# There's more to filtration than stable operation: How knowledge about performance variations can be used to inform management of microbial risks

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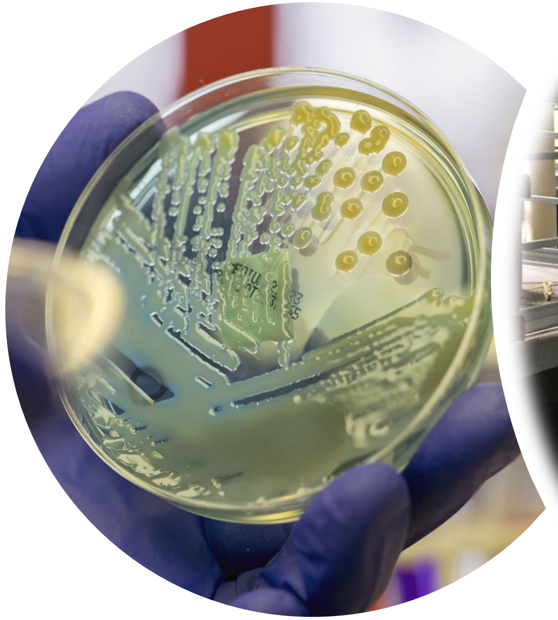
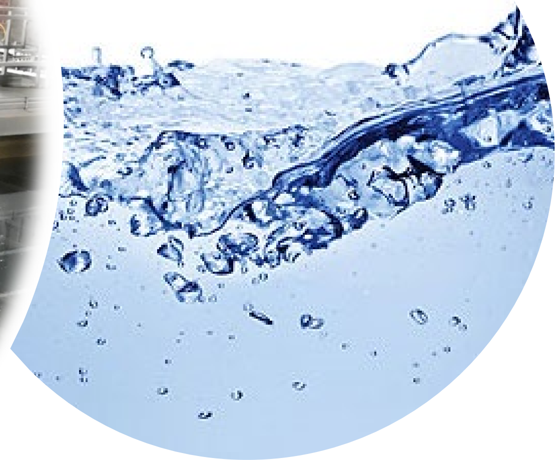
# Filtration and safe drinking water

**Granular media filtration**

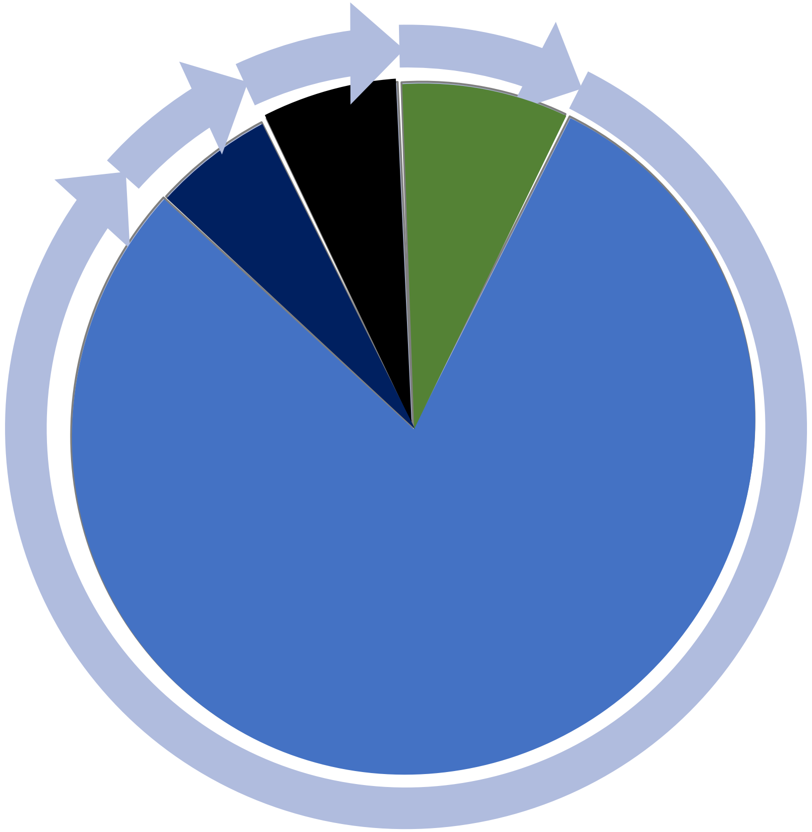


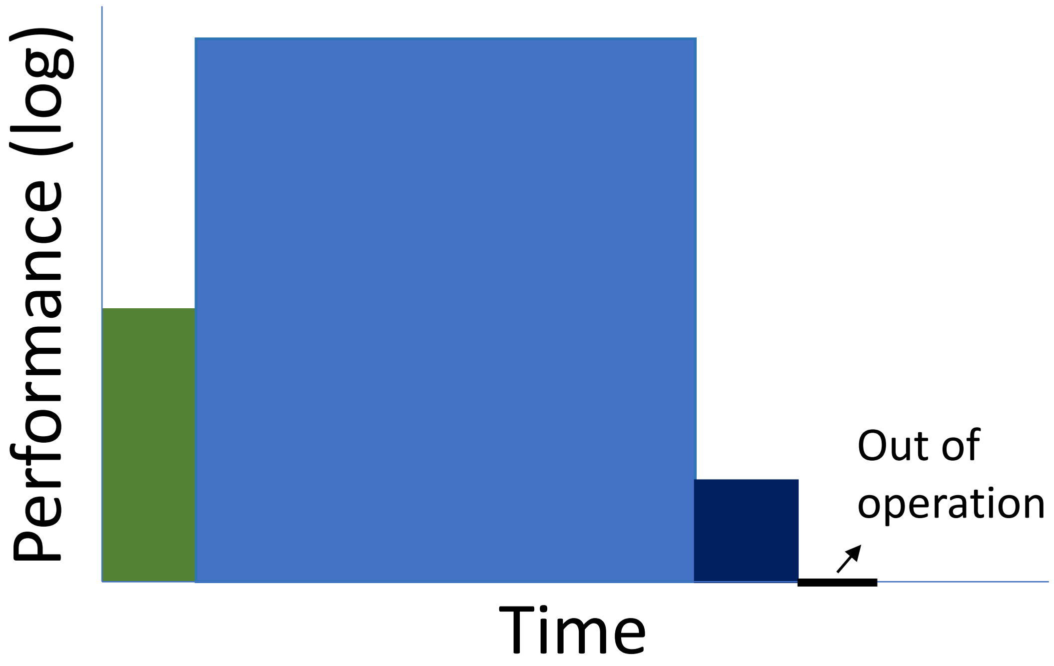


Source: Water STP

# Filtration: An inherently variable process

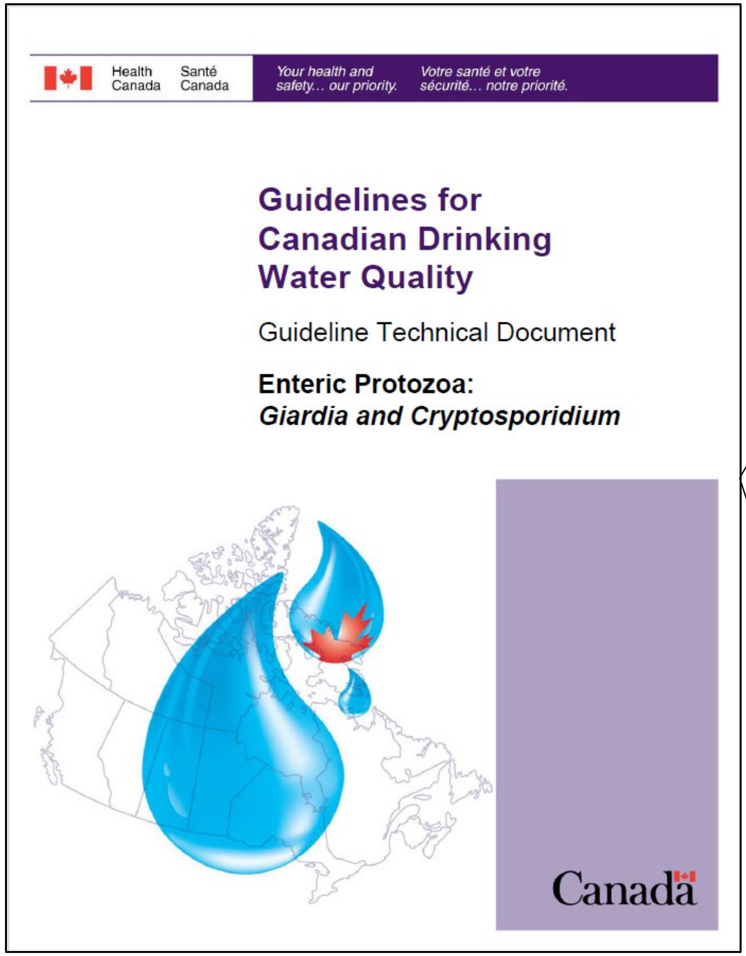
**FILTER CYCLE**






ripening | stable operation | breakthrough | backwashing

# Filtration: an inherently variable process




**Constant** log-removal credits

Optimizing removal during **stable operation**

**Table 6.** *Cryptosporidium* and *Giardia* removal credits for various treatment technologies

| Treatment barrier | *Cryptosporidium* removal credit | *Giardia* removal credit |
|---|---|---|
| Conventional filtration[a] | 3 log[b] | 3 log[b] |
| Direct filtration[a] | 2.5 log[b] | 2.5 log[b] |
| Slow sand filtration[a] | 3 log[b] | 3 log[b] |
| Diatomaceous earth filtration[a] | 3 log[b] | 3 log[b] |
| Microfiltration and ultrafiltration[a] | Demonstration and challenge testing[c] | Demonstration and challenge testing[c] |
| Nanofiltration and reverse osmosis[a] | Demonstration and challenge testing[c,d] | Demonstration and challenge testing[c,d] |
| Riverbank filtration | Site-specific determination[e] | Site-specific determination[e] |

[a] Credits are awarded when in compliance with the individual filter effluent turbidity specified in the Guidelines for Canadian Drinking Water Quality (Health Canada, 2012d)

[b] Values from Health Canada, 2012d.

[c] Removal efficiency demonstrated through challenge testing and verified by direct integrity testing.

[d] NF/RO membranes do not currently come equipped with direct integrity testing capability – acceptable verification methods should be approved by the jurisdiction having authority.

[e] As required by the jurisdiction having authority.

# Plants have multiple filters

Source: Water STP

# Objectives

**Evaluate how temporal variability in pathogen removal performance affects the combined, plant-scale performance of filters operated in parallel**

**Investigate the effects of alternative design and/or operational strategies to improve overall filtration performance**

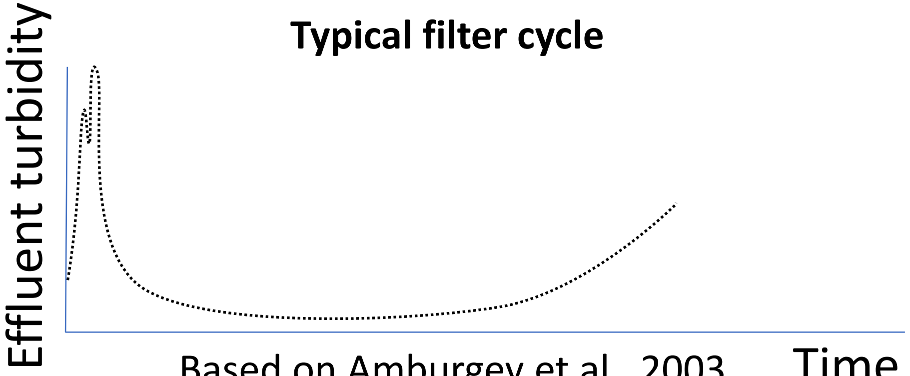
# Methods – Filter cycle

**Filter cycle variability – *Cryptosporidium* oocysts removal**

| Filter cycle phase | Duration (h) | Log-reduction |
|---|---|---|
| **Ripening** | 0.5 | 4.7 |
| **Stable operation** | 60 | 5.3 |
| **Early breakthrough** | 1 | 2.8 |
| **Late breakthrough** | 0.5 | 1.2 |
| **Backwash** | 0.5 | - |

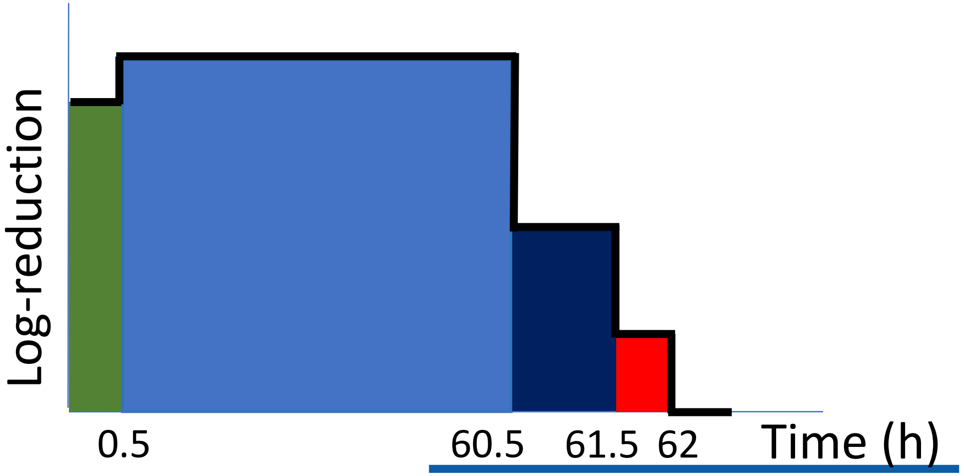
Based on Huck et al., 2001

https://www.waterrf.org/research/projects/filter-operation-effects-pathogen-passage

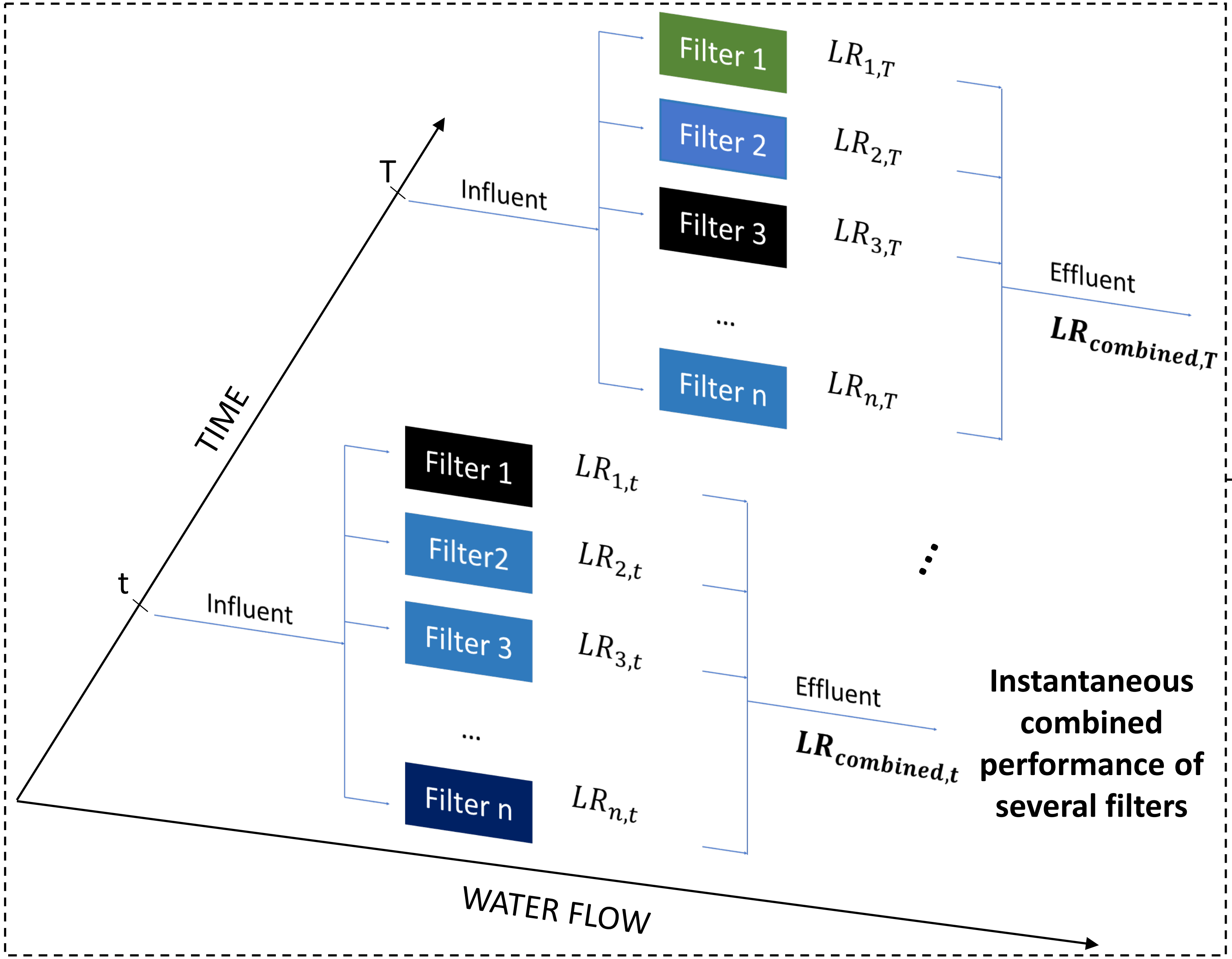



Based on Amburgey et al., 2003

https://doi.org/10.1002/j.1551-8833.2003.tb10513.x



# Methods - Performance assessment



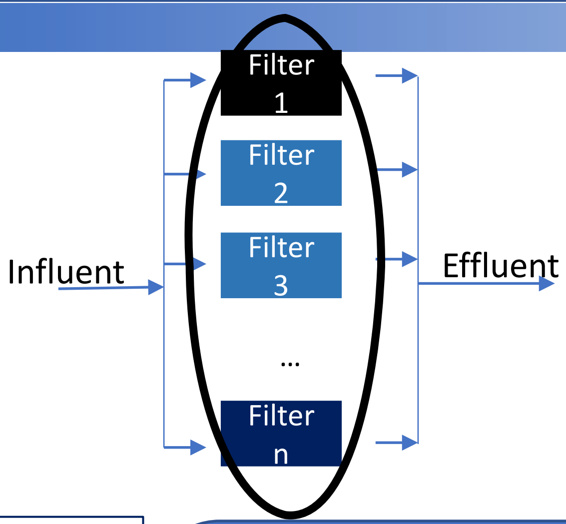

Effective log-reduction (Schmidt et al., 2020)

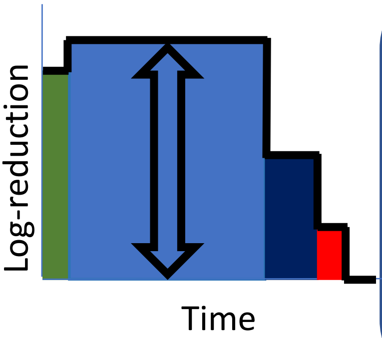
https://doi.org/10.1016/j.watres.2020.115702

**System performance over a full filter cycle $LR_{overall}$**

# Scenarios

Number of filters




Filter performance during stable operation

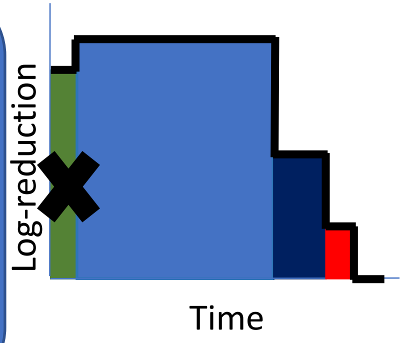
**Base case**

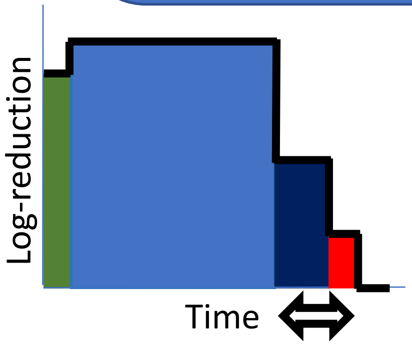
4 filters

Even backwash staggering

Filter cycle as described

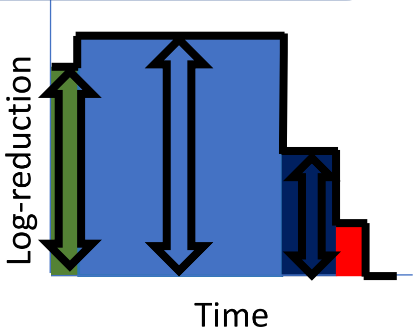
Filter-to-waste



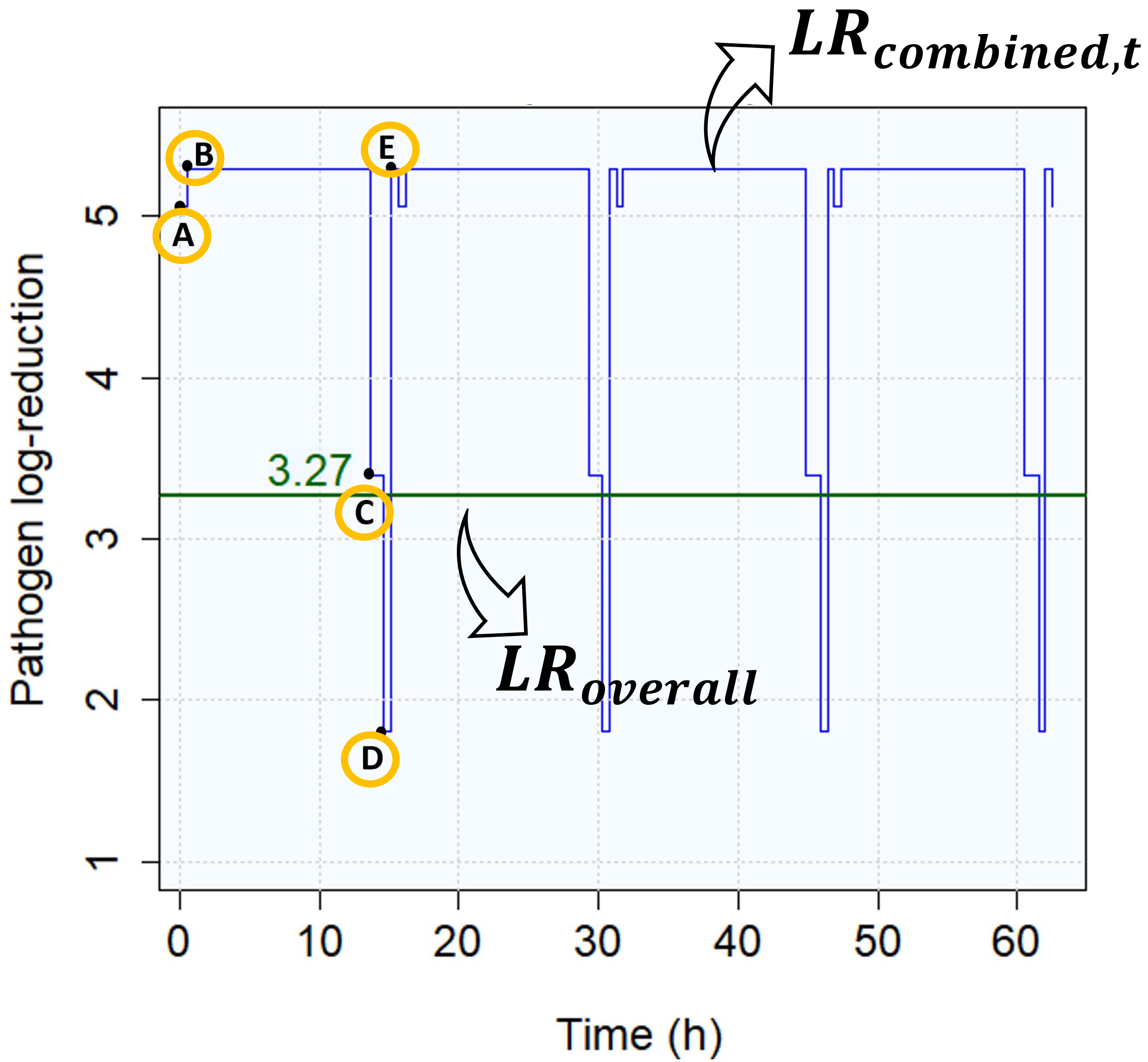




Duration of early / late breakthrough

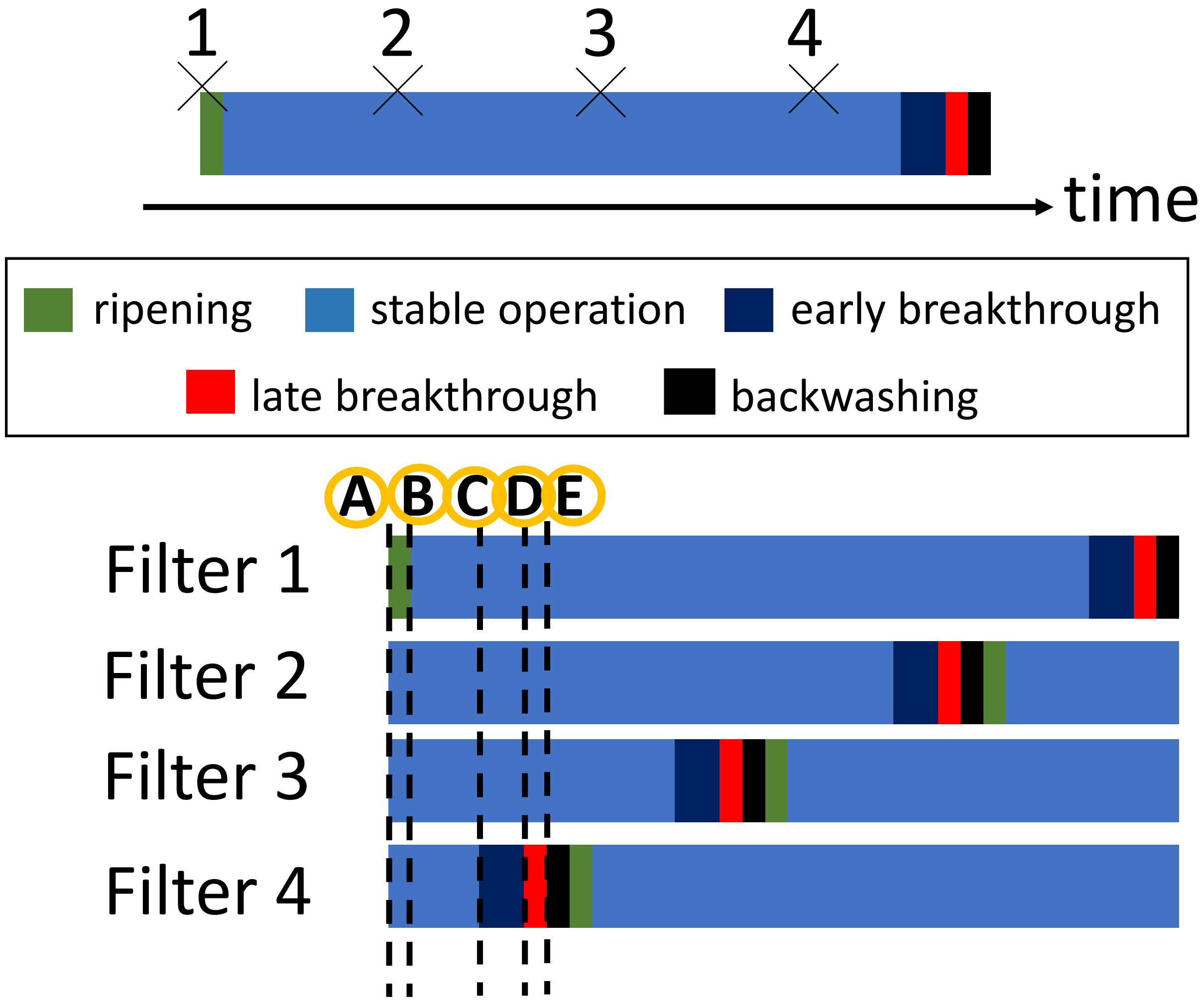
Coagulation



# Base case

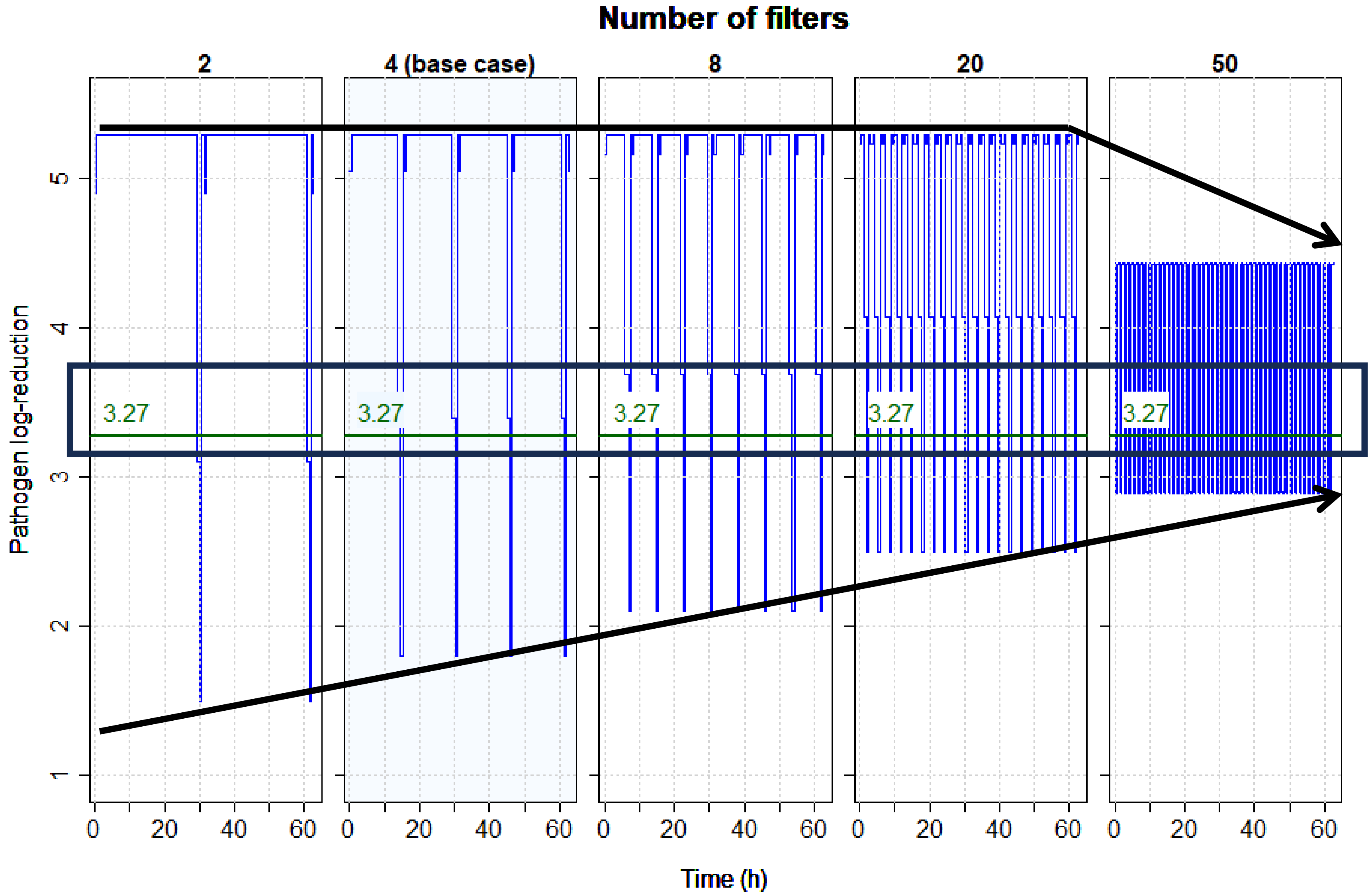


$LR_{combined,t}$
$LR_{overall}$
3.27
A
B
C
D
E
Pathogen log-reduction
Time (h)
0
10
20
30
40
50
60
1
2
3
4
5

1
2
3
4
time
ripening
stable operation
early breakthrough
late breakthrough
backwashing
A
B
C
D
E
Filter 1
Filter 2
Filter 3
Filter 4

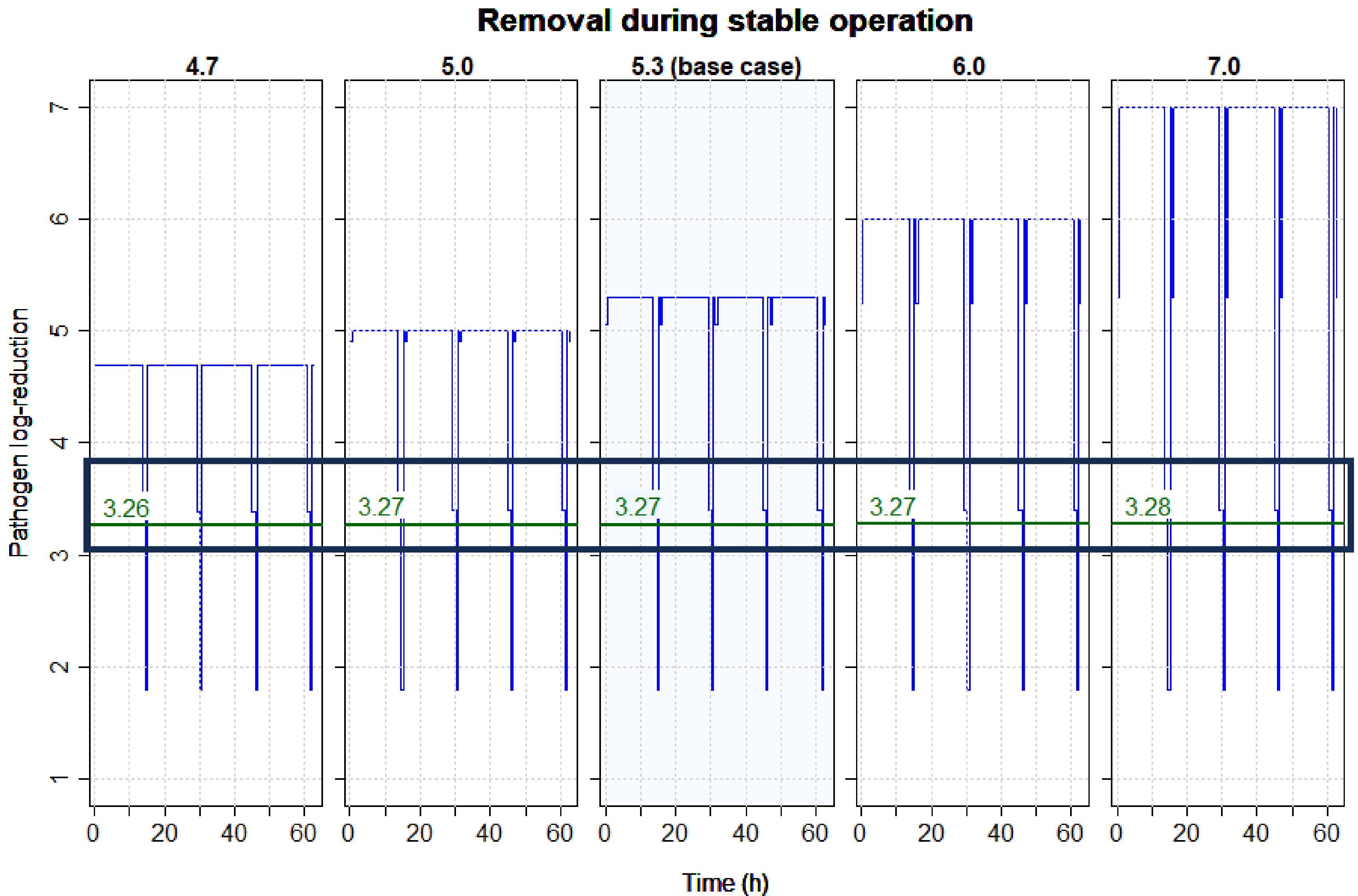
# Number of parallel filters




Same overall performance

Increasing number of filters attenuates variability

# Filter performance during stable operation




Negligible improvement on average if removal$_{MIN}$ << removal$_{MAX}$

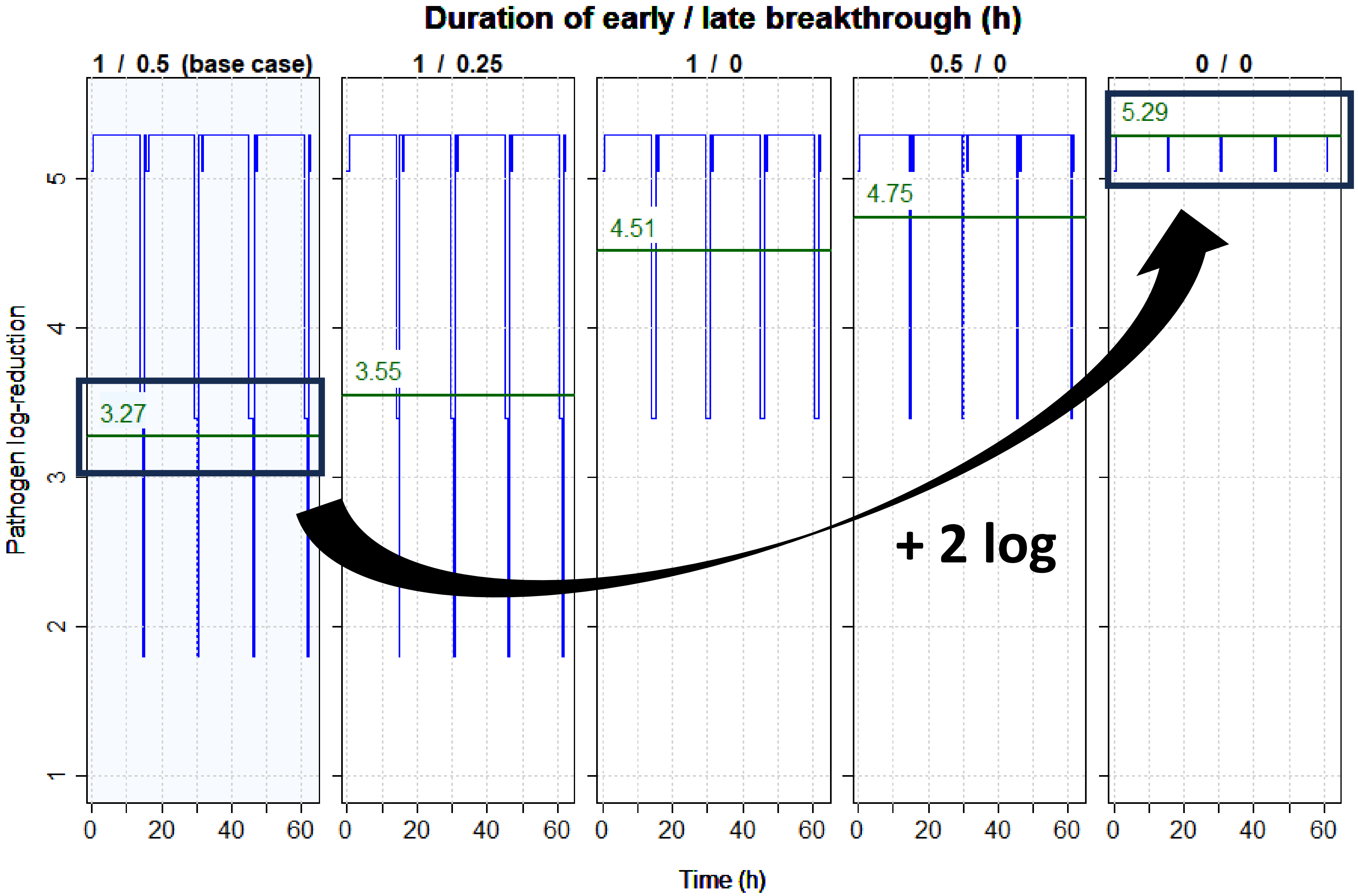
# Filter performance during stable operation

**Pathogen passage in the base case**

| Phase | Pathogen passage (%) |
|---|---|
| Ripening | 0.03 |
| Stable operation | 0.90 |
| Early breakthrough | 4.74 |
| Late breakthrough | 94.33 |

*If it is cold inside, don’t close your window if your door is open!*

# Duration of breakthrough

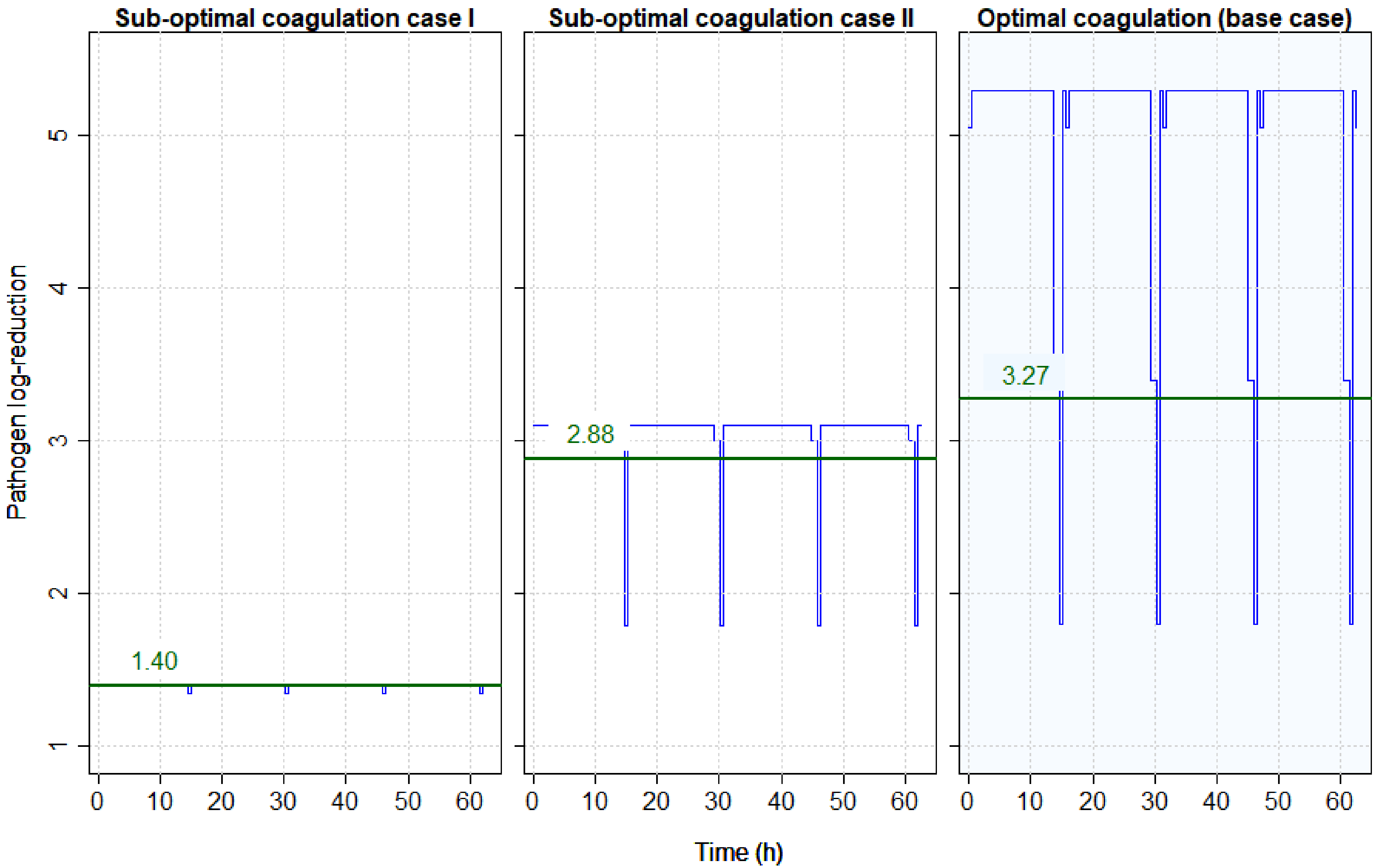



Reducing breakthrough leads to substantial increases in performance

Monitoring individual filter effluent

Timely backwashing

# Coagulation



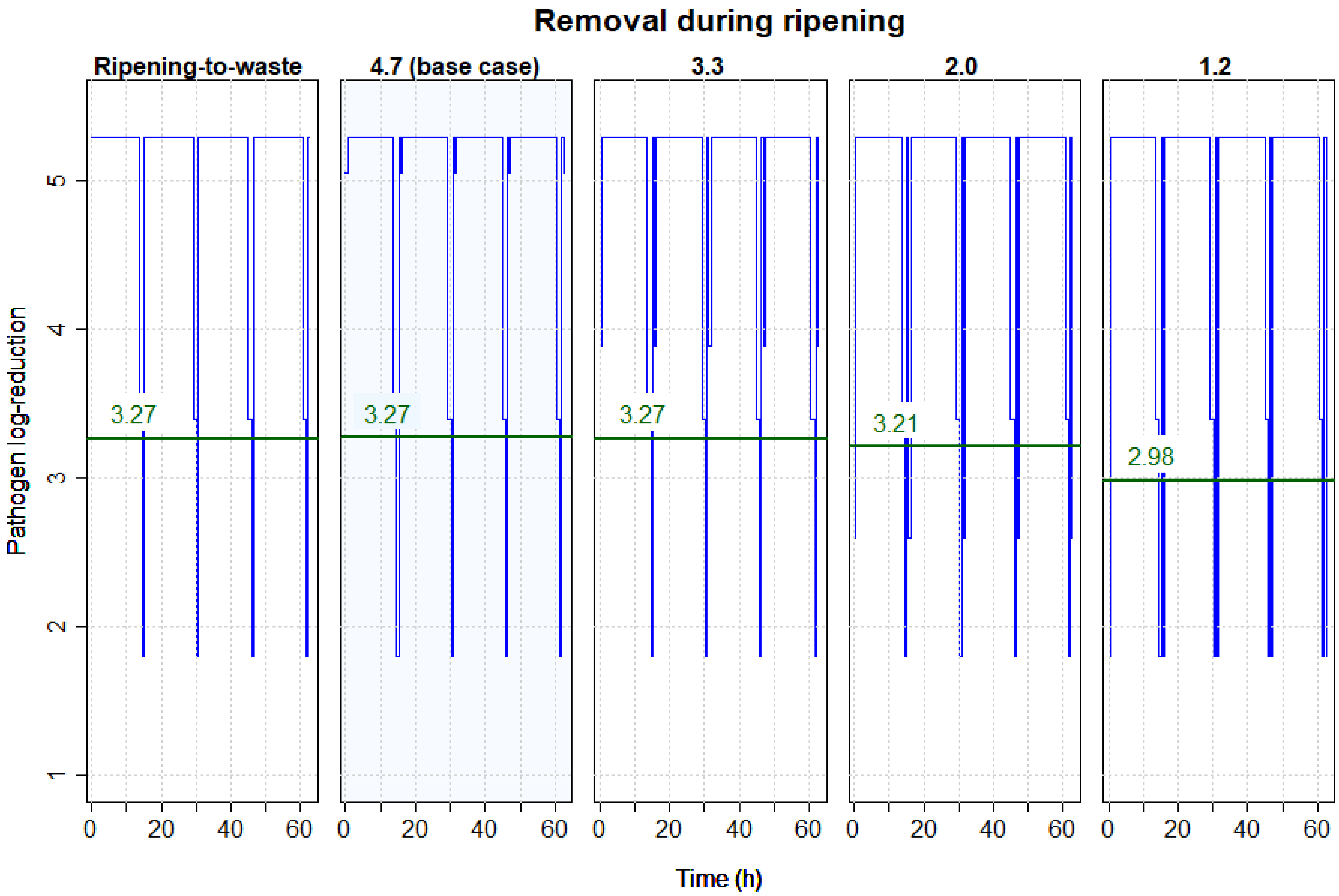

**Pathogen log-reduction**

| Scenario | R | SO | EB |
|---|---|---|---|
| No coagulation | 2.1 | **2.1** | 2.1 |
| Sub-optimal coagulation | 3.1 | **3.1** | 2.8 |
| Optimal coagulation | 4.7 | **5.3** | 2.8 |

R: ripening / SO: stable operation / EB: early breakthrough

Coagulation is important to plant-scale filtration performance

# Filter-to-waste operation




**Pathogen passage in the base case**

| Phase | Pathogen passage (%) |
|---|---|
| **R** | **0.03** |
| SO | 0.90 |
| EB | 4.74 |
| LB | 94.33 |

R: ripening / SO: stable operation / EB: early breakthrough / LB: late breakthrough

Beneficial if removal during ripening <<< overall removal during the remainder of the filter cycle

# Conclusions

- There is more to filtration than stable operation
- Filter cycle variability can be attenuated with more filters
- Individual filter monitoring, timely backwashing and optimal coagulation are important to plant-scale filtration performance
- Know your system!

# For more…

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ORIGINAL RESEARCH

AWWA WATER SCIENCE

## Filter operation effects on plant-scale microbial risk: Opportunities for enhanced treatment performance

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- **Number of filters**
- **Filter performance during stable operation**
- **Duration of early/late breakthrough**
- **Coagulation**
- **Filter-to-waste operation**
- Duration of stable operation
- Filter performance during breakthrough
- Backwashing staggering

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# Thank you

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