Upstream contamination in water pouring

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We report the observation of upstream transport of floating particles when clear water is poured on the surface of a flat water surface on which mate or chalk particles are sprinkled. As a result, particles originally located only at the surface of the lower container can contaminate the upper water source by "riding" on vorticial water currents. We speculate that Marangoni forces in combination with geometry-induced vortices may explain the observed phenomenon.

We briefly report a phenomenon apparently not previously reported in the literature, which may have potential implications in many chemical, medical, pharmaceutical and industrial processes.

The phenomenon was first observed during the preparation of the typical Argentinian drink, mate, when hot water was poured, from a pot, on a water surface “contaminated” with floating mate particles (each particle is like a grass leaf of an average area near $0.5 \text{mm}^2$). If the column of falling water was short enough (say, under $1 \text{cm}$-height), particles of mate were observed to “swim up the stream”, actually reaching the originally “uncontaminated” water pot.

We checked that the phenomenon could take place with the two water containers at room temperature, and that chalk particles (instead of mate leaves) worked as well.

In order to perform controlled experiments, we constructed a “pouring setup” illustrated in Figure 1. A flux of water in the range 0-15 cm$^3$/s flows along a 62-mm-long horizontal channel shaped as a half cylinder of 20 mm radius. As the water reaches the edge of the channel, it falls on a large container of water, whose surface is at a distance $h$ underneath the edge of the channel (all parts are made of aluminium). For distances of the order of 1 cm or less, some of the floating particles eventually start to “climb up the stream” and invade the channel, as part of one of the two elongated vortices appearing along the two sides of the channel. The vorticity is such that the upstream particles flow near the edges of the channel, while the downstream particles flow near the center of the channel (see Fig 2). Apparently, the vortices continue along the free falling stream, and reach the water surface in the lower reservoir.

While our vortices resemble those well-known to occur in horizontal channels due to edge effects [1], their existence has not been reported, as far as we know, in connection to falling streams of water. We speculate that the “upstream” vortex formation could be reinforced by a Marangoni-type force [2] associated to a decrease of the surface tension in the lower reservoir due to particle addition. To explore this possibility, we measured the influence of different surface densities of mate and chalk particles on the surface tension of water, using the Ring Method [3]. As seen in Fig 3, we have demonstrated that the surface tension decreases as the surface density increases for both materials.

We are currently performing experiments on a hori-
horizontal channel connecting two water reservoirs, where a water stream is imposed from right to left. Then, we add mate or chalk particles to the left container, and study the vortices appearing in the channel by tracking the floating particles. The idea is to experimentally evaluate under what conditions such vortices can persist when as the horizontal setup “evolves” into the water-pouring channel geometry.

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FIG. 3: Dependence of the surface tension of water on the superficial density of mate and of chalk particles, measured using the ring method.

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