A Fluidic Hourglass

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Solid or semi-solid objects passing through geometric constrictions tend to get eventually stuck. It occurs no matter what type of object you consider: sand in an hourglass, particles in a fluid through a porous medium or people leaving a room in panic. However, it is well-known that hourglasses work optimally when the particle-to-neck ratio is within certain ratio without interruption, while arching occurs for particle-to-neck ratios above $d/D \approx 1/2$. In the case of porous mediums, filters and membranes, these get easily clogged by particles in the fluid and therefore become unfunctional after a certain amount of time. Being the only solution the replacement of the membrane/filter. Certainly the adherence of the particles to the walls and to each other is an important parameter [1], but even without adherence, the clogging probability is far from negligible. To study these regimes, we study microfluidic devices with a bottleneck of squared cross-section through which we force dilute polystyrene particle solutions with diameters comparable to the bottleneck size and down to one tenth its size.

The experimental results show that particles flowing through a geometrical constriction in these conditions (as it occurs with the flow in certain filters and membranes) have strong statistical similarities with granular systems (hourglasses or silos [2, 3], for example). The results show very clearly that the clogging events can be described as an almost purely stochastic process that can be described using a simple statistical model. This allows us to propose scalings and rules-of-thumb for designing constrictions with negligible clogging probabilities.

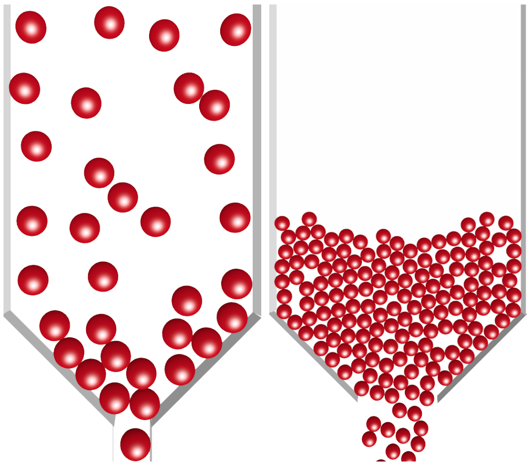

FIG. 1. Left: Illustration of a case of particle-to-neck diameter $d/D \approx 1$, in which clogging is highly probable even in the absence of adherence. Right: Illustration of a case of particle-to-neck diameter $d/D \approx 1/4$, in which clogging is hardly visible even at high particle concentrations.

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