An Electroporation Device with Microbead-Enhanced Electric Field for Bacterial Inactivation

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S1. DEP Response

The time-averaged dielectrophoresis force experienced by the particles is given by (Pethig 2010)

$$F_{DEP} = 2\pi R^3 \varepsilon_m \operatorname{Re}\left(\frac{\varepsilon_p^* - \varepsilon_m^*}{\varepsilon_p^* + 2\varepsilon_m^*}\right)\nabla\left|E^2\right| \qquad 1$$

where $\nabla\left|E^2\right| = \nabla(E \bullet E^*)$ is the gradient of the squared electric field, $F_{cm} = \frac{\varepsilon_p^* - \varepsilon_m^*}{\varepsilon_p^* + 2\varepsilon_m^*}$ is the Clausius–Mossotti (CM) factor, and $\varepsilon^* = \varepsilon - j(\sigma / \omega)$ is the complex permittivity. Based on the sign of the CM factor, DEP can be of two types: negative DEP (nDEP) or positive DEP (pDEP). For the DC field ($\omega = 0$) cases, the CM factor can be calculated as

$$F_{cm} = \frac{\sigma_p - \sigma_m}{\sigma_p + 2\sigma_m}.$$

Under a DC electric field, cells act as perfect insulators, $\sigma_p = 0$, which results in F_{cm} being −0.5. This suggests that bacterial cells experience nDEP inside our device under a DC electric field. Meanwhile, for an AC field, F_{cm} changes with frequency as shown in Figure S1. The plot suggests that for AC electric fields, bacteria experience pDEP under our operating conditions.

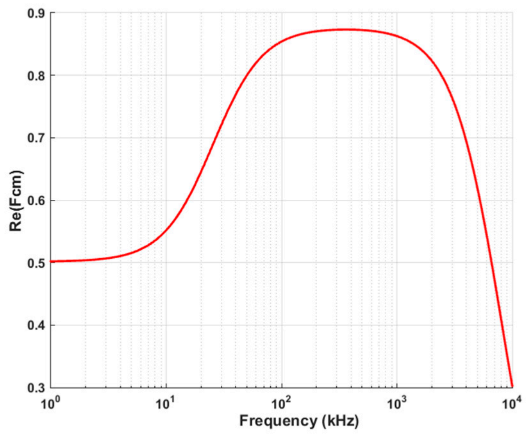

Figure S1: The Clausius–Mossotti (CM) factor calculated for live *E. coli* suspended in DI water for various frequencies.

S2. Our Electroporation Device and Setup

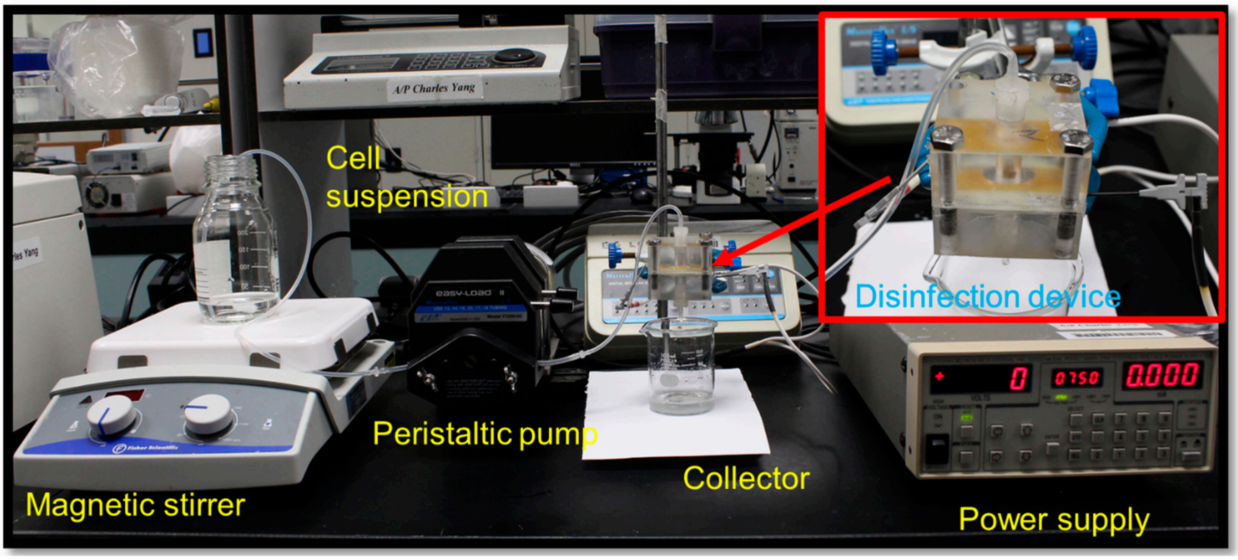

Figure S2: Actual setup with an enlarged view showing the electroporation device with electrical connections and fluidic access.

S3. Energy Consumption Estimation

HRT (s)	Flux (mL/s)	Voltage (V)	Current (mA)	Energy consumption (kJ/L)
6.08	0.06	400	2.15	12.90

$$Energy\ consumption = \frac{V * I}{Flux}$$