

TRANSMISSION OF RESPIRATORY INFECTIONS VIA SHOWERS

An Annotated Bibliography from the Penn Medicine Center for Evidence-based Practice

May 2020

Project director: S. Ryan Greysen, MD, MHS, MA (CEP)

Lead analyst: Matthew D. Mitchell, PhD (CEP)

Internal review: Patrick J. Brennan, M.D. (CMO)

Keywords: COVID-19, respiratory infection, infection control, shower, dormitory

Summary

- We found no articles specifically referring to transmission of respiratory infections in dormitory showers.
- Three key papers discussing risk factors for transmission of respiratory infections in dormitories note that poor ventilation is associated with increased risk of infection but did not report on shared bathroom or shower facilities.
- Plumbing systems were implicated in a large SARS coronavirus outbreak at the Amoy Gardens high-rise apartments in Hong Kong, but the route of transmission was through a poorly-designed floor drain system rather than person-to-person from showering or using the toilet.
- Showerheads can be a reservoir for bacterial biofilms. We found no reports on viral contamination of showerheads.
- Bacterial contamination of surfaces like toilet handles and bathroom door handles is common in dormitory settings. We found no reports on viral contamination of these surfaces
- Additional articles relating to viral disease transmission in university and school dormitories are presented.
- We found numerous articles relating to transmission of legionella infection via showers. However, these infections are usually associated with contamination of the water supply rather than person to person transmission.

** A CEP Annotated Bibliography is an expedited search for evidence and a presentation of selected articles intended to address a particular issue for Penn Medicine stakeholders. Searches are systematic but not necessarily comprehensive, and the results must not be taken as definitive. Additional studies may exist, including studies whose findings may differ from those cited in this report or identify significant limitations in their clinical applicability. Some citations may be to material supplied by drug or device manufacturers, published online, or in "grey literature." Readers should be aware that such material is not peer-reviewed, and CEP does not assess the methodological quality of studies cited in this report. The studies are informative and may provide important perspectives, but their validity and reliability has not been evaluated or confirmed. If you have specific questions about any of the studies cited here, or you wish to commission a full Evidence Review or Evidence Advisory on this or a related topic, please contact CEP.*



© Copyright 2020 by the Trustees of the University of Pennsylvania. All rights reserved.
No part of this publication may be reproduced without permission in writing
from the Trustees of the University of Pennsylvania. AB517

Results

Key references

5. Zhu S, Jenkins S, Addo K, Heidarinejad M, Romo SA, Layne A, et al. Ventilation and laboratory confirmed acute respiratory infection (ARI) rates in college residence halls in College Park, Maryland. *Environ Int.* 2020;137:105537

<https://dx-doi-org.proxy.library.upenn.edu/10.1016/j.envint.2020.105537>

Abstract: Strategies to protect building occupants from the risk of acute respiratory infection (ARI) need to consider ventilation for its ability to dilute and remove indoor bioaerosols. Prior studies have described an association of increased self-reported colds and influenza-like symptoms with low ventilation but have not combined rigorous characterization of ventilation with assessment of laboratory confirmed infections. We report a study designed to fill this gap. We followed laboratory confirmed ARI rates and measured CO₂ concentrations for four months during the winter-spring of 2018 in two campus residence halls: (1) a high ventilation building (HVB) with a dedicated outdoor air system that supplies 100% of outside air to each dormitory room, and (2) a low ventilation building (LVB) that relies on infiltration as ventilation. We enrolled 11 volunteers for a total of 522 person-days in the HVB and 109 volunteers for 6069 person-days in the LVB, and tested upper-respiratory swabs from symptomatic cases and their close contacts for the presence of 44 pathogens using a molecular assay. We observed one ARI case in the HVB (0.70/person-year) and 47 in the LVB (2.83/person-year). Simultaneously, 154 CO₂ sensors distributed primarily in the dormitory rooms collected 668,390 useful data points from over 1 million recorded data points. Average and standard deviation of CO₂ concentrations were 1230 ppm and 408 ppm in the HVB, and 1492 ppm and 837 ppm in the LVB, respectively. Importantly, this study developed and calibrated multi-zone models for the HVB with 229 zones and 983 airflow paths, and for the LVB with 529 zones and 1836 airflow paths by using a subset of CO₂ data for model calibration. The models were used to calculate ventilation rates in the two buildings and potential for viral aerosol migration between rooms in the LVB. With doors and windows closed, the average ventilation rate was 12 L/s in the HVB dormitory rooms and 4 L/s in the LVB dormitory rooms. As a result, residents had on average 6.6 L/(s person) of outside air in the HVB and 2.3 L/(s person) in the LVB. LVB rooms located at the leeward side of the building had smaller average ventilation rates, as well as a somewhat higher ARI incidence rate and average CO₂ concentrations when compared to those values in the rooms located at the windward side of the building. Average ventilation rates in twenty LVB dormitory rooms increased from 2.3 L/s to 7.5 L/s by opening windows, 3.6 L/s by opening doors, and 8.8 L/s by opening both windows and doors. Therefore, opening both windows and doors in the LVB dormitory rooms can increase ventilation rates to the levels comparable to those in the HVB. But it can also have a negative effect on thermal comfort due to low outdoor temperatures. Simulation results identified an aerobiologic pathway from a room occupied by an index case of influenza A to a room occupied by a possible secondary case. Copyright © 2020 The Authors. Published by Elsevier Ltd.. All rights reserved.

18. Van Kerkhove M,D., Alaswad S, Assiri A, Perera RAPM, Peiris M, El Bushra H,E., et al. Transmissibility of MERS-CoV Infection in Closed Setting, Riyadh, Saudi Arabia, 2015. *Emerg Infect Dis.* 2019;25(10):1802-9

<https://dx-doi-org.proxy.library.upenn.edu/10.3201/eid2510.190130>

Abstract: To investigate a cluster of Middle East respiratory syndrome (MERS) cases in a women-only dormitory in Riyadh, Saudi Arabia, in October 2015, we collected epidemiologic information, nasopharyngeal/oropharyngeal swab samples, and blood samples from 828 residents during November 2015 and December 2015-January 2016. We found confirmed infection for 19 (8 by reverse transcription

PCR and 11 by serologic testing). Infection attack rates varied (2.7%-32.3%) by dormitory building. No deaths occurred. Independent risk factors for infection were direct contact with a confirmed case-patient and sharing a room with a confirmed case-patient; a protective factor was having an air conditioner in the bedroom. For 9 women from whom a second serum sample was collected, antibodies remained detectable at titers >1:20 by pseudoparticle neutralization tests (n = 8) and 90% plaque-reduction neutralization tests (n = 2). In closed high-contact settings, MERS coronavirus was highly infectious and pathogenicity was relatively low.

195. Rushdy AA, Cooke RP, Iversen AM, Pickering BJ. Boarding school outbreak of group A streptococcal pharyngitis. *Commun Dis Rep CDR Rev.* 1995;5(7):R106-8 [CEP NOTE: journal not available online]

Abstract: In an outbreak of pharyngitis caused by group A beta-haemolytic *Streptococcus pyogenes* in a boarding school of 261 pupils and 45 staff, 14 cases and 16 asymptomatic carriers were identified in pupils and one case was a member of staff. One symptomatic pupil had negative swabs. Two pupils had recurrent *S. pyogenes* pharyngitis before the outbreak. The attack rate was significantly greater in two dormitories than in the other seven. Swabs were taken from all staff and pupils, and the outbreak was controlled by treating all carriers and cases. Environmental factors enhancing airborne transmission were considered. The two dormitories with the most cases were poorly ventilated.

References relating to university dormitories

82. Miko BA, Cohen B, Haxall K, Conway L, Kelly N, Stare D, et al. Personal and household hygiene, environmental contamination, and health in undergraduate residence halls in New York City, 2011. *PLoS ONE.* 2013;8(11):e81460

<https://dx-doi-org.proxy.library.upenn.edu/10.1371/journal.pone.0081460>

Abstract: BACKGROUND: While several studies have documented the importance of hand washing in the university setting, the added role of environmental hygiene remains poorly understood. The purpose of this study was to characterize the personal and environmental hygiene habits of college students, define the determinants of hygiene in this population, and assess the relationship between reported hygiene behaviors, environmental contamination, and health status., METHODS: 501 undergraduate students completed a previously validated survey assessing baseline demographics, hygiene habits, determinants of hygiene, and health status. Sixty survey respondents had microbiological samples taken from eight standardized surfaces in their dormitory environment. Bacterial contamination was assessed using standard quantitative bacterial culture techniques. Additional culturing for coagulase-positive *Staphylococcus* and coliforms was performed using selective agar., RESULTS: While the vast majority of study participants (n = 461, 92%) believed that hand washing was important for infection prevention, there was a large amount of variation in reported personal hygiene practices. More women than men reported consistent hand washing before preparing food (p = .002) and after using the toilet (p = .001). Environmental hygiene showed similar variability although 73.3% (n = 367) of subjects reported dormitory cleaning at least once per month. Contamination of certain surfaces was common, with at least one third of all bookshelves, desks, refrigerator handles, toilet handles, and bathroom door handles positive for >10 CFU of bacteria per 4 cm(2) area. Coagulase-positive *Staphylococcus* was detected in three participants' rooms (5%) and coliforms were present in six students' rooms (10%). Surface contamination with any bacteria did not vary by frequency of cleaning or frequency of illness (p>.05)., CONCLUSIONS: Our results suggest that surface contamination, while prevalent, is unrelated to reported hygiene or health in the university setting. Further research into environmental reservoirs of infectious diseases may delineate whether surface decontamination is an effective target of hygiene interventions in this population.

539. Haxall K., Cohen B., Miko B.A., Conway L., Kelly N., Stare D., et al. Personal and household hygiene, microbial contamination, and health status in undergraduate residence halls in New York City. *Am J Infect Control*. 2012;40(5):e93-5

<http://dx.doi.org.proxy.library.upenn.edu/10.1016/j.ajic.2012.04.163>

Abstract: Background/Objectives: Studies have described college students' hygienic practices but not the association between hygiene and microbial contamination or frequency of illnesses. The purposes of this study were to describe students' knowledge, practices, and beliefs about hygiene; examine microbial flora in dormitories; and assess whether microbial contamination varied according to frequency of cleaning, dormitory style, and frequency of illnesses. Methods: Undergraduate students at Columbia University, New York, NY, were recruited at a campus dining location. Students completed a 10-minute survey assessing demographics, health history, and knowledge, practices, and beliefs about hygiene. A subsample of survey respondents volunteered to have their dormitory environments sampled. Two trained researchers swabbed, with a sterile DACRON[®]-tipped applicator, a 2-cm² area of these surfaces in each student's dorm: computer keyboard, bookshelf, desk, reusable cup/dish, television remote, overhead light switch, refrigerator handle, toilet flush handle, and bathroom stall/door handle. Bacterial contamination was assessed using standard quantitative bacterial culture techniques. Results: Four hundred and fourteen students (196 men, 217 women, 1 transgender), 17-23 years old, completed the survey. Less than half of students were aware that hand washing reduces transmission of colds, flu, and gastroenteritis, and 39.8% believed that hand washing is unimportant to prevent disease (Table 1). More women than men reported hand washing always or most of the time for all indications surveyed and reported that handwashing can prevent colds, flu, and gastroenteritis. More underclassmen than upperclassmen reported hand washing prior to preparing food and eating, but no significant differences were noted between science and humanities majors. Most students (56%) felt that their personal hygiene was the same as others', and only 5% felt theirs was worse. Microbiologic data were collected from the dorms of 40 participants (18 men and 22 women). Bacterial growth ranged from 0-35 colony forming units (CFUs) with little variation by type of dorm, frequency of cleaning, or frequency of illnesses (Table 2). *Staphylococcus aureus* was detected in three participants' rooms (on a dish, bookshelf, and remote control), and coliforms were present in six students' rooms (on a remote control, keyboard, desk, light switch, refrigerator handle, bathroom door handle, and three bookshelves). Two of these students reported cleaning daily, three weekly, two monthly, and one never. Conclusions: Despite reporting frequent cleaning, coliforms were found in some students' rooms, on surfaces used for cooking and eating, and on surfaces shared by multiple students, suggesting that opportunities for transmission may be possible, even when hygienic measures are taken.

150. Foxman B, Gillespie B, Manning SD, Howard LJ, Tallman P, Zhang L, et al. Incidence and duration of group B *Streptococcus* by serotype among male and female college students living in a single dormitory. *Am J Epidemiol*. 2006;163(6):544-51

<https://doi-org.proxy.library.upenn.edu/10.1093/aje/kwj075>

Abstract: Group B *Streptococcus* causes a variety of morbid and sometimes fatal conditions affecting individuals of all age groups. There are nine known serotypes of this Gram-positive coccus but few estimates of the incidence and duration of its colonization and none by serotype in the literature. In 2001, the authors conducted a prospective cohort study among 257 men and women living in a single dormitory in Ann Arbor, Michigan. The 3-week incidence with any serotype was 11.3% (+/-3.9%) among women and 8.8% (+/-3.0%) among men; 3-week incidence rates were highest for serotype V (4.7% for women and 3.5% for men) and type Ia (2.3% for women and 2.4% for men), with no significant differences by gender. The estimated average duration of any group B *Streptococcus* colonization was longer for women (13.7 weeks) than men (8.5 weeks); serotype Ia was carried an average of 6.5 weeks longer in women, and serotype III was carried 4.9 weeks longer. Colonization with more than one serotype occurred significantly

less than would be expected by chance ($p \lll 0.001$). Based on the overall incidence, transmission occurred between roommate pairs at the rate expected. Group B Streptococcus colonization is frequent and dynamic, but it is not transmitted by casual contact.

135. Kak V. Infections in confined spaces: cruise ships, military barracks, and college dormitories. *Infect Dis Clin North Am.* 2007;21(3):773-x <https://www-clinicalkey-com.proxy.library.upenn.edu/#!/content/playContent/1-s2.0-S0891552007000591>

Abstract: The presence of a vast cohort of individuals in semi-confined settings such as cruise ships, military barracks, and college dormitories is often accompanied by an increase in the risk of particular infections. These are often gastrointestinal infections on cruise ships and respiratory pathogens that are easily transmitted in the barrack and dormitory setting. The control of these infections involves attention to good personal hygiene, safe food and water handling, and use of vaccines to prevent vaccine-preventable diseases.

42. Poletti P, Visintainer R, Lepri B, Merler S. The interplay between individual social behavior and clinical symptoms in small clustered groups. *BMC Infect Dis.* 2017;17(1):521 <https://dx-doi-org.proxy.library.upenn.edu/10.1186/s12879-017-2623-2>

Abstract: BACKGROUND: Mixing patterns of human populations play a crucial role in shaping the spreading paths of infectious diseases. The diffusion of mobile and wearable devices able to record close proximity interactions represents a great opportunity for gathering detailed data on social interactions and mixing patterns in human populations. The aim of this study is to investigate how social interactions are affected by the onset of symptomatic conditions and to what extent the heterogeneity in human behavior can reflect a different risk of infection., METHODS: We study the relation between individuals' social behavior and the onset of different symptoms, by making use of data collected in 2009 among students sharing a dormitory in a North America university campus. The dataset combines Bluetooth proximity records between study participants with self-reported daily records on their health state. Specifically, we investigate whether individuals' social activity significantly changes during different symptomatic conditions, including those defining Influenza-like illness, and highlight to what extent possible heterogeneities in social behaviors among individuals with similar age and daily routines may be responsible for a different risk of infection for influenza., RESULTS: Our results suggest that symptoms associated with Influenza-like illness can be responsible of a reduction of about 40% in the average duration of contacts and of 30% in the daily time spent in social interactions, possibly driven by the onset of fever. However, differences in the number of daily contacts were found to be not statistically significant. In addition, we found that individuals who experienced clinical influenza during the study period were characterized by a significantly higher social activity. In particular, both the number of person-to-person contacts and the time spent in social interactions emerged as significant risk factors for influenza infection., CONCLUSIONS: Our findings highlight that Influenza-like illness can remarkably reduce the social activity of individuals and strengthen the idea that the heterogeneity in social habits among individuals can significantly contribute in shaping differences among the individuals' risk of infection.

89. Tonn K, Ryan TJ. Community-associated methicillin-resistant *Staphylococcus aureus* in college residential halls. *J Environ Health.* 2013;75(6):44-9 <https://www-jstor-org.proxy.library.upenn.edu/stable/26329554?seq=1>

Abstract: Methicillin-resistant *Staphylococcus aureus* (MRSA) was once a predominantly hospital-acquired organism but community-associated MRSA (CA-MRSA) has become a concern in athletics, prisons, and other nonclinical closed populations. As such, college residential hall occupants and workers may be at elevated risk of spreading or contracting MRSA. Environmental samples were obtained to identify the occurrence of MRSA on surfaces in bathrooms of 15 university residential halls. Sterile swabs and BBL

CHROMagar plates were used to sample seven categories of potentially contaminated surfaces in each location. Frequencies and descriptive statistics were prepared. All sites had at least one positive sample for MRSA, and shower floors displayed the greatest prevalence (50%). These results indicate areas for heightened sanitation, and illustrate CA-MRSA potential from such surfaces. The need for hygiene education of affected persons about skin and soft tissue infections like MRSA, and intervention opportunities for public health professionals, are discussed.

168. White C, Kolble R, Carlson R, Lipson N, Dolan M, Ali Y, et al. The effect of hand hygiene on illness rate among students in university residence halls. *Am J Infect Control*. 2003;31(6):364-70 [https://doi-org.proxy.library.upenn.edu/10.1016/S0196-6553\(03\)00041-5](https://doi-org.proxy.library.upenn.edu/10.1016/S0196-6553(03)00041-5)

Abstract: BACKGROUND: Several studies have indicated a connection between hand sanitization and infection control in numerous settings such as extended care facilities, schools, and hospitals. The purpose of this study was to assess the effectiveness of both a hand-hygiene message campaign and the use of an alcohol gel hand sanitizer in decreasing the incidence of upper-respiratory illness among students living in university residence halls., METHOD: This study involved a total of 430 students recruited from 4 residence halls during the fall semester at the University of Colorado at the Boulder campus. Dormitories were paired into control and product groups. In the product groups, alcohol gel hand-sanitizer dispensers were installed in every room, bathroom, and dining hall. The data were statistically analyzed for the differences between product and control groups in reported symptoms, illness rates, and absenteeism from classes., RESULTS: The overall increase in hand-hygiene behavior and reduction in symptoms, illness rates, and absenteeism between the product group and control group was statistically significant. Reductions in upper respiratory-illness symptoms ranged from 14.8% to 39.9%. Total improvement in illness rate was 20%. The product group had 43% less missed school/work days., CONCLUSION: Hand-hygiene practices were improved with increased frequency of handwashing through increasing awareness of the importance of hand hygiene, and the use of alcohol gel hand sanitizer in university dormitories. This resulted in fewer upper respiratory-illness symptoms, lower illness rates, and lower absenteeism.

11. Sharma A, Richardson M, Cralle L, Stamper CE, Maestre JP, Stearns-Yoder K, et al. Longitudinal homogenization of the microbiome between both occupants and the built environment in a cohort of United States Air Force Cadets. *Microbiome*. 2019;7(1):70 <https://dx-doi-org.proxy.library.upenn.edu/10.1186/s40168-019-0686-6>

Abstract: BACKGROUND: The microbiome of the built environment has important implications for human health and wellbeing; however, bidirectional exchange of microbes between occupants and surfaces can be confounded by lifestyle, architecture, and external environmental exposures. Here, we present a longitudinal study of United States Air Force Academy cadets (n = 34), which have substantial homogeneity in lifestyle, diet, and age, all factors that influence the human microbiome. We characterized bacterial communities associated with (1) skin and gut samples from roommate pairs, (2) four built environment sample locations inside the pairs' dormitory rooms, (3) four built environment sample locations within shared spaces in the dormitory, and (4) room-matched outdoor samples from the window ledge of their rooms., RESULTS: We analyzed 2,170 samples, which generated 21,866 unique amplicon sequence variants. Linear convergence of microbial composition and structure was observed between an occupants' skin and the dormitory surfaces that were only used by that occupant (i.e., desk). Conversely, bacterial community beta diversity (weighted Unifrac) convergence between the skin of both roommates and the shared dormitory floor between the two cadet's beds was not seen across the entire study population. The sampling period included two semester breaks in which the occupants vacated their rooms; upon their return, the beta diversity similarity between their skin and the surfaces had significantly decreased compared to before the break ($p < 0.05$). There was no apparent convergence between the gut and building microbiota, with the exception of communal bathroom door-handles, which suggests that

neither co-occupancy, diet, or lifestyle homogenization had a significant impact on gut microbiome similarity between these cadets over the observed time frame. As a result, predictive classifier models were able to identify an individual more accurately based on the gut microbiota (74%) compared to skin (51%)., CONCLUSIONS: To the best of our knowledge, this is the first study to show an increase in skin microbial similarity of two individuals who start living together for the first time and who are not genetically related or romantically involved. Cohabitation was significantly associated with increased skin microbiota similarity but did not significantly influence the gut microbiota. Following a departure from the occupied space of several weeks, the skin microbiota, but not the gut microbiota, showed a significant reduction in similarity relative to the building. Overall, longitudinal observation of these dynamics enables us to dissect the influence of occupation, diet, and lifestyle factors on occupant and built environment microbial ecology.

103. Sun Y, Wang Z, Zhang Y, Sundell J. In China, students in crowded dormitories with a low ventilation rate have more common colds: evidence for airborne transmission. PLoS ONE. 2011;6(11):e27140 <https://dx-doi-org.proxy.library.upenn.edu/10.1371/journal.pone.0027140>

Abstract: OBJECTIVE: To test whether the incidence of common colds among college students in China is associated with ventilation rates and crowdedness in dormitories., METHODS: In Phase I of the study, a cross-sectional study, 3712 students living in 1569 dorm rooms in 13 buildings responded to a questionnaire about incidence and duration of common colds in the previous 12 months. In Phase II, air temperature, relative humidity and CO₂ concentration were measured for 24 hours in 238 dorm rooms in 13 buildings, during both summer and winter. Out-to indoor air flow rates at night were calculated based on measured CO₂ concentrations., RESULTS: In Phase I, 10% of college students reported an incidence of more than 6 common colds in the previous 12 months, and 15% reported that each infection usually lasted for more than 2 weeks. Students in 6-person dorm rooms were about 2 times as likely to have an incidence of common colds ≥ 6 times per year and a duration ≥ 2 weeks, compared to students in 3-person rooms. In Phase II, 90% of the measured dorm rooms had an out-to indoor air flow rate less than the Chinese standard of 8.3 L/s per person during the heating season. There was a dose-response relationship between out-to indoor air flow rate per person in dorm rooms and the proportion of occupants with annual common cold infections ≥ 6 times. A mean ventilation rate of 5 L/(s*person) in dorm buildings was associated with 5% of self reported common cold ≥ 6 times, compared to 35% at 1 L/(s*person)., CONCLUSION: Crowded dormitories with low out-to indoor airflow rates are associated with more respiratory infections among college students.

343. Li Y., Ge Y., Wu C., Guan D., Liu J., Wang F. Assessment of culturable airborne bacteria of indoor environments in classrooms, dormitories and dining hall at university: a case study in China. Aerobiologia. 2020 <http://dx.doi.org.proxy.library.upenn.edu/10.1007/s10453-020-09633-z>

Abstract: University students' health may be adversely affected by exposure to indoor bacterial contaminants on their campuses. This study aims (1) to quantify culturable bacterial concentrations in three indoor environments at a university, (2) to investigate the influence of meteorological factors and gender, to assess the relationship between indoor and outdoor, and (3) to estimate the bacterial dose for university students in different indoor environments. Airborne bacteria samples were collected in 12 classrooms, in 12 living rooms and four bathrooms in two dormitory buildings, and in a dining hall. The results showed that the microenvironment in the female dormitory had the highest mean bacterial concentration (2847 CFU/m³), whereas the lowest mean bacterial concentration was observed in classrooms (162 CFU/m³). Indoor bacterial concentrations in male dormitories were significantly lower than in female dormitories probably because of crowding and increased ventilation. Outdoor weather conditions were associated with the indoor concentrations with regard to insufficient ventilation and varying outdoor concentration. The occupants' activity level was also more closely related to the indoor

bacteria concentration in the residential setting. Students experienced about four times higher dose of airborne bacteria in the dormitories than in the classrooms and dining hall.

Other references relating to transmission of pathogens in showers and other bathroom facilities

258. Abe J, Alop-Mabuti A, Burger P, Button J, Ellsberry M, Hitzeman J, et al. Comparing the temporal colonization and microbial diversity of showerhead biofilms in Hawai'i and Colorado. *FEMS Microbiol Lett.* 2016;363(4)

<https://dx-doi-org.proxy.library.upenn.edu/10.1093/femsle/fnw005>

Abstract: The household is a potential source of opportunistic pathogens to humans, a particularly critical issue for immunodeficient individuals. An important human-microbe interface is the biofilm that develops on showerhead surfaces. Once microbe-laden biofilms become aerosolized, they can potentially be inhaled into the lungs. Understanding how quickly a new showerhead becomes colonized would provide useful information to minimize exposure to potentially pathogenic environmental microbes. High school scientists sampled the inner surfaces of pre-existing and newly fitted showerheads monthly over a nine-month period and applied standard microbiologic culture techniques to qualitatively assess microbial growth. Water chemistry was also monitored using commercial test strips. Sampling was performed in households on Oahu, Hawai'i and Denver, Colorado, representing warm/humid and cold/arid environments, respectively. Pre-existing showerheads in Hawai'i showed more diverse microbial growth and significantly greater microbial numbers than a comparable showerhead from Colorado. New, chrome-plated or plastic showerheads in Hawai'i showed diverse and abundant growth one month after installment compared to new showerheads from Colorado. The pH, total chlorine and water hardness levels varied significantly between the Hawai'i and Colorado samples. Enthusiastic student and teacher participation allowed us to answer long-standing questions regarding the temporal colonization of microbial biofilms on pre-existing and new showerhead surfaces. Copyright © FEMS 2016. All rights reserved. For permissions, please e-mail: journals.permissions@oup.com.

152. Barker J, Jones MV. The potential spread of infection caused by aerosol contamination of surfaces after flushing a domestic toilet. *J Appl Microbiol.* 2005;99(2):339-47

<https://doi-org.proxy.library.upenn.edu/10.1111/j.1365-2672.2005.02610.x>

Abstract: AIMS: To determine the level of aerosol formation and fallout within a toilet cubicle after flushing a toilet contaminated with indicator organisms at levels required to mimic pathogen shedding during infectious diarrhoea., METHODS AND RESULTS: A semisolid agar carrier containing either *Serratia marcescens* or MS2 bacteriophage was used to contaminate the sidewalls and bowl water of a domestic toilet to mimic the effects of soiling after an episode of acute diarrhoea. Viable counts were used to compare the numbers of *Serratia* adhering to the porcelain surfaces and those present in the bowl water before and after flushing the toilet. Air sampling and settle plates were used to determine the presence of bacteria or virus-laden aerosols within the toilet cubicle. After seeding there was a high level of contamination on the porcelain surfaces both under the rim and on the sides of the bowl. After a single flush there was a reduction of 2.0-3.0 log cycles cm⁻² for surface attached organisms. The number of micro-organisms in the bowl water was reduced by 2.0-3.0 log cycles ml⁻¹ after the first flush and following a second flush, a further reduction of c. 2.0 log cycles ml⁻¹ was achieved. Micro-organisms in the air were at the highest level immediately after the first flush (mean values, 1370 CFU m⁻³ for *Serratia* and 2420 PFU m⁻³ for MS2 page). Sequential flushing resulted in further distribution of micro-organisms into the air although the numbers declined after each flush. *Serratia* adhering to the sidewalls, as well as free-floating organisms in the toilet water, were responsible for the formation of bacterial aerosols.,

CONCLUSIONS: Although a single flush reduced the level of micro-organisms in the toilet bowl water when contaminated at concentrations reflecting pathogen shedding, large numbers of micro-organisms persisted on the toilet bowl surface and in the bowl water which were disseminated into the air by further flushes., SIGNIFICANCE AND IMPACT OF THE STUDY: Many individuals may be unaware of the risk of air-borne dissemination of microbes when flushing the toilet and the consequent surface contamination that may spread infection within the household, via direct surface-to-hand-to mouth contact. Some enteric viruses could persist in the air after toilet flushing and infection may be acquired after inhalation and swallowing.

52. Chattopadhyay S, Perkins SD, Shaw M, Nichols TL. Evaluation of Exposure to *Brevundimonas diminuta* and *Pseudomonas aeruginosa* during Showering. *J Aerosol Sci.* 2017;114:77-93 <https://dx-doi-org.proxy.library.upenn.edu/10.1016/j.jaerosci.2017.08.008>

Abstract: This study experimentally assessed bacterial water-to-air partitioning coefficients resulting from showerhead aerosolization of water contaminated with *Brevundimonas diminuta* or *Pseudomonas aeruginosa*, and estimated human exposure through inhalation. Dechlorinated tap water was spiked with two cell densities (10⁹ and 10¹⁰ CFU l⁻¹) and cycled at three temperatures (10, 25, and 37 or 40C) through a full-scale shower system. For reproducibility, spiked water concentrations were intentionally higher than found in natural environments. Three types of samplers measured size distribution and viable concentrations throughout the system. Results indicate low levels of respirable bioaerosols were generated. The ratio of bacterial contaminant that was effectively aerosolized (bacterial water-to-air partitioning coefficient, PC_{bwa}) was low - averaging 1.13x10⁻⁵ L m⁻³ for *B. diminuta* and 8.31x10⁻⁶ L m⁻³ for *P. aeruginosa*. However, the respirable fraction of aerosolized organisms was high, averaging above 94% (in shower) and above 99% (downstream) for both organisms. This study found no significant difference in bioaerosol load for a forward facing versus reverse facing individual. Further, for the average hot shower (33-43degreeC) the total number of respirable bioaerosols is higher, but the observed culturability of those aerosolized cells is lower when compared to lower temperatures. Bacterial water to air partitioning coefficients were calculated to predict microbial air concentration and these empirical parameters may be used for assessing inhalation as a route of exposure to pathogens in contaminated waters.

57. Cooper J, Bryce E, Astrakianakis G, Stefanovic A, Bartlett K. Efficacy of an automated ultraviolet C device in a shared hospital bathroom. *Am J Infect Control.* 2016;44(12):1692-4 <https://dx-doi-org.proxy.library.upenn.edu/10.1016/j.ajic.2016.07.004>

Abstract: Toilet flushing can contribute to disease transmission by generating aerosolized bacteria and viruses that can land on nearby surfaces or follow air currents. Aerobic and anaerobic bacterial bioaerosol loads, and bacterial counts on 2 surfaces in a bathroom with a permanently installed, automated ultraviolet C (UVC) irradiation device, were significantly lower than in a comparable bathroom without the UVC device. Permanently installed UVC lights may be a useful supplementary decontamination tool in shared patient bathrooms. Copyright © 2016 Association for Professionals in Infection Control and Epidemiology, Inc. Published by Elsevier Inc. All rights reserved.

144. Cowen KA, Ollison WM. Continuous monitoring of particle emissions during showering. *J Air Waste Manag Assoc.* 2006;56(12):1662-8 <https://search-proquest-com.proxy.library.upenn.edu/docview/214377132?accountid=14707>

Abstract: Particle formation from showering may be attributed to dissolved mineral aerosols remaining after evaporation of micron-sized satellite droplets produced by the showerhead or from splashing of larger shower water droplets on surfaces. Duplicate continuous particle monitors measured particle size distributions in a ventilated residential bathroom under various showering conditions, using a full-size

mannequin in the shower to simulate splashing effects during showering. Particle mass concentrations were estimated from measured shower particle number densities and used to develop emission factors for inhalable particles. Emission source strengths of 2.7-41.3 microg/ m³/min were estimated under the various test conditions using residential tap water in Columbus, OH. Calculated fine particulate matter (PM_{2.5}) concentrations in the bathroom reached several hundred micrograms per cubic meter; calculated coarse particulate matter (PM₁₀) levels approached 1000 microg/m³. Rates of particle formation tended to be highest for coarse shower spray settings with direct impact on the mannequin. No consistent effects of water temperature, water pressure, or spray setting on overall emission rates were apparent, although water temperature and spray setting did have an effect when varied within a single shower sampling run. Salt solutions were injected into the source water during some tests to assess the effects of total dissolved solids on particle emission rates. Injection of salts was shown to increase the PM_{2.5} particle formation rate by approximately one third, on average, for a doubling in tap water-dissolved solids content; PM₁₀ source strengths approximately doubled under these conditions, because very few particles >10 microm were formed.

36. Estrada-Perez C, Kinney KA, Maestre JP, Hassan YA, King MD. Droplet distribution and airborne bacteria in an experimental shower unit. *Water Res.* 2018;130:47-57
<https://dx-doi-org.proxy.library.upenn.edu/10.1016/j.watres.2017.11.039>

Abstract: Although human exposure to water aerosols is common in residential showers, the droplet distribution patterns generated in showers are not well understood nor is the bacteria released during shower operation. In this study, a two-phase flow Particle Tracking Velocimetry (PTV) algorithm was successfully used to characterize the spatial spray pattern and velocity field in two experimental showers (one low-flow and one high-flow). In addition, the airborne bacteria present in the shower over nearly 5 months of controlled operation was determined for both showers. The results indicate that the droplet velocity out of the low-flow showerhead (which had fewer orifices) was significantly higher than that out of the high-flow showerhead resulting in a higher aerosol number concentration in the low-flow shower and more consistent wetting of the shower wall. Both showerheads generated droplets in the respirable range and genera of potential health concern were observed in the shower aerosols measured both prior to and following shower operation. The study provides one of the first visualizations of droplet spray patterns in residential showers and provides insight into the airborne bacteria present in showers. Copyright © 2017 Elsevier Ltd. All rights reserved.

122. Feazel LM, Baumgartner LK, Peterson KL, Frank DN, Harris JK, Pace NR. Opportunistic pathogens enriched in showerhead biofilms. *Proc Natl Acad Sci U S A.* 2009;106(38):16393-9
<https://dx-doi-org.proxy.library.upenn.edu/10.1073/pnas.0908446106>

Abstract: The environments we humans encounter daily are sources of exposure to diverse microbial communities, some of potential concern to human health. In this study, we used culture-independent technology to investigate the microbial composition of biofilms inside showerheads as ecological assemblages in the human indoor environment. Showers are an important interface for human interaction with microbes through inhalation of aerosols, and showerhead waters have been implicated in disease. Although opportunistic pathogens commonly are cultured from shower facilities, there is little knowledge of either their prevalence or the nature of other microorganisms that may be delivered during shower usage. To determine the composition of showerhead biofilms and waters, we analyzed rRNA gene sequences from 45 showerhead sites around the United States. We find that variable and complex, but specific, microbial assemblages occur inside showerheads. Particularly striking was the finding that sequences representative of non-tuberculous mycobacteria (NTM) and other opportunistic human pathogens are enriched to high levels in many showerhead biofilms, >100-fold above background water contents. We conclude that showerheads may present a significant potential exposure to aerosolized

microbes, including documented opportunistic pathogens. The health risk associated with showerhead microbiota needs investigation in persons with compromised immune or pulmonary systems.

48. Gormley M, Aspray TJ, Kelly DA, Rodriguez-Gil C. Pathogen cross-transmission via building sanitary plumbing systems in a full scale pilot test-rig. PLoS ONE. 2017;12(2):e0171556 <https://dx-doi-org.proxy.library.upenn.edu/10.1371/journal.pone.0171556>

Abstract: The WHO Consensus Document on the epidemiology of the SARS epidemic in 2003, included a report on a concentrated outbreak in one Hong Kong housing block which was considered a 'super-spreading event'. The WHO report conjectured that the sanitary plumbing system was one transmission route for the virus. Empty U-traps allowed the aerosolised virus to enter households from the sewerage system. No biological evidence was presented. This research reports evidence that pathogens can be aerosolised and transported on airstreams within sanitary plumbing systems and enter buildings via empty U-traps. A sanitary plumbing system was built, representing two floors of a building, with simulated toilet flushes on the lower floor and a sterile chamber with extractor fan on the floor above. Cultures of a model organism, *Pseudomonas putida* at 106-109 cfu ml⁻¹ in 0.85% NaCl were flushed into the system in volumes of 6 to 20 litres to represent single or multiple toilet flushes. Air and surface samples were cultured on agar plates and assessed qualitatively and semi-quantitatively. Flushing from a toilet into a sanitary plumbing system generated enough turbulence to aerosolise pathogens. Typical sanitary plumbing system airflows (between 20-30 ls⁻¹) were sufficient to carry aerosolised pathogens between different floors of a building. Empty U-traps allowed aerosolised pathogens to enter the chamber, encouraging cross-transmission. All parts of the system were found to be contaminated post-flush. Empty U-traps have been observed in many buildings and a risk assessment indicates the potential for high risk cross-transmission under defect conditions in buildings with high pathogen loading such as hospitals. Under defective conditions (which are not uncommon) aerosolised pathogens can be carried on the airflows within sanitary plumbing systems. Our findings show that greater consideration should be given to this mode of pathogen transmission.

146. Heung LCL, Li T, Mak SK, Chan WM. Prevalence of subclinical infection and transmission of severe acute respiratory syndrome (SARS) in a residential care home for the elderly. Hong Kong Med J. 2006;12(3):201-7 <https://www.hkmj.org/abstracts/v12n3/201.htm>

Abstract: OBJECTIVE: To ascertain the prevalence of subclinical severe acute respiratory syndrome-coronavirus (SARS-CoV) infection and study the transmission of SARS-CoV in a local outbreak at a residential care home for the elderly., DESIGN: Cross-sectional study., SETTING: A residential care home for the elderly in Hong Kong with a local outbreak of SARS., PARTICIPANTS: Residents and staff in the residential care home who had contact with three patients with SARS (residents A and B, and staff C)., MAIN OUTCOME MEASURES: Blood samples were tested for total antibodies to SARS-CoV by immunofluorescence antibody test. The transmission of SARS was elucidated based on information from standardised questionnaires, and records of investigation and surveillance by the Department of Health., RESULTS: Among the 90 eligible residents, three died, one moved out, and 19 refused to participate. Of the 32 eligible staff, six refused to participate. None of the remaining 93 participants tested positive for antibody to SARS-CoV. Based on the chronological order, resident A might have transmitted infection to resident B and staff C. Sitting close to the bathroom doorway while resident A took a shower was the only contact of resident B with resident A. The only opportunity for staff C to have contact with body fluids/excreta of resident A was in the handling of rubbish from the resident's room., CONCLUSION: Subclinical SARS-CoV infection was rare in a residential care home for the elderly with an outbreak of SARS. Nonetheless the close working and living conditions for staff and residents in such a home may facilitate transmission of SARS despite vigilant precautionary measures.

147. McKinney KR, Gong YY, Lewis TG. Environmental transmission of SARS at Amoy Gardens. *J Environ Health*. 2006;68(9):26-2

<https://www-jstor-org.proxy.library.upenn.edu/stable/44533466?seq=1>

Abstract: Recent investigations into the March 2003 outbreak of SARS in Hong Kong have concluded that environmental factors played an important role in the transmission of the disease. These studies have focused on a particular outbreak event, the rapid spread of SARS throughout Amoy Gardens, a large, private apartment complex. They have demonstrated that, unlike a typical viral outbreak that is spread through person-to-person contact, the SARS virus in this case was spread primarily through the air. High concentrations of viral aerosols in building plumbing were drawn into apartment bathrooms through floor drains. The initial exposures occurred in these bathrooms. The virus-laden air was then transported by prevailing winds to adjacent buildings at Amoy Gardens, where additional exposures occurred. This article reviews the results of the investigations and provides recommendations for maintenance and other measures that building owners can take to help prevent environmental transmission of SARS and other flulike viruses in their buildings.

301. Nygard K, Vold L, Halvorsen E, Bringeland E, Rottingen JA, Aavitsland P. Waterborne outbreak of gastroenteritis in a religious summer camp in Norway, 2002. *Epidemiol Infect*. 2004;132(2):223-9 <https://www-jstor-org.proxy.library.upenn.edu/stable/3865813?seq=1>

Abstract: In July 2002 an outbreak of acute gastroenteritis occurred in a camp facility in western Norway during a 10-day seminar, with around 300 guests staying overnight and several day-time visitors. Environmental and epidemiological investigations were conducted to identify and eliminate the source of the outbreak, prevent further transmission and describe the impact of the outbreak. Of 205 respondents, 134 reported illness (attack rate, 65%). Multivariate analysis showed drinking water and taking showers at the camp-site to be significant risk factors. Secondary person-to-person spread among visitors or outside of the camp was found. Norovirus was identified in 8 out of the 10 stool samples analysed. Indicators of faecal contamination were found in samples from the private untreated water supply, but norovirus could not be identified. This outbreak investigation illustrates the importance of norovirus as a cause of waterborne illness and the additional exacerbation through person-to-person transmission in closed settings. Since aerosol transmission through showering contributed to the spread, intensified hygienic procedures such as isolation of cases and boiling of water may not be sufficient to terminate outbreaks with norovirus.

16. Teare L, Martin N, Elamin W, Pilgrim K, Tredoux T, Swanson J, et al. Acinetobacter - the trojan horse of infection control? *J Hosp Infect*. 2019;102(1):45-53

<https://dx-doi-org.proxy.library.upenn.edu/10.1016/j.jhin.2018.12.013>

Abstract: BACKGROUND: Five cases of multi-resistant *Acinetobacter baumannii* (MRA) producing OXA-23 and OXA-51 occurred in a regional burn intensive care unit (BICU). Three were repatriated from other parts of the world (Dubai and Mumbai) and colonized on admission. Despite optimal precautions, two patients acquired MRA. Both had been nursed in the same room., METHODS: Multi-disciplinary outbreak investigation of MRA in a regional BICU., FINDINGS: The mechanism of transfer for the first case is thought to have been contaminated air from theatre activity releasing MRA bacteria into the communal corridor. No MRA patients went to theatre between the first and second acquired cases. The mechanism of transfer for the second case is thought to have been via a shower unit that was decontaminated inadequately between patients., CONCLUSION: In an outbreak where contact precautions and environmental cleaning are optimal, it is important to give careful consideration to other mechanisms of spread. If there is a failure to do this, it is likely that the true causes of transmission will not be addressed and the problem will recur. It is recommended that burn theatres within burn facilities should be designed to operate at

negative pressure; this is the opposite of normal operating theatre ventilation. Where showers are used, both the shower head and the hose should be changed after a patient with a resistant organism. The role of non-contact disinfection (e.g. hydrogen peroxide dispersal) should be reconsidered, and constant vigilance should be given to any 'trojan horse' item in the room. Copyright © 2018. Published by Elsevier Ltd.

73. Verani M, Bigazzi R, Carducci A. Viral contamination of aerosol and surfaces through toilet use in health care and other settings. *Am J Infect Control*. 2014;42(7):758-62
<https://dx-doi-org.proxy.library.upenn.edu/10.1016/j.ajic.2014.03.026>

Abstract: BACKGROUND: The airborne spreading of enteric viruses can occur through the aerosol and droplets produced by toilet flushing. These can contaminate the surrounding environment, but few data exist to estimate the risk of exposure and infection. For this reason environmental monitoring of air and selected surfaces was carried out in 2 toilets of an office building and in 3 toilets of a hospital before and after cleaning operations., METHODS: To reveal the presence of norovirus, enterovirus, rhinovirus, human rotavirus, and Torque teno virus and to quantify human adenovirus and bacteria counts, molecular and cultural methods were used., RESULTS: On the whole, viruses were detected on 78% of surfaces and in 81% of aerosol. Among the researched viruses, only human adenovirus and Torque teno virus were found in both surface and air samples. In several cases the same adenovirus strain was concurrently found in all matrices. Bacterial counts were unrelated to viral presence and cleaning did not seem to substantially reduce contamination., CONCLUSIONS: The data collected in our study confirm that toilets are an important source of viral contamination, mainly in health care settings, where disinfection can have a crucial role in preventing virus spread. Copyright © 2014 Association for Professionals in Infection Control and Epidemiology, Inc. Published by Mosby, Inc. All rights reserved.

141. Zhou Y, Benson JM, Irvin C, Irshad H, Cheng Y. Particle size distribution and inhalation dose of shower water under selected operating conditions. *Inhal Toxicol*. 2007;19(4):333-42
<https://doi.org/10.1080/08958370601144241>

Abstract: Showering produces respirable droplets that may serve to deposit pollutants such as trihalomethane decontamination products, heavy metals, inorganic salts, microbes, or cyanobacterial toxins within the respiratory tract. The extent and importance of this route of indoor exposure depend on the physical characteristics of the aerosol as well as the pollutant profile of the source water. The purpose of this study was to characterize shower-generated aerosols as a function of water flow rate, temperature, and bathroom location. Aerosols were generated within a shower stall containing a mannequin to simulate the presence of a human. Using hot water, the mass median diameter (MMD) of the droplets inside the shower and in the bathroom were 6.3-7.5 µm and 5.2-6 µm, respectively. Size was independent of water flow rate. The particle concentration inside the shower ranged from 5 to 14 mg/m³. Aerosols generated using cold water were smaller (2.5-3.1 µm) and concentrations were lower (0.02-0.1 mg/m³) inside the shower stall. No aerosols were detected in the bathroom area when cold water was used. The International Commission on Radiological Protection model was used to estimate water deposition in the respiratory tract. For hot water, total deposition ranged from 11 to 14 mg, depending on water flow rate, with approximately 50% of this deposited in the extrathoracic region during assumed mouth breathing, and greater than 86% when nose breathing was assumed. Alveolar deposition was 6-10% and 0.9% assuming oral and nasal breathing, respectively. The consequences deposition of shower water droplets will depend on the nature and extent of any pollutants in the source water.

Articles relating to legionella and showers

50. Collins S, Stevenson D, Bennett A, Walker J. Occurrence of Legionella in UK household showers. *Int J Hyg Environ Health*. 2017;220(2):401-6
75. Wiik R, Krovel AV. Necessity and effect of combating Legionella pneumophila in municipal shower systems. *PLoS ONE*. 2014;9(12):e114331
76. Hines SA, Chappie DJ, Lordo RA, Miller BD, Janke RJ, Lindquist HA, et al. Assessment of relative potential for Legionella species or surrogates inhalation exposure from common water uses. *Water Res*. 2014;56:203-13
104. Schoen ME, Ashbolt NJ. An in-premise model for Legionella exposure during showering events. *Water Res*. 2011;45(18):5826-36
131. Bauer M, Mathieu L, Deloge-Abarkan M, Remen T, Tossa P, Hartemann P, et al. Legionella bacteria in shower aerosols increase the risk of Pontiac fever among older people in retirement homes. *J Epidemiol Community Health*. 2008;62(10):913-20
137. Delia S, Lagana P, Minutoli E. Occurrence of Legionella in beach shower facilities. *J PREV MED HYG*. 2007;48(4):114-7
210. Aldea MJ, Moreno MP, Gutierrez V, Pac MR, Guimbao J, Santodomingo R. [Outbreak of Legionnaires' disease in a private apartment building]. *Enferm Infecc Microbiol Clin*. 1992;10(7):403-8
214. Liu X. [An epidemiological investigation of an outbreak of Legionnaires' disease in a college in Tang Shan]. *Chung Hua Liu Hsing Ping Hsueh Tsa Chih*. 1990;11(5):278-80
228. Bollin GE, Plouffe JF, Para MF, Hackman B. Aerosols containing Legionella pneumophila generated by shower heads and hot-water faucets. *Appl Environ Microbiol*. 1985;50(5):1128-31
275. Silk BJ, Moore MR, Bergtholdt M, Gorwitz RJ, Kozak NA, Tha MM, et al. Eight years of Legionnaires' disease transmission in travellers to a condominium complex in Las Vegas, Nevada. *Epidemiol Infect*. 2012;140(11):1993-2002

Methods

CENTER FOR EVIDENCE-BASED PRACTICE PROTOCOL FOR SYSTEMATIC REVIEW

SPECIFIC AIM:

Identify articles of interest relating to transmission of viral diseases via showers in dormitories and other communal housing facilities.

METHODS:

Study designs: Any

Inclusion and exclusion criteria:

Participants: All

Interventions: Not applicable

Comparisons: Not applicable

Outcomes: Presence of viral particles in aerosols or droplets associated with showering or bathing, transmission of viral diseases through shared bathing facilities.

Other: No language, date, or geographic restrictions.

Data collection

Databases: Medline, EMBASE, ECRI Institute

Guideline quality assessment: Not applicable

Data synthesis (calculation of relative risks and confidence intervals, meta-analyses, exploration of heterogeneity): Assemble list of relevant references.

Literature Searches

In addition to the planned searches, we used the “find similar” feature of OVID Medline to extend the search from seed papers.

Table 1. Medline search

Search	Syntax	Hits	Included
1	Shower*.mp.	2,997	–
2	(toilet or bath*).mp.	63,192	–
3	aerosol*.mp.	55,053	–
4	((virus* or viral) adj3 (aerosol* or droplet* or mist*)).mp.	731	–
5	(1 and 3) or (2 and 4)	104	–
6	(dormitory or dormitories or (universit* adj3 residen*)).mp.	1,852	–
7	6 and (1 or 2 or 3 or 4)	34	–
8	transmission.mp. or exp Disease Transmission, Infectious/	533,410	–
9	1 and 8	89	–
10	6 and 8	149	–
11	5 or 7 or 9 or 10	334	–
	exclude 1 duplicate reference	333	

mp: keyword (title, abstract, subject heading)

Table 2. EMBASE search

Search	Syntax	Hits	Included
1	shower*	4,259	–
2	(toilet or bath*)	118,142	–
3	aerosol*	88,489	–
4	(virus* or viral) near/3 (aerosol* or droplet* or mist*)	827	–
5	(#1 and #3) or (#2 and #4)	162	–
6	dormitory or dormitories or (universit* near/3 residen*)	4,756	–
7	#6 and (#1 or #2 or #3 or #4)	60	–
8	Transmission or 'Disease Transmission'/exp	685.283	–
9	#1 and #8	160	–
10	#6 and #8	112	–
11	#5 or #7 or #9 or #10	460	–
	exclude 5 duplicate references within set and 217 references duplicating Medline results	238	