Fluid fragmentation from hospital toilets

G. Traverso[1,2], S. Laken[3], C.-C. Lu[4], R. Maa[5], R. Langer[2,5], and L. Bourouiba*[6,7]

[1]MGH Division of Gastroenterology and Harvard Medical School
[2]Koch Institute for Integrative Cancer Research, MIT
[3]Pavoda, Inc.
[4]ENSTA ParisTech
[5]Department of Chemical Engineering, MIT
[6]Department of Mathematics, MIT
[7]Department of Civil and Environmental Engineering, MIT

Hospital-acquired infections represent significant health and financial burdens to society. Hospital-acquired *Clostridium difficile* (*C. difficile*) is a particularly challenging bacteria with the potential to cause severe diarrhea and death. In the US alone, *C. difficile* is estimated to lead to more than 14,500 deaths, and result in more than $1.1 billion in costs per year [10, 6, 9].

One mode of transmission for *C. difficile*, as well as other pathogens, which has received little attention is the potential air contamination by pathogen-bearing droplets emanating from toilets. So far, modern mitigation strategies focused on cleaning hospital surfaces with products such as bleach, ignoring air contamination. Though toilets have been in use for over a century, little is known about the fluid dynamics governing their potential for pathogen-bearing droplet generation. Best et al (2012) [2] reported finding spores in the air an hour after flushing. This is a major concern given that modern hospital toilets in North America do not have lids and are cleared using high flow rate flushes.

Fluid dynamics is playing an increasingly important role in understanding the transmission of a variety of diseases [3]. In this approach, the first step relies on characterizing the flows contributing to the pathogen transfer within or outside the infected host. High-speed visualizations are used to capture the fast-time scale dynamics of fluid fragmentation such as that occurring during real sneezes and coughs [4, 5] or rain impacts on contaminated plant leaves [8]. Relying on the insight gained in this first step, complemented by clinical data, joint physical analog experiments and mathematical models can be developed to elucidate the fluid mechanisms contributing or shaping disease transmission [5, 8].

In the fluid dynamics video submitted to the APS DFD Gallery of Fluid Motion, we present the first step of characterization of the problem of indoor contamination from hospital toilets. Flow visualization via high-speed recordings show the capture of the product of the fluid fragmentation occurring during hospital high-pressure flushing events. The recordings were performed at 1000 to 2000 frames per second and display a side view of the section just above the toilet bowl. The visualizations capture large quantities of both large and small droplets. The former are defined as those that would settle quickly and contaminate surfaces; while the latter could remain suspended in the air carrying *C. difficile* spores among other pathogens [7]. In the video, we illustrate how high-pressure flushes and cleaning products currently used in hospital toilets result in a dramatic increase of small droplet ejections without killing spores; thus aggravating, rather than alleviating, the suspension and recirculation of tenacious potential pathogens. Our full results on the fluid fragmentation dynamics of flush-induced droplet ejecta will be published elsewhere.

* corresponding author: lbouro@mit.edu

Acknowledgments

The authors thank H. Flexman and B. Vijaykumar for their help with some facets of the project.

References Cited

[1] ACS. Cancer facts & figures. *American Cancer Society*, 2012.

[2] E.L. Best, J.A. Sandoe, and M.H Wilcox. Potential for aerosolization of clostridium difficile after flushing toilets: the role of toilet lids in reducing environmental contamination risk. *J. hosp. infection*, 80:1–5, 2012.

[3] L. Bourouiba and J. W. M. Bush. *Drops and Bubbles. Chapter 32 in Handbook of Environmental Fluid Dynamics Volume one: Overview and Fundamentals.* Taylor & Francis Book Inc., 2013.

[4] L. Bourouiba, E. Dehandschoewercker, and John. W. M. Bush. The fluid dynamics of coughing and sneezing. *Refereed proceedings of the International Society of Indoor Air Quality and Climate. 10th Healthy Buildings Conference. Brisbane, AU.*, 2012.

[5] L. Bourouiba, E. Dehandschoewercker, and John. W. M. Bush. Violent expiratory events: on coughing and sneezing. *J. Fluid Mech.*, 2013. under review.

[6] CDC. Making healthcare safer - stopping C. difficile infections. 2012. http://www.cdc.gov/vitalsigns/pdf/2012-03-vitalsigns.pdf.

[7] H. M. Darlow and W. R. Bale. Infective hazards of water-closets. *Lancet*, 273:1196–1200, 1959.

[8] T. Gilet and L. Bourouiba. Rain-induced foliar disease transmission. 2013. under review.

[9] C.P. Johnston, Ha. Qiu, J.R. Ticehurst, P. Dickson, C.and Rosenbaum, P. Lawson, A.B. Stokes, C.J. Lowenstein, M. Kaminsky, S.E. Cosgrove, K.Y. Green, and T.M. Perl. Outbreak management and implications of a nosocomial norovirus outbreak. *Clin. Infect. Dis*, 45:534–540, 2007.

[10] L. Kyne, H.B. Hamel, R. Polavaram, and C.P. Kelly. Health care costs and mortality associated with nosocomial diarrhea due to clostridium difficile. *Clin. Infect. Dis*, 42:346–53, 2002.