Multiple-Barrier Treatment: Pathogen Removal Reliability

Days per year at each overall log removal for a train of identical treatment barriers that fail at random, against one barrier giving the same normal removal.

Method: Independent random failures of identical barriers (binomial distribution)

Input parameters

Unit system: SI

Parameter	Value	Unit
Number of barriers in series	3.0000	
Log removal of each barrier when working	2.0000	
Share of time each barrier is in failure mode	2.0000	%
Share of normal removal achieved when failed	50.000	%
Required overall log removal	5.0000	

Calculated results

Parameter	Value	Unit
Overall removal with every barrier working	6.0000	
Days a year with no barrier failed	343.54	d
Days a year with exactly one barrier failed	21.033	d
Days a year with two or more failed	0.43216	d
Removal with every barrier failed	3.0000	
Expected overall removal	5.9400	
Days a year below the required removal	10.372	h
Same for one barrier giving the whole normal removal	175.20	h

Notes for this case

- Barriers fail independently and at random; a failed barrier achieves the stated share of its normal removal. The comparison is a single barrier with the whole normal removal and the same failure behaviour.

Formula and method

$$P(k) = \binom{n}{k} p^k (1-p)^{n-k}, \quad LR_k = (n-k)LR + k\,\phi\,LR$$

$$t_{<target} = 365\,\mathrm{d} \sum_{LR_k < LR_{target}} P(k)$$

Variables

n	Number of barriers in series	-
LR	Log removal of each barrier when working	-
p	Share of time each barrier is in failure mode	-
ϕ	Share of normal removal achieved when failed	-
LR_{target}	Required overall log removal	-
LR_{normal}	Overall removal with every barrier working	-
t_0	Days a year with no barrier failed	s
t_1	Days a year with exactly one barrier failed	s
$t_{\geq 2}$	Days a year with two or more failed	s

LR_{min}	Removal with every barrier failed	-
$\overline{LR}$	Expected overall removal	-
$t_{<target}$	Days a year below the required removal	s
$t_{<target,1}$	Same for one barrier giving the whole normal removal	s

Method and standards

Binomial model of independent barrier failures with partial removal when failed.

Assumptions and limits

- Identical barriers; independent failures; steady removal values.

References

Independent random failures of identical barriers (binomial distribution)

Report details

Report reference	FCC-CX0A-8WSW (the same inputs always give the same reference)
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Release checks	4 reference cases of this calculator, computed independently, are checked on every release

Results are for engineering estimation. Verify critical designs against the referenced standards and your own data.

This calculator online

https://calc.firecad.com/environmental/drinking-water/multiple-barrier-reliability

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.