Am. J. Trop. Med. Hyg., 89(5), 2013, pp. 869–872
doi:10.4269/ajtmh.12-0425

Short Report: Fecal Indicator Bacteria Contamination of Fomites and Household Demand for Surface Disinfection Products: A Case Study from Peru

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Abstract. Surface-mediated disease transmission is understudied in developing countries, particularly in light of the evidence that surface concentrations of fecal bacteria typically exceed concentrations in developed countries by 10- to 100-fold. In this study, we examined fecal indicator bacterial contamination of dinner plates at 21 households in four peri-urban communities in the Peruvian Amazon. We also used surveys to estimate household use of and demand for surface disinfectants at 280 households. Despite detecting total coliform, enterococci, and *Escherichia coli* on 86%, 43%, and 24% of plates sampled, respectively, less than one-third of households were regularly using bleach to disinfect surfaces. Among non-users of bleach, only 3.2% of respondents reported a new demand for bleach, defined as a high likelihood of using bleach within the next year. This study highlights the potential for marketing approaches to increase use of and demand for surface disinfectants to improve domestic hygiene.

Fomites, inanimate objects capable of transmitting disease, are recognized reservoirs of fecal pathogens.[1] Disease transmission by fomites is understudied in developing countries, particularly in light of evidence that surface concentrations of fecal bacteria typically exceed concentrations in developed countries by 10- to 100-fold.[2–4] High concentrations of fecal indicator bacteria (FIB) and pathogens can be in food, water, soil, and on hands and surfaces.[3,5] Elevated levels of fecal contamination in the environment are attributed to inadequate sanitation, a leading cause of child morbidity and mortality from diarrheal diseases, malnutrition, and stunting.[6] In addition, fecal contamination on surfaces is linked to increased risk of diarrheal disease, as highlighted by a study at a child care center in the United States.[7]

A domestic hygiene approach that incorporates disinfection is well recognized as an effective approach to infection control in the developed world.[8] As cleaning with soap and water may cross-contaminate surfaces, disinfection is recommended to reduce prevalence of pathogens on surfaces after illness, and prevent cross-contamination during food preparation.[8,9] The International Scientific Forum on Home Hygiene (ISFHH) promotes surface disinfection as an important intervention for reducing disease transmission risk.[10] In the developing world, ISFHH prioritizes sufficient feces disposal, access to safe water, and hand washing practices as the "basic pillars for building effective hygiene practice" but emphasizes that home hygiene practices including surface disinfection are "key to controlling a significant portion of" infectious diseases.[10,11] As an example of the importance of hygiene, a study in Cape Town, South Africa showed a significant reduction in gastrointestinal illness of children under five in households provided with a joint hand and environmental hygiene education intervention.[12]

Despite the acceptance of the importance of surface disinfection in developed countries, few studies have investigated surface decontamination as a sanitation option in developing countries. Surface decontamination may be important, as, for example, one study from Tanzania showed dinner plates were readily contaminated with FIB and gastrointestinal pathogen markers in peri-urban households.[3] In this study, we examined household cleaning practices and the prevalence of FIB (e.g., total coliform, enterococci, and *Escherichia coli*) on dinner plates as indicators of the need for improved cleaning practices (e.g., surface disinfection using bleach) in four peri-urban communities near Iquitos, Peru. We also estimated the rate of new household demand for bleach for domestic disinfection using the conceptual model of adoption stages and behavioral indicators of a new demand for sanitation developed by Jenkins and Scott (2007).[13]

In January 2012, local enumerators conducted structured interviews with the female heads of 280 households in Spanish. All study participants gave informed consent before enrollment. The study was approved by the Institutional Review Board of the Johns Hopkins Bloomberg School of Public Health and the Asociación Benéfica PRISMA, Peru.

Within each community, clusters of 10–20 households were identified and seven clusters, chosen at random using a random number generator, were visited. Within each cluster, the first household was selected at random. Surveys were then conducted in a clockwise direction visiting each subsequent household in the cluster until data were collected from 10 households. Vacant households, or households in which the head of household was absent or declined to participate, were replaced by the next household.

Bacteria were recovered from dinner plates at a subset of 21 households (every 10th household surveyed in three of the four communities) using polyester tipped swabs following a method that recovers an estimated 20% of surface *E. coli*.[14] Participants were asked to provide a dinner plate ready to use for eating. Plates provided were not classified as washed or unwashed. Two swabs were collected from different areas of the same fomite (dinner plate) to test for three types of bacteria (enterococci, *E. coli*, and total coliform) using two assays. A swab was prewet in 1/4-strength Ringer's solution (Oxoid Ltd., Hampshire, UK) and used to sample ~100 cm^2 areas on the fomite. The swab was then placed in a Whirl-Pak bag (Nasco, Fork Atkinson, WI), stored on ice, and transported back to the laboratory within 6 hours. In the laboratory, 100 mL of phosphate buffered saline and the appropriate media (Enterolert or Colilert, IDEXX Laboratories, Westbrook,

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TABLE 1
The proportion of the population within each of five stages of adoption*

Survey questions	Response	Nested adoption stage
What do you use to clean cups, plates, and utensils?	Bleach	**Adoption**
-or- other surfaces in the household?	Other	Non-adoption
Of the non-adopters: Have you considered using bleach to clean	Yes	Consideration
cups, plates, or utensils? -or- other surfaces?	No	**No consideration**
Of those considering: What is the likelihood that if I come back in a year you will be using bleach to clean cups, plates or utensils?	High	**High likelihood (new demand)**
-or- other surfaces in the household?	Low/medium	**Low/med likelihood**
	None	**No likelihood**

*(Column 3, shown in bold) was determined based on responses (column 2) to a series of survey questions (column 1) on use, consideration of use, and intention to use bleach as a surface disinfectant according to the model and indicators developed by Jenkins and Scott (2007).[13]

ME) was added to the Whirl-Pak bag, the swab was hand mixed in buffer and media to elute bacteria, and the bacteria were enumerated using the most probable number (MPN) IDEXX Quanti-tray System. Estimated lower and upper limits of detection are 1 and 2,420 MPN/100 cm^2, respectively.

In addition, a survey lasting ~1 hour was conducted as part of a larger study on water, sanitation, and hygiene. The survey collected data on basic sociodemographic indicators and risk factors for infection, including knowledge, behavior, and perceptions of water, sanitation, hygiene, and health. The average respondent was 39 years of age. Nearly all respondents had completed primary school (90.6%), and 43.9% had completed secondary school. Respondents used a private latrine (49%), private bathroom (35%), shared latrine (4%), shared bathroom (5%), cesspool (3%), open field (3%), or river (1%) for sanitation needs. Of 236 respondents who answered a question concerning household flooring material, 53%, 28%, 7%, and 12% reported floors that were dirt, cement, wood, or a combination of materials, respectively. Respondents were also asked an unprompted question about chlorine use in the home. Responses, other than using chlorine for surfaces and dishes, included washing clothes (98%), drinking water treatment (16%), and bathing (5%).

Modifying survey questions developed by Jenkins and Scott[13] to measure preference and adoption, households were classified into one of five stages of adoption of bleach as a surface disinfectant in Table 1.

All statistical analyses were performed using R (version 2.9.0, R Foundation for Statistical Computing, Vienna, Austria).

Total coliform, *E. coli*, and enterococci were detected on 86%, 43%, and 24% of plates sampled, respectively. On plates with detectable FIB, the geometric mean (MPN/100 cm^2) was 156.5, 7.2, and 2.1 for total coliform, *E. coli*, and enterococci, respectively (Table 2). For comparison, Oswald and others (2007)[15] reported stored drinking water *E. coli* concentrations of 35 colony-forming units (CFU)/100 mL in peri-urban areas outside Lima, Peru.

Of the 280 respondents, 267 (95%) reported usually cleaning their cups, plates, and utensils (hereafter referred to as "tableware"). Of the respondents who usually cleaned tableware, 232 (83%) reported doing so after each use; the rest reported a frequency of at least once per day. The majority of households (255 or 91%) also reported regularly cleaning other surfaces (e.g., tables, chairs, walls). Of these, 85 (33%), 162 (64%), and 231 (91%) reported cleaning after each use, at least once per day, and at least once per week, respectively. Of the 13 who did not report usually cleaning tableware, three declined to answer and the remaining 10 were different from the rest of the population in their reported cleaning of other surfaces (90% reported not cleaning other surfaces compared with 2% of the rest of the population) and the use of shared latrines and/or open defecation (30% compared with 7% of the rest of the population). Soap and water were the most commonly used cleaning agents (Table 3).

Most respondents (70%) reported having bleach in the house at the time of the survey. Among them, 65% declined to show bleach when prompted. Among respondents who reported using bleach to wash tableware and surfaces, 57% and 62%, respectively, declined to show bleach when prompted. This suggests that bleach use may be over reported.

Approximately 60% of sampled households did not use bleach as a surface disinfectant for either tableware or other surfaces (*non-adopters*); their main reasons included perceiving surfaces to be sufficiently clean (43% of 190 households), not knowing how to use bleach (20%), prohibitive cost (14%), and using other cleaning products or methods (12%). Other reasons included insufficient time (3%), and not knowing where to purchase bleach (3%).

Study households were classified into one of five nested adoption stages based on survey results (see Tables 1 and 4). *New demand* households are those reporting a high likelihood of using bleach within the next 12 months. *New demand* for bleach was 7.3% among non-adopter households (15 non-adopter households representing 5.4% of all households) for disinfecting tableware and 7.0% among all non-adopter households (15 non-adopter households representing 5.4% of all households) for disinfecting other surfaces. The combined rate of *new demand* for bleach as a surface disinfectant (tableware or other surfaces) was 13% among non-adopter

TABLE 2
The percentage of fomite samples (dinner plates) with detectable FIB*

	FIB on dinner plates (MPN/100 cm^2)				
	< 1	1–10	11–100	101–1,000	> 1,000
Total coliform (*N* = 21)	14% (3)	19% (4)	19% (4)	19% (4)	29% (6)
E. coli (*N* = 21)	57% (12)	29% (6)	5% (1)	5% (1)	5% (1)
Enterococci (*N* = 21)	76% (16)	19% (4)	5% (1)	0% (0)	0% (0)

*The number of samples with fecal indicator bacteria (FIB) concentrations within each range is provided in parentheses.

Table 3
Respondents who reported usually cleaning tableware and other surfaces were asked unprompted questions about what cleaning methods were used*

	Cleaning method (unprompted)						
	Water	Soap	Bleach	Cloth	Hand	Sponge	Sand or ash
Tableware (N = 267)	99.6% (266)	92% (246)	28% (75)	20% (54)	20% (53)	6.7% (18)	1.5% (4)
Other surfaces (N = 255)	91% (231)	68% (174)	26% (66)	9.0% (23)	16% (42)	2.0% (5)	0.4% (1)

*Numbers of households for each category are provided in parentheses below percentages.

households (22 unique non-adopter households representing 7.8% of all households).

The limited sample size (N = 21) precluded statistical analysis of associations between reported bleach use and microbial contamination on plates. However, qualitative comparisons showed no evidence of a reduced rate of surface contamination on plates among reported bleach users. For example, *E. coli* was detected on 42% (3 of 7) of the plates in households reporting adoption of bleach for tableware compared to 42% (6 of 14) in non-adopter households. Similarly, enterococci were detected on 43% (3 of 7) of the plates in households reporting adoption, but only 14% (2 of 14) of the plates in non-adopter households. Only 14% (3 of 21) households in which a plate was sampled were able to show bleach to the health worker. A larger sample size is needed to link reported cleaning and disinfection practices to surface contamination.

The study also highlights similarities and differences between adopter and non-adopter households. Households adopting bleach use for any surfaces were reportedly less likely to clean surfaces at least daily (42% versus 66%, two-sided Student t test $P < 0.001$). Observed differences between adopter and non-adopter households that were not statistically significant included access to a private tap (52% of adopter households had access as compared with 40% in non-adopter households, two-sided Student t test $P = 0.06$), and presence of dirt floors (48% in adopter households as compared with 57% in non-adopter households, two-sided Student t test, $P = 0.15$). No difference was observed in access to a private latrine or a toilet (86% in adopter households versus 84% in non-adopter households, two-sided Student t test $P = 0.68$) or in likelihood to treat drinking water (30% in adopter households versus 25% in non-adopter households, two-sided Student t test $P = 0.44$).

The proportion of plates with detectable *E. coli* in the Peru study setting was similar to what has been reported on fomites in households in Tanzania and Cambodia, where *E. coli* were detected on 30–50% of surfaces tested and is higher than in the United States and European Union, where fecal coliform were detected on 2–20% of surfaces tested.[3,4,8,16–18]

The FIB was observed on plates even though survey respondents reportedly cleaned tableware frequently, with most (80%) reporting use of soap when cleaning. These findings suggest one or more of the following: reported cleaning methods do not reflect methods used to clean the sampled plate, cleaning methods do not effectively disinfect tableware, surfaces may be rapidly recontaminated after cleaning or disinfection, or survey responses were biased to over report bleach use. Following the 1991 cholera outbreak in the region, disinfection of fruits and vegetables using a bleach solution was widely recommended[19]; the households that reported bleach use on tableware may be doing so because of their previous education on disinfection practices.

There are some limitations to the current study that warrant further investigation. Bleach was the only surface disinfectant discussed, but respondents may have been more familiar with alternative products such as quaternary ammonium compounds, laundry detergents, glutaraldehyde, and pine oil. Households' self-reported bleach adoption, consideration, and likelihood of future use of bleach as a tableware or other general surface disinfectant may be biased by social desirability factors. Additionally, FIB concentrations on dinner plates are not necessarily reflective of FIB concentrations on other surfaces in the household. Importantly, the sample size for dinner plate contamination assays precludes rigorous statistical analysis, including inclusion of potential covariates (e.g., frequency of cleaning, household adoption stage), correlations with sources of contamination (e.g., hands, latrines) and adverse health outcomes (e.g., diarrheal rates). Although FIB are frequently used to indicate fecal pollution, their presence in this study does not necessarily indicate fecal contamination; *E. coli* and enterococci may be naturalized in tropical soil.[20] Finally, presence of FIB does not necessarily constitute a health risk.[8]

Survey results highlight that, despite high reported prevalence of bleach at home (albeit unconfirmed) for other reasons (e.g., laundry, water treatment), there is low reported use of bleach or other surface disinfectants to disinfect tableware and other surfaces. Most households had not considered using

Table 4
The proportion of respondents in Peru at each adoption stage of using bleach as a disinfectant*

	Adoption	High likelihood (new demand)	Low/med likelihood	No likelihood	No consideration	Decline to answer
Tableware (N = 280)	27% (75)	5.4% (15)	20% (55)	23% (64)	13% (37)	13% (34)
Other surfaces (N = 280)	24% (66)	5.4% (15)	15% (42)	18% (51)	22% (61)	16% (45)

*(Row 1) for tableware and (row 2) other surfaces in their households, based on the model and indicators developed by Jenkins and Scott (2007).[13] Numbers of households for each category are provided in parentheses below percentages.

bleach or were unlikely to use it for these purposes in the near future. A lack of awareness may explain low demand: respondents who did not use bleach believed that surfaces were already clean, current cleaning methods were sufficient, or did not know how to use bleach. These results suggest that low use is caused by limited demand for, not supply of, surface disinfection products. This study highlights the need for further investigations of the appropriateness of domestic hygiene as an intervention to reduce disease transmission in developing countries. Bleach is readily available in the study region, and knowledge about bleach and its role in cleaning are well recognized.

Received July 10, 2012. Accepted for publication July 1, 2013.

Published online September 9, 2013.

Financial support: This work was supported by the Osprey Foundation of Maryland, Inc., the Johns Hopkins Center for Global Health, and the Johns Hopkins University Global Water Program.

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