Measuring Particle and Bioaerosol Concentrations Generated from Toilet Flushes During Hospital-Based Patient Care

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Background

In the U.S., 1.7 million people annually contract a healthcare acquired infection, which costs billions of dollars for treatment.[1,2,3]

There are concerns that some healthcare acquired infections are spread through flushing loose fecal waste in patient toilets.

Some studies have used culture based analysis to detect aerosolized microorganisms after a toilet flushing event.[4,5,6]

Higher bioaerosol concentrations have been found closer to toilets and the majority of particles produced from toilet flushing are < 2 µm.[6,7]

No information is available about particle and bioaerosol concentrations while flushing loose fecal waste from hospitalized patients.

Objectives

Compare the particle concentrations measured before and after a toilet flush across particle size diameters during patient care in a hospital setting.

Compare bioaerosol concentrations among three experimental bathroom conditions: no waste no flush, no waste with flush, and waste with flush during patient care in a hospital setting.

Compare the effect of time and distance on the bioaerosol concentrations across the three experimental conditions.

Methods

Particle and bioaerosol concentrations were investigated in three hospital bathroom conditions during patient care: no waste no flush, no waste with flush and loose fecal waste with flush.

Particle concentrations were measured with a particle counter (AeroTrak 9306, Shoreview, MN) programmed to measure the sum of particles for each sampling minute across six size channels (*i.e.,* 0.3, 0.5, 1, 3, 5, 10 µm) before and after a toilet flush.

Impactor samplers (SKC BioStage, Eighty Four, PA) collected aerosolized microorganisms on tryptic soy agar (TSA) plates attached to a sampling cart at 0.15, 0.5, and 1 meters from the toilet for sampling intervals of 5, 10 and 15 minutes after a toilet flush. Colony counts were used to calculate the bioaerosol concentration.

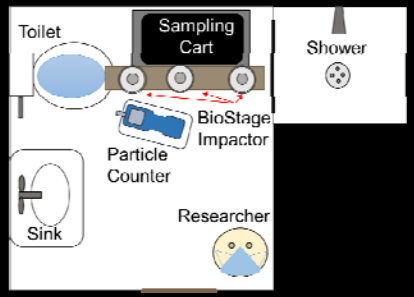

Figure 1. Diagram of common hospital bathroom with bioaerosol sampling cart and particle counter setup.

Results

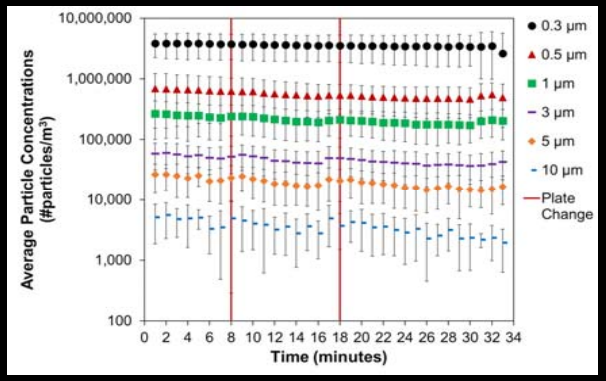

Figure 2. Average particle concentrations with standard deviation error bars across time for bathroom trials of no waste no flush (n=10).

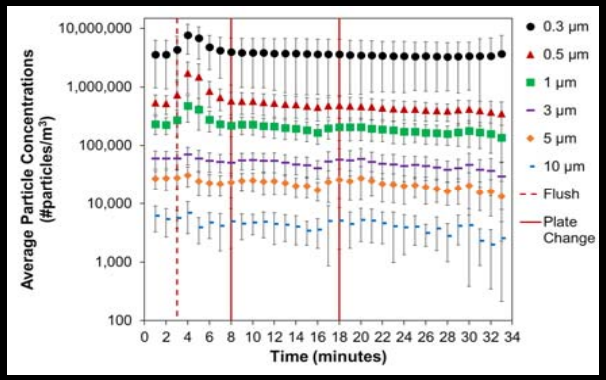

Figure 3. Average particle concentrations with standard deviation error bars across time for bathroom trials of no waste with flush (n=10).

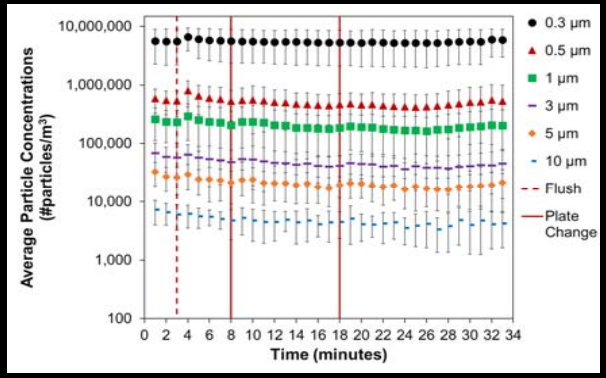

Figure 4. Average particle concentrations with standard deviation error bars across time for bathroom trials of fecal waste with flush (n=10).

Results Cont.

Table 1. Average bioaerosol concentrations for each bathroom sampling condition (n=270).

Toilet Conditions	Ave. Bioaerosol Conc. (SD), CFU/m³
No Waste No Flush	210 (136)*
No Waste With Flush	240 (132)
Fecal Waste With Flush	278 (149)*

*Indicates significantly different conditions found by Tukey test.

Table 2. P-values of statistical tests performed across condition, time, and distance of bioaerosol concentrations.

Statistical Test	P-value
1-Way ANOVA (Conditions)	0.005*
2-Way ANOVA (Condition, Time)	0.977
2-Way ANOVA (Condition, Distance)	0.911

Conclusion & Discussion

Particle concentrations significantly increased among the smaller particle size bins as a result of toilet flushing (Figures 3 & 4).

The flushing of unmanipulated patient fecal wastes in hospital bathrooms significantly increased the bioaerosol concentrations in comparison to the experimental control condition (*i.e.*, no waste and no flush) (Table 1).

The variables of time and distance from flush were not associated with a difference in bioaerosol concentrations (Table 2).

Bioaerosols within the bathroom air may cause environmental surface contamination and inhalation exposures that may place both patients and workers at risk for healthcare acquired infections.

Future Research

Perform metagenomic shotgun sequencing on collected bioaerosol samples to determine species of microorganisms collected in hospital bathrooms during patient care and toilet flushing.

Conduct experiments using selective agar and anaerobic incubation conditions to culture for problematic pathogens (*e.g.*, *Clostridium difficile)* that commonly cause hospital acquired infections.

Acknowledgements & References

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1.Klevens, R. M., Edwards, J. R., Richards Jr, C. L., et al. (2007). Estimating health care-associated infections and deaths in US hospitals, 2002. Public health reports, 160-166
2.Committee, H.-A. I. W. G. o. t. J. P. P. (N.D.). Essentials of Public Reporting of Healthcare-Associated Infections: A Tool Kit.
3.Hassan, M., Tuckman, H. P., Patrick, R. H., et al. (2010). Cost of hospital-acquired infection. Hospital topics, 88(3), 82-89.
4.Darlow, H., & Bale, W. (1959). Infective hazards of water-closets. The Lancet, 273(7084), 1196-1200.
5.Gerba, C. P., Wallis, C., & Melnick, J. L. (1975). Microbiological hazards of household toilets: droplet production and the fate of residual organisms. Applied Microbiology, 30(2), 229-237.
6.Best, E. L., Sandoe, J., & Wilcox, M. (2012). Potential for aerosolization of Clostridium difficile after flushing toilets: the role of toilet lids in reducing environmental contamination risk. Journal of Hospital Infection, 80(1), 1-5.
7.Johnson, D., Lynch, R., Marshall, C., et al. (2013). Aerosol generated by modern flush toilets. Aerosol Science and Technology, 47(9), 1047-1057.