MULTI-PHYSICS APPROACHES FOR MODELING CIVIL SYSTEMS

GROUP B/S/X
MODELING A WATER SUPPLY SYSTEM

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THE ENVIRONMENT: NYAMASHEKE - RWANDA

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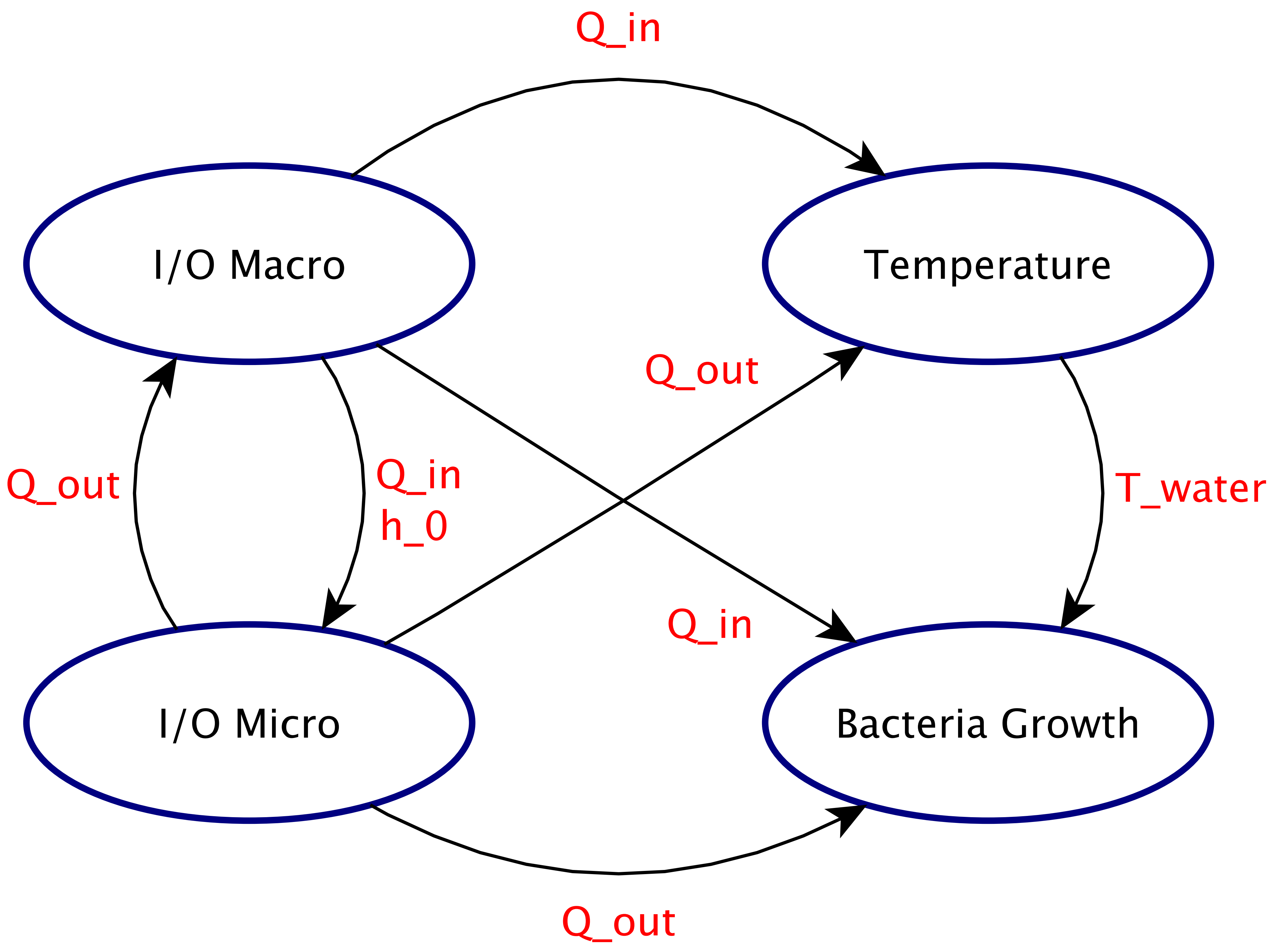
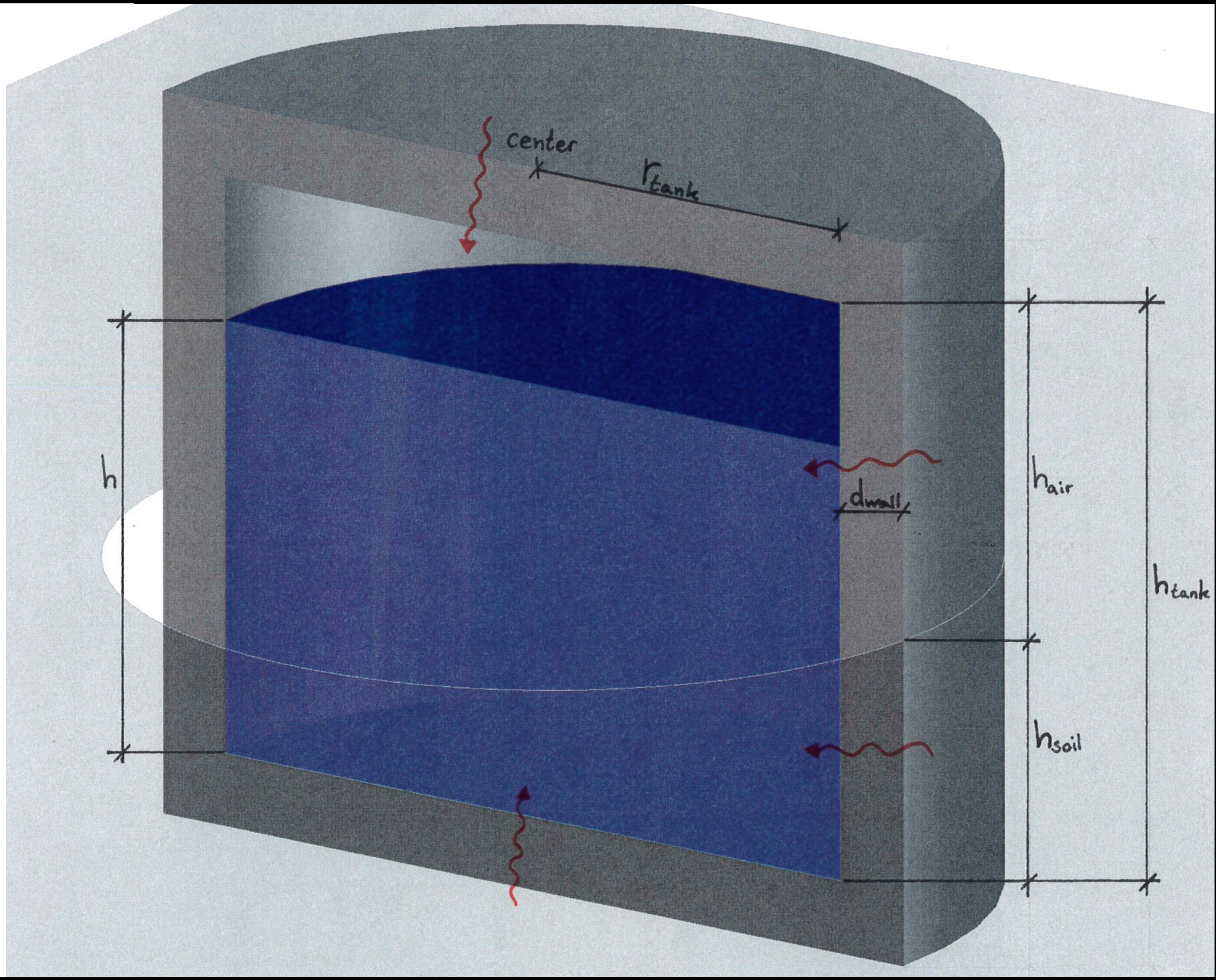
THE SYSTEM



Q_in
I/O Macro
Temperature
Q_out
Q_out
Q_in
h_0
T_water
Q_in
I/O Micro
Bacteria Growth
Q_out



center
r_{tank}
h
h_{air}
d_{wall}
h_{tank}
h_{soil}

HIGH PERFORMANCE CRITERIA

Objective	Key indicator	Unit	Extent
provide enough water for each individual within school time	bottles filled on a school day	1	> 2500
provide healthy water	bacteria concentration	num/m^3	< 25 * 10^{-4}
provide a pleasant drinking temperature	temperature	°C	max. 17°C

DYNAMIC INPUTS

DIFFERENTIAL EQUATIONS

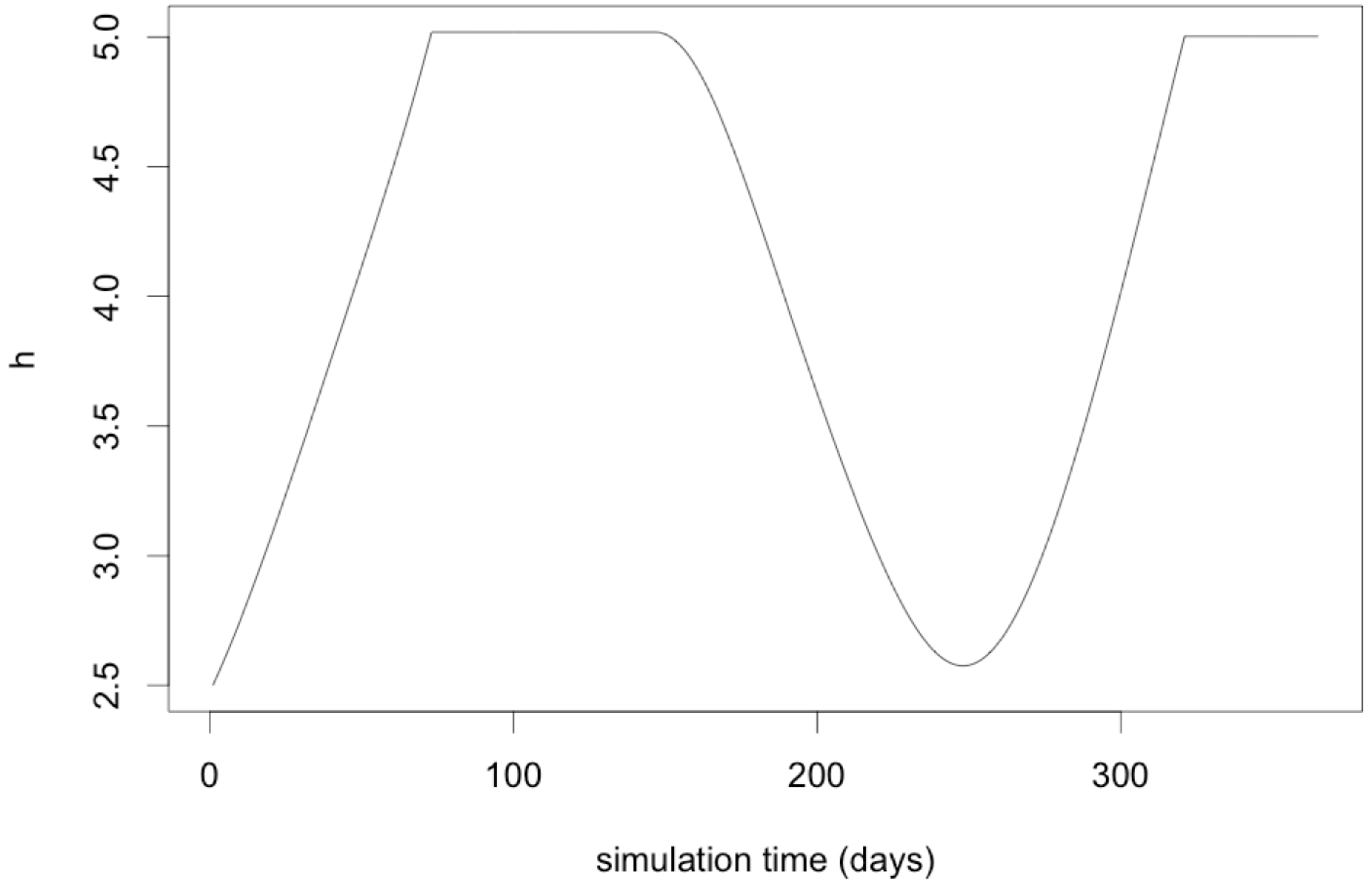
$$\frac{dV}{dt} = \begin{cases} 0 & \text{if } V > 2 * h_{tank} \cdot \pi \cdot r_{tank} \wedge dV > 0 \\ 0 & \text{if } V < 0 \wedge dV < 0 \\ Q_{in,rain}(t) \cdot A_{roof} - Q_{out} & \text{else} \end{cases}$$

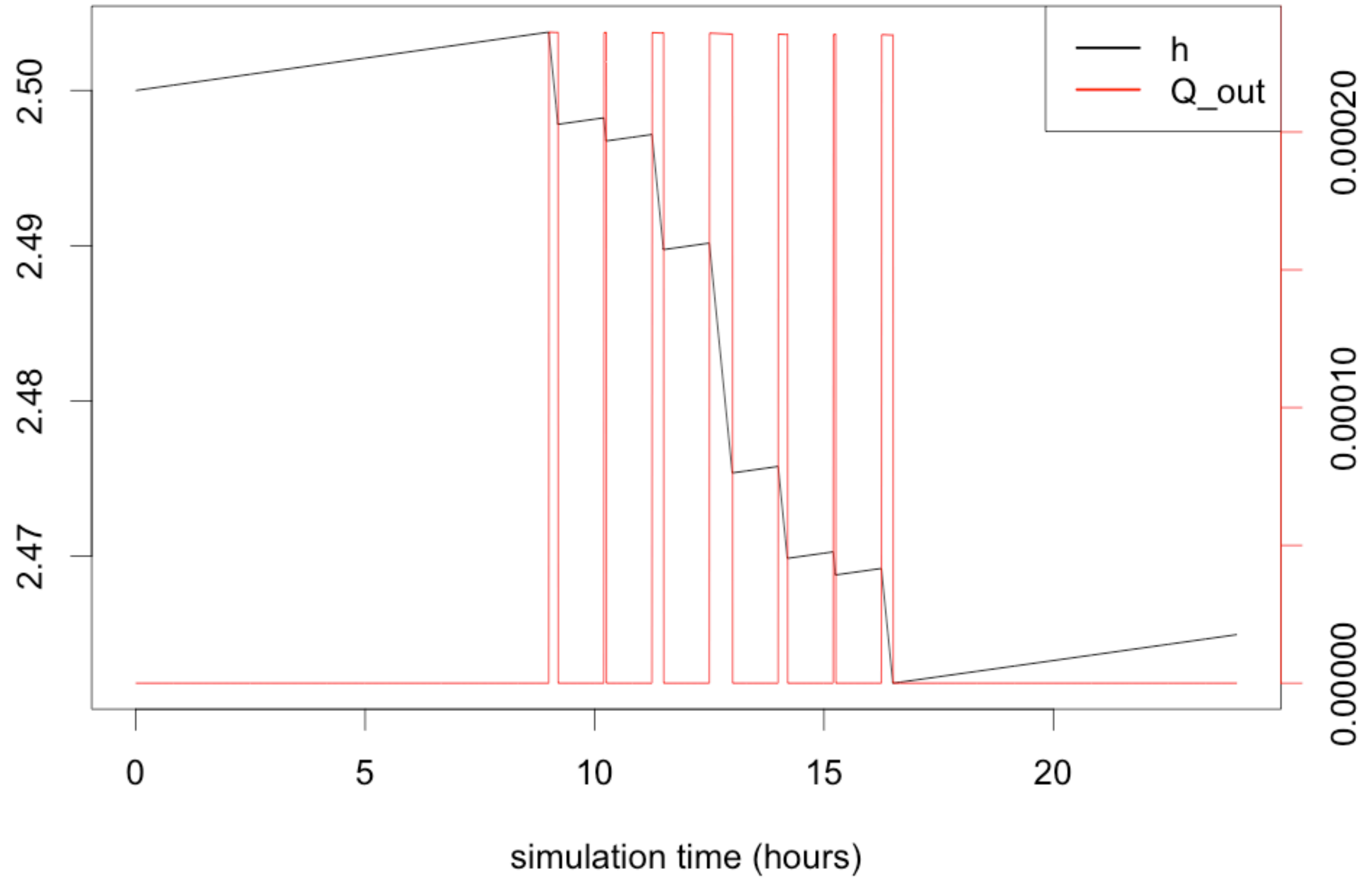
$$\frac{dh}{dt} = \frac{Q_{in} - Q_{out}}{\pi r_{tank}^2} \qquad \frac{dQ_{out}}{dt} = g \cdot n_{taps} \cdot \pi r_{taps}^2 \left(2g(h+z)\right)^{-1/2} \frac{dh}{dt} \qquad \frac{dn_{bottles}}{dt} = \frac{Q_{out}}{V_{bottles}}$$

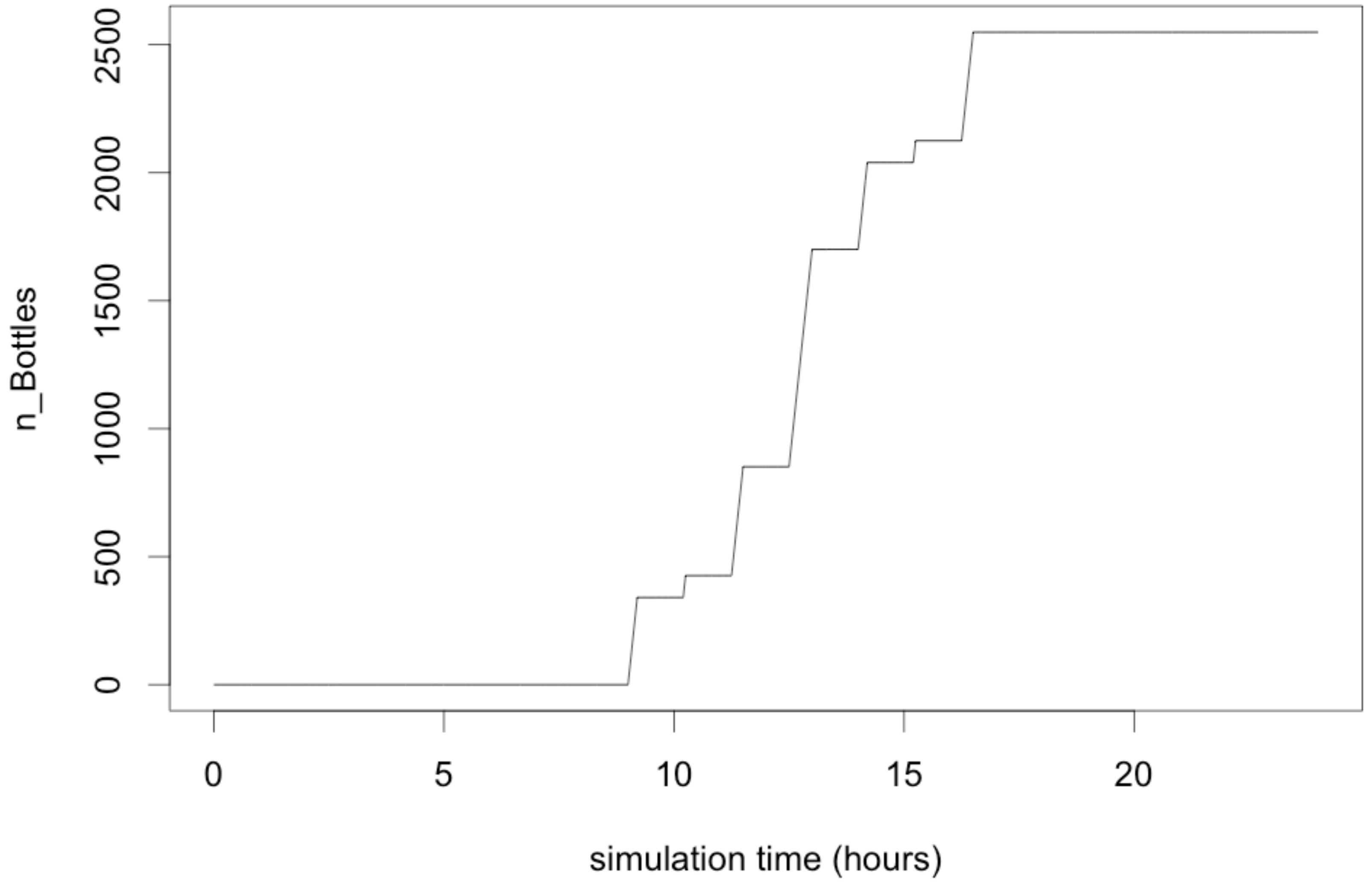
$$\frac{dT_{water}}{dt} = \frac{T_{soil} - T_{water}}{R_{ia,bottom} \cdot c_{i,bottom}} + \frac{T_{soil} - T_{water}}{R_{ia,side,soil} \cdot c_{i,side,soil}} + \frac{T_{air} - T_{water}}{R_{ia,side,air} \cdot c_{i,side,air}} + \frac{T_{air} - T_{water}}{R_{ia,top} \cdot c_{i,top}} + \frac{Q_{in}T_{in}dt + VT_{water} - Q_{out}T_{water}dt}{Q_{in}dt + V - Q_{out}dt} \cdot \frac{1}{dt} - \frac{T_{water}}{dt}$$

$$dc = \left[\left(\frac{Q_{in}c_{in}dt + Vc - Q_{out}cdt}{Q_{in}dt + V - Q_{out}dt} \right) + \left(k_{20} Q_{10}^{(T_{water} - T_{20})/10} c \right) dt \right] - c$$

SYSTEM BEHAVIOR







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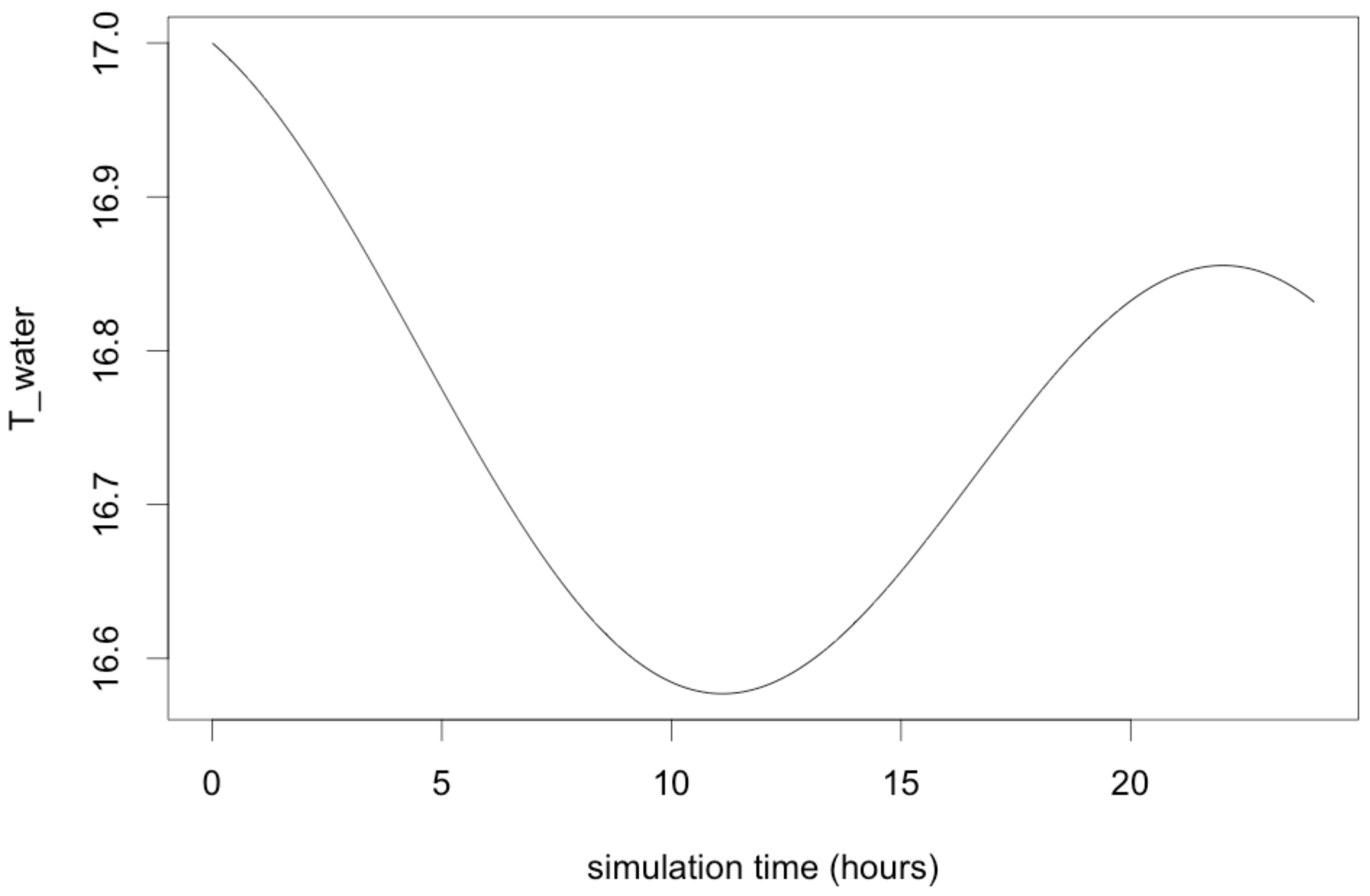

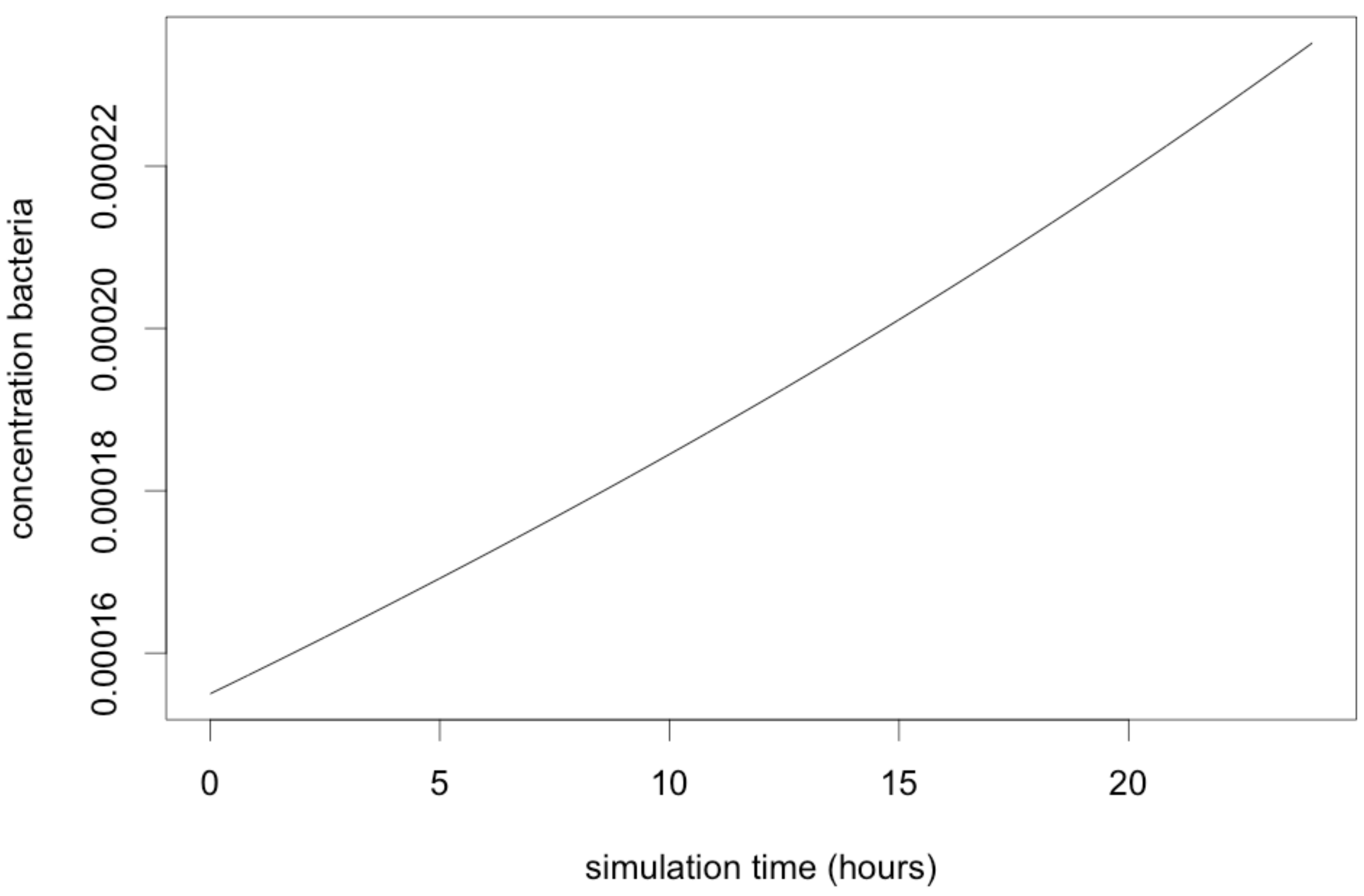

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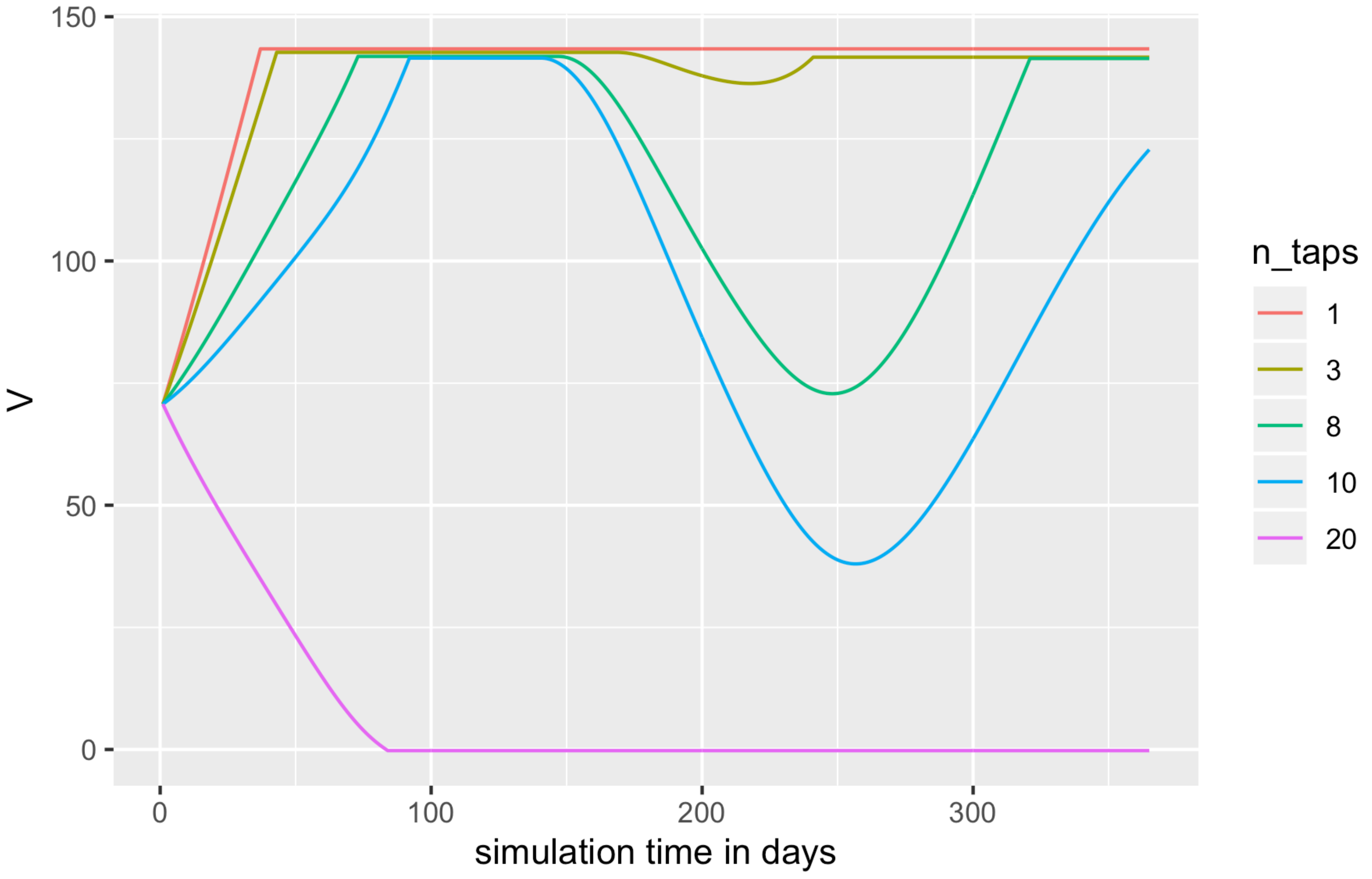
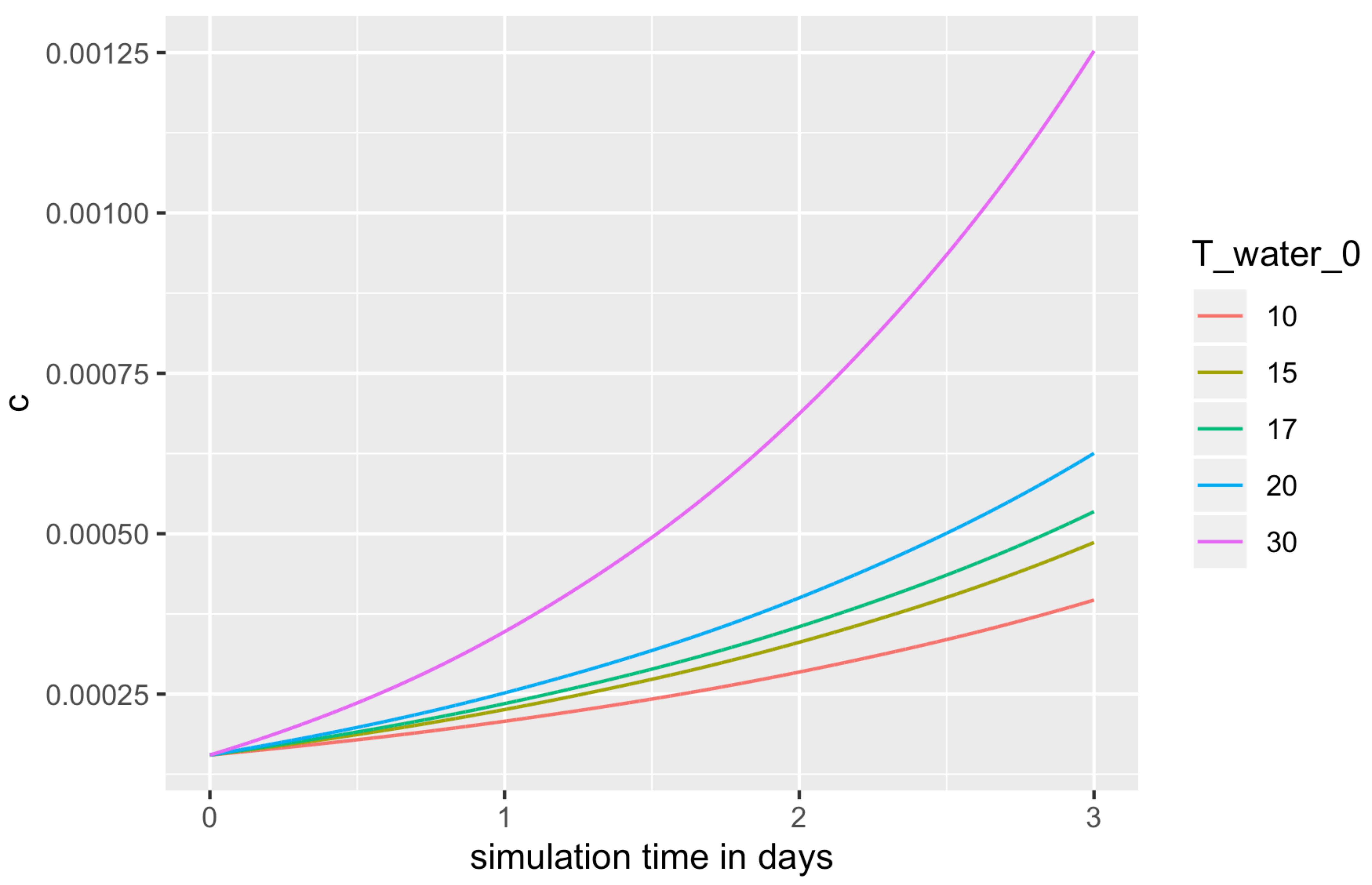
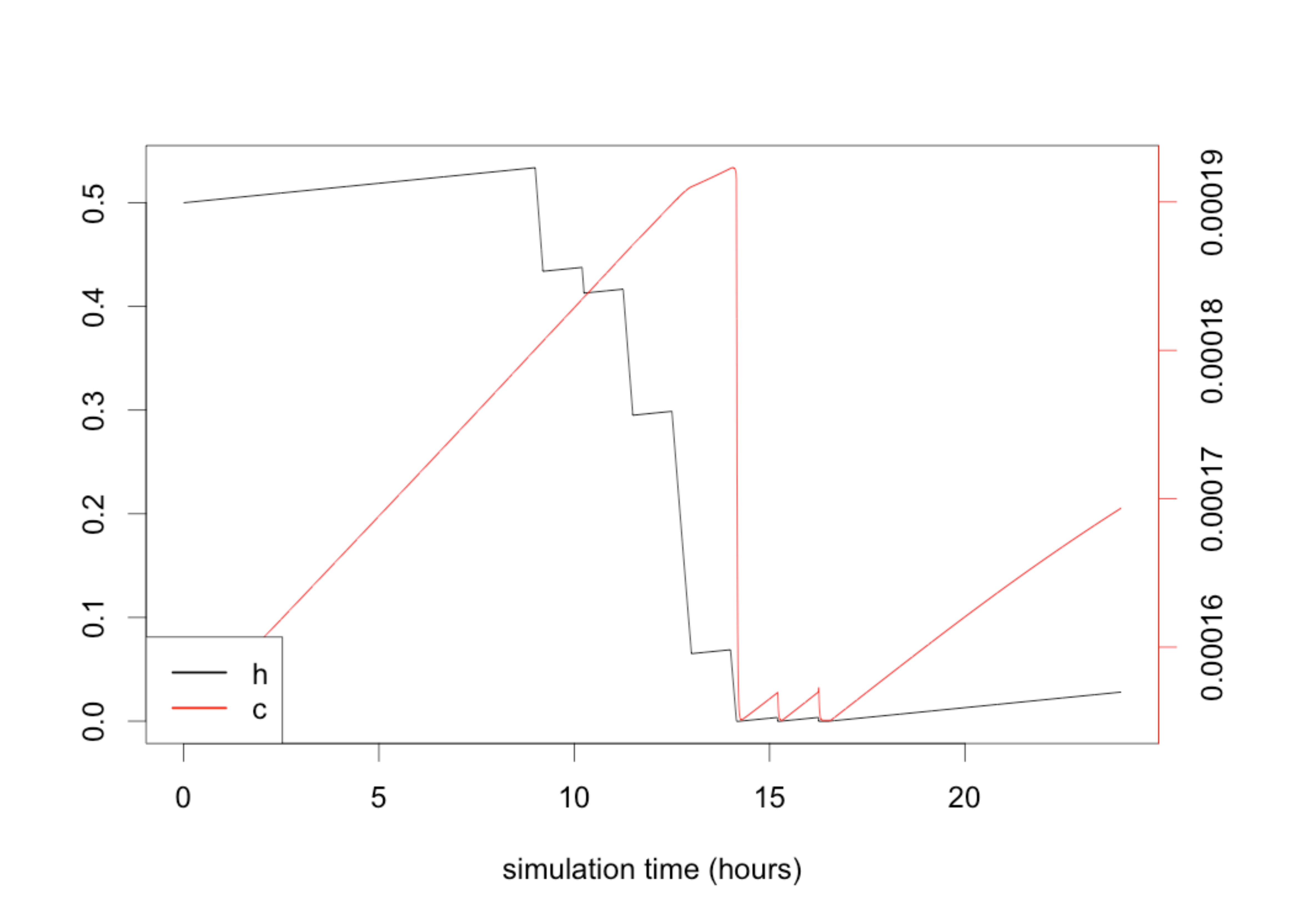




LIMITS OF THE SYSTEM

- ONLY ONE CISTERN INSTEAD OF MULTIPLE IN THE ORIGINAL PLAN
- DETERMINISTIC RAINFALL AND TEMPERATURE
- SIMPLIFIED SCHEDULE
- OUTFLOW WITHOUT PAUSES IN SCHOOL BREAKS
- SOLAR FLUX IS NEGLECTED
- NO BACTERIA ACCUMULATION ON THE MATERIAL



DISCUSSION OF RESULTS & HPC

✔ MORE THAN 2500 BOTTLES CAN BE DRAWN EACH DAY

✔ DRINKING TEMPERATURE IS REACHED IN THE LONG TERM

✔ BACTERIA CONCENTRATION LIMIT OF $25 * 10^{-4}$ IS REACHED EVERY COUPLE DAYS

THANK YOU FOR YOUR ATTENTION!