minimum water demand in outdoor:

$$WD_{I_{Min}}(L/garden/year) = ET_0 \cdot A \cdot PF \quad (10)$$

Table S2-1 (Table 9). Values of MCB_I for different climate types and types of plants.

Climate Type	ET_0 (mm/Year)	PF_i	MCB_I (m^3/Year)	
Temperate regions	700	0.7	$0.490 \cdot \sum_i (A_i)$	(11)
Mild Mediterranean	1250	0.6	$0.750 \cdot \sum_i (A_i)$	(12)
Damp tropical regions	1750	0.5	$0.875 \cdot \sum_i (A_i)$	(13)

Water consumption in laundry

General water demand in laundry:

$$WD_L(L/laundry/day) = C_W \cdot N_C \quad (14)$$

where:

WD_L is the laundry water demand (L/laundry/day);
C_W is the washer consumption factor (L/kg);
N_C is the amount of clothes per guest that should be washed daily (kg/laundry/day).

Assessed minimum water demand in laundry:

$$WD_{L_{Min}}(L/laundry/day) = 5 \cdot N_C \quad (15)$$

Assuming that there is (only) one laundry in the hotel:

$$N_C\ (kg/day) = N_G \cdot N_R \cdot Occ_{Hotel} \cdot \left(N_{C_R} + N_{C_K}\right) \quad (116)$$

where:

N_G, N_R, and Occ_{Hotel} are the same variables already explained;
N_{CR} is the amount of clothes per guest in rooms (kg/guest/day);
N_{CK} is the amount of clothes per guest in kitchen-restaurant (kg/guest/day).

Assessment of average clothes use per guest:

$$N_C\ (kg/day) = N_G \cdot N_R \cdot Occ_{Hotel} \cdot \left(1.46 + 0.32 \cdot (K_{break} + K_{lunch} + K_{dinner})\right) \quad (17)$$

Therefore,

$$WD_{L_{Min}}(L/day) = 5 \cdot N_G \cdot N_R \cdot Occ_{Hotel} \cdot \left(1.46 + 0.32 \cdot (K_{break} + K_{lunch} + K_{dinner})\right) \quad (18)$$

Minimum consumption benchmark for laundry:

$$MCB_L(m^3/year) = N_G \cdot N_R \cdot Occ_{Hotel} \cdot \left(2.67 + 0.59 \cdot (K_{break} + K_{lunch} + K_{dinner})\right) \quad (19)$$

Water consumption in swimming-pools

General water demand in swimming-pools:

$$WD_P = WD_{Evap} + WD_{Maint} + WD_{Swimmers} \quad (20)$$

where:

WD_P is the swimming pool's total water demand;
WD_{Evap} is the water losses evaporation in a swimming pool;
WD_{Maint} is the water used in filters backwashing;
$WD_{Swimmers}$ is the water consumption due to swimmers' activity.

Water demand due to evaporation:

$$WD_{Evap}(L/pool/day) = 15 \cdot 24 \cdot A_p \cdot F_a.(p_w - p_a) \quad (21)$$

where:

A_P is the pool surface area (m^2);
F_a is the activity factor, which depends on the type of pool;
P_w is the saturation vapour pressure taken at the temperature of water at its surface (bar);

p_a is the saturation pressure at ambient air dew point (bar).

Water demand due to regular maintenance:

$$\mathrm{WD_{Maint}(L/pool/day)} = \frac{4 \cdot 1000}{365} \cdot \mathrm{V_p} = 11 \cdot \mathrm{V_p} \quad (22)$$

where:

V_p is the pool volume (m^3).

Water demand due to swimmers' activity:

$$\mathrm{WD_{Swimmers}(L/pool/day)} = \mathrm{C_s} \cdot \mathrm{N_s} \quad (23)$$

where:

C_s is unitary water consumption per swimmer (L/day/swimmer);

N_s is the number of swimmers in the swimming pool.

Assessed minimum water demand in swimming-pools:

$$\mathrm{WD_{P_{Min}}(L/pool/day)} = 7.4 \cdot \mathrm{A_p} + 11 \cdot 1.5 \cdot \mathrm{A_p} + 40 \cdot \mathrm{N_s} \quad (24)$$

Minimum consumption benchmark in swimming-pools:

$$\mathrm{MCB_P(m^3/year)} = 0.365 \cdot \left(23.9 \cdot \mathrm{A_p} + 40 \cdot \mathrm{N_s}\right) \cdot \mathrm{Pool_{Open}} \quad (25)$$

where:

$Pool_{Open}$ is the percentage of annual pool open days

Water consumption in air conditioning

General water demand for air conditioning:

$$\mathrm{WD_{AC}} = \mathrm{WD_{AC_{Occupied\ rooms}}} + \mathrm{WD_{AC_{Common\ areas}}} \quad (26)$$

Water demand for air conditioning in occupied rooms:

$$\mathrm{WD_{AC_{Occupied\ rooms}}(L/AC\ system/day)} = \mathrm{C_{AC}} \cdot \mathrm{N_R} \cdot \mathrm{Occ_{Hotel}} \quad (27)$$

where:

$WD_{AC\ Occupied\ Rooms}$ is the water consumption of the air conditioning system for occupied rooms (L/AC system/day);

C_{AC} is the unit water consumption per room of the air conditioning system (L/room/day).

Water demand for air conditioning in common areas:

$$\mathrm{WD_{AC_{Common\ areas}}(L/AC\ system/day)} = 0.15 \cdot \mathrm{C_{AC}} \cdot \mathrm{N_R} \quad (28)$$

Assuming that there is (only) one air conditioning system in the hotel:

$$\mathrm{WD_{AC}(L/day)} = \mathrm{C_{AC}} \cdot \mathrm{N_R} \cdot (\mathrm{Occ_{Hotel}} + 0.15) \quad (29)$$

Assessed minimum water demand for air conditioning:

$$\mathrm{WD_{AC_{Min}}(L/day)} = 25 \cdot \mathrm{N_R} \cdot (\mathrm{Occ_{Hotel}} + 0.15) \quad (30)$$

Minimum consumption benchmark for air conditioning:

$$\mathrm{MCB_{AC}(m^3/year)} = 9.13 \cdot \mathrm{N_R} \cdot (\mathrm{Occ_{Hotel}} + 0.15) \quad (31)$$

The Hotel Water Consumption Index (HWCI)

General minimum consumption benchmark for the whole hotel:

$$\text{MCB } (\text{m}^3/\text{year}) = \text{MCB}_\text{R} + \text{MCB}_\text{K} + \text{MCB}_\text{I} + \text{MCB}_\text{L} + \text{MCB}_\text{P} + \text{MCB}_\text{AC} \quad (32)$$

Final calculation of the HWCI:

$$\text{HWCI} = \frac{\text{Current annual water consumption } (\text{m}^3/\text{year})}{\text{MCB } (\text{m}^3/\text{year})} \quad (33)$$