

1 **Supporting Information**

2 **Role of Microbial Cell Properties on Bacterial Pathogen and**  
3 **Coliphage Removal in Biochar-modified Biofilters**

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5 *Environmental Science: Water Research and Technology*

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Table S1: Physicochemical properties of the collectors <sup>1</sup>

Properties	Biochar			Sand	
Water Contact Angle (°)	106.5±1.5			Completely wetting	
Roughness (nm)	Stylus Force (mg)	R <sub>a</sub>	R <sub>q</sub>	R <sub>a</sub>	R <sub>q</sub>
	1	41.4±22.6	75.5±41.6	0*	0*
	3	92.4±71.9	111.1±81.9	0*	0*
	8	0*	0*	3510.8±365.8	3706.6±391.4
Specific Surface Area (m <sup>2</sup> /gm)	104.64±7.80			0.20±0.04	

34 \*indicates indeterminable data either because of too low (sand) or too high (biochar) stylus force.

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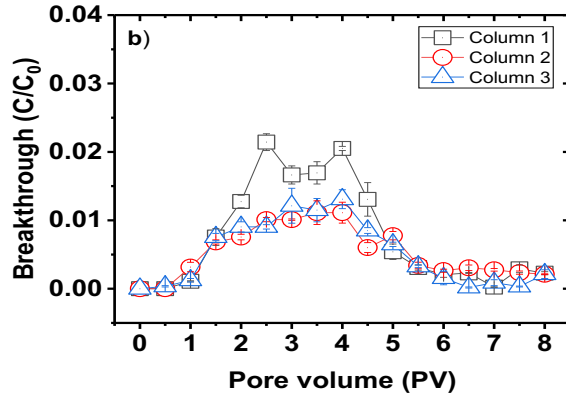
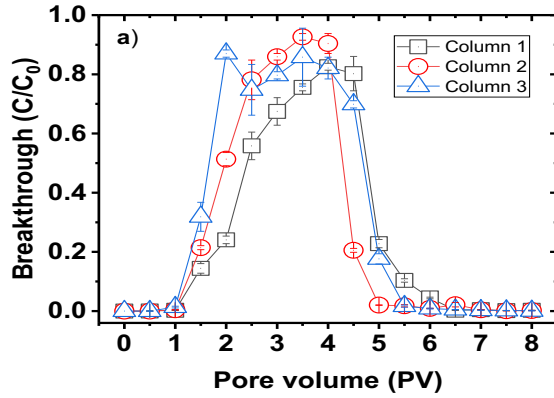
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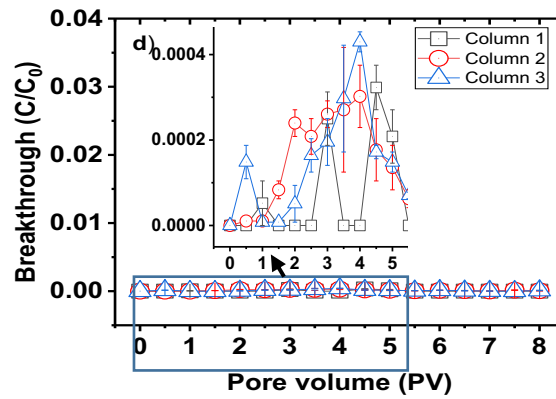
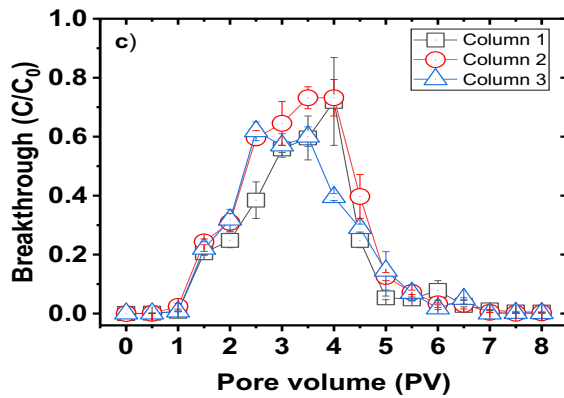
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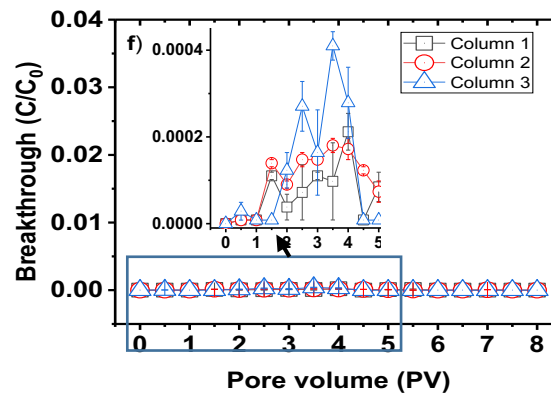
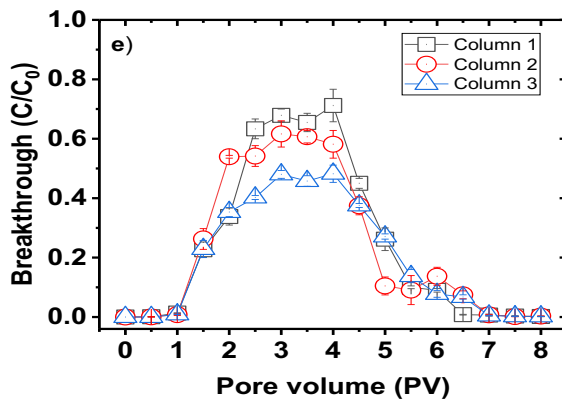
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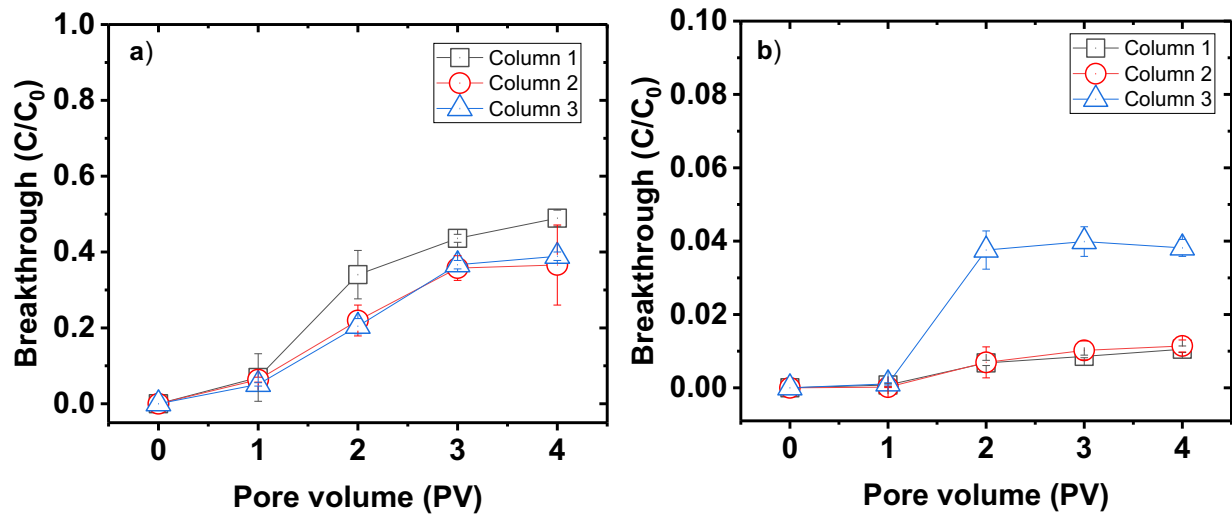
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50 Fig S1. Bacterial transport in 15 x 2.5 cm (sand or biochar-amended sand packed) laboratory  
 51 biofilter columns. a) *E. coli* transport in sand; b) *E. coli* transport in biochar-amended sand; c)  
 52 *Salmonella* transport in sand; d) *Salmonella* transport in biochar-amended sand; e) *Staphylococcus*  
 53 transport in sand; f) *Staphylococcus* transport in biochar-amended sand. Breakthrough curves for  
 54 *Salmonella* (Figure d) and *Staphylococcus* (Figure f) are small compared to *E. coli* (Figure b):

55 hence the breakthrough curves for *Salmonella* and *Staphylococcus* are enlarged and shown as  
56 insets. Error bars represent standard deviation between replicate technical measurements ( $n = 2$ ).  
57 All experiments were conducted at room temperature.

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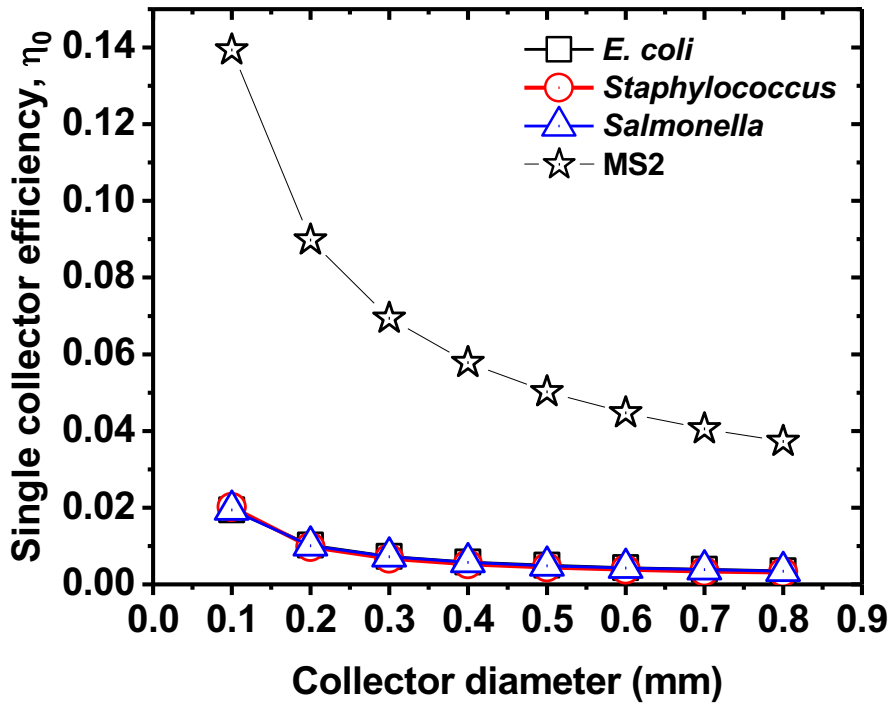
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61 Fig S2. MS2 coliphage transport in 15x2.5 cm (sand or biochar-amended sand packed) laboratory  
62 biofilter columns. a) MS2 transport in sand; b) MS2 transport in biochar-amended sand. Due to  
63 resource limitations, only half the breakthrough curves were analyzed. Error bars represent  
64 standard deviation between replicate technical measurements (n = 2). All experiments were  
65 conducted at room temperature.

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70 Figure S3: Theoretical total single collector contact efficiency of the collectors for the bacteria  
 71 and bacteriophage used in this study. Total contact efficiency is a summation of the efficiencies  
 72 obtained from Brownian diffusion, interception, and sedimentation. Individual contact  
 73 efficiencies were calculated using the correlation equation described in equation 2. The average  
 74 hydrodynamic diameter values of the microbial particles were used for calculating the collector  
 75 efficiency. The Hamaker Constants were assumed to be  $6.5 \times 10^{-21}$  for the bacteria and  $3.64 \times 10^{-21}$   
 76 for the bacteriophage.

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82 **DLVO modeling details.** DLVO forces were calculated using adapted Wiese and-Healy  
 83 expression for a sphere–flat plate system <sup>2, 3</sup>. Following equations are used to make the  
 84 computation:

$$85 \quad V_{EDL} = 2\pi a n_{\infty} K T \frac{\Phi_p^2 + \Phi_e^2}{2} \left[ \left( \frac{2\Phi_p \Phi_e}{\Phi_p^2 + \Phi_e^2} * \ln \frac{1 + \exp(-\kappa h)}{1 - \exp(-\kappa h)} \right) + \ln(1 - \exp(-2\kappa h)) \right]$$

$$86 \quad \Phi_i = \frac{Z e \Psi_i}{4 K T}$$

$$87 \quad \kappa = \left( \frac{e^2 \sum n_{i,\infty} z_i^2}{\epsilon \epsilon_0 K T} \right)^{0.5}$$

$$88 \quad V_{VdW} = -\frac{A_{123}}{6} \left[ \frac{a}{h} + \frac{a}{h+2a} + \ln\left(\frac{h}{h+2a}\right) \right]$$

$$89 \quad V_{Tot} = V_{EDL} + V_{VdW}$$

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91 Where,

92  $V_{EDL}$  = Electrical double layer repulsive energy

93  $V_{VdW}$  = Van-der-Waals attractive energy

94  $V_{Tot}$  = DLVO energy barrier

95  $a$  = Radii of microbial cells = 742 nm for *E. coli*; 944 nm for *Staphylococcus*; 770 nm for  
 96 *Salmonella* and 35.5 nm mV for MS2.

97  $e$  = Negative charge of an electron =  $1.6 * 10^{-19}$  C

98  $n_{i,\infty}$  = Equivalent concentration of electrolyte  $i$

99  $z_i$  = Valence of electrolyte  $i$

100  $n_{\infty}$  = Bulk electrolyte density of the stormwater = 4.7 mM equivalent (using the recipe of the  
 101 synthetic stormwater)

102  $Z = 1$  (using the recipe of the synthetic stormwater for a 4.7 mM ionic strength)

103  $K$  = Boltzmann constant =  $1.38 \times 10^{-23}$  m<sup>2</sup> kg s<sup>-2</sup> K<sup>-1</sup>

104  $T$  = Temperature = 298 K

105  $\Psi_p$  = Average Zeta potential of biochar particles in stormwater = -19.6 mV

106  $\Psi_c$  = Zeta potential of microbial cells in stormwater = -23.4 mV for *E. coli*; -21.2 mV for  
 107 *Staphylococcus*; -11.7 for *Salmonella* and -13.7 mV for MS2.

108  $\epsilon_0$  = Permittivity of vacuum =  $8.854 \times 10^{-12}$  F/m

109  $\epsilon$  = Relative permittivity of water = 80

110  $h$  = Separation distance = 1-30 nm (dependent variable)

111  $A_{123}$  = Hamaker constant =  $6.5 \times 10^{-21}$  J for collector-water-bacteria<sup>4</sup> and  $3.64 \times 10^{-21}$  for collector-  
112 water- MS2<sup>5</sup>

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114 **Collector efficiency and deposition rate constant calculation:**

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$$\eta_0 = 2.4A_s^{0.333}N_R^{-0.081}N_{Pe}^{-0.715}N_{vdW}^{0.052} + 0.55A_sN_R^{1.675}N_A^{0.125}$$

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$$+ 0.22N_R^{-0.24}N_G^{1.11}N_{vdW}^{0.053}$$

118 
$$K_d = \frac{3(1-f)V\alpha\eta_0}{2fd_c}$$

119 Values of  $A_s$ ,  $N_R$ ,  $N_{Pe}$ ,  $N_{vdW}$ ,  $N_A$ , and  $N_G$  were calculated using the equations described in the  
120 literature<sup>6</sup> and the following values for corresponding parameters:

121  $f$  = porosity of the column = 0.39 for sand columns and 0.44 for biochar columns

122  $d_c$  = diameter of the collectors = 0.718 for sand; and a range of diameter (0.5 to 0.04 mm) for biochar  
123 to account for various percentage as revealed by the sieve analysis: the deposition coefficient was  
124 calculated as a weighted average of the deposition coefficient for each size range of biochar  
125 particles.

126  $V$  = flow velocity =  $3.53 \times 10^{-21}$  m/s

127  $\mu$  = dynamic Viscosity of stormwater,  $\mu = 0.001$  Pa.S

128  $\rho$  = relative density of the microbial cells, assumed 1.105 for bacteria<sup>7</sup> and 1.38 for MS2<sup>8</sup>

129  $\alpha$  = attachment efficiency = assumed 1 for all microbes

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132 **Theoretical log removal value (LRV) calculation:**

133 To calculate the theoretical log removal for a 15-cm column packed with 70:30 mix of sand and  
 134 biochar, we assumed 70 % length of the column (10.5 cm) is packed with sand and the rest is  
 135 packed with biochar. We estimated the log removal in the sand portion and the biochar portion  
 136 individually and added them to obtain the total LRV for the biochar-amended biofilters. The LRV  
 137 was calculated using the following equation

$$138 \quad LRV = \frac{fLK_d}{2.303V}$$

139 Where  $f$  is the porosity of the packed media,  $L$  is the length of the column,  $K_d$  the deposition rate  
 140 constant, and  $V$  the flow velocity.

141 Table S2: LRV in 4.5 cm biochar biofilter

Microbe	Column Porosity	Column Length (m)	Deposition Rate Constant (1/s)	LRV
Staph	0.44	0.045	0.001328	-0.32341
E. coli	0.44	0.045	0.001726	-0.42048
Salmonella	0.44	0.045	0.001749	-0.42604
Virus	0.44	0.045	0.016546	-4.03062

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143 Table S3: LRV in 10.5 cm sand biofilter

Bacteria	Column Porosity	Column Length (m)	Deposition Rate Constant (1/s)	LRV
Staph	0.39	0.105	0.000459	-0.23102
E. coli	0.39	0.105	0.000519	-0.26173
Salmonella	0.39	0.105	0.000529	-0.26639
Virus	0.39	0.105	0.005286	-2.66312

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