

Description of Additional Supplementary Files

Supplementary movie 1: This movie illustrates the dynamics of streamlines in the local PR region for sic packing. The color of the streamlines represents bacterial concentration, with red indicating higher concentration and black indicating lower concentration. Around $T = 150$ minutes, precipitation forms in the upper part of the local region, obstructing bacterial transport along the y -direction. This restriction limits bacterial spatial diffusion and reduces local mixing, thereby inducing an inverse correlation between the mixing rate and vortex strength (see Fig. 10c in the manuscript).

Supplementary movie 2: This movie illustrates the dynamics of streamlines in the local CR region for fcc packing. After $T = 400$ minutes, precipitation-induced blockage intensifies within the CR region, reducing pore channels connectivity and suppressing the enhancement of Ca^{2+} mixing (see Fig.S13g in the Supplementary information). This indicates that precipitation not only alters fluid flow patterns but also diminishes the ability of vortices to promote mixing.

Supplementary movie 3: This movie illustrates the dynamics of three-dimensional structures visualized using the Liutex for bcc packing.

Supplementary movie 4: This movie illustrates the dynamics of three-dimensional structures visualized using the Liutex for fcc packing.

Supplementary movie 5: This movie illustrates the dynamics of three-dimensional structures visualized using the Liutex for sic packing.

Supplementary movie 6: This movie illustrates the dynamics of three-dimensional structures visualized using the Liutex for mbf packing.