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Conditions, Behaviors, and Fecal Contamination of Nursery Schools in Four Low and Medium Income Neighborhoods of Accra, Ghana

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Master of Public Health

Global Health

_____

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Conditions, Behaviors, and Fecal Contamination of Nursery Schools in Four Low and Medium Income Neighborhoods of Accra, Ghana

By

Benjamin Natkin

Bachelor of Arts
George Washington University
2009

Thesis Committee Chair: Matthew Freeman, PhD

An abstract of
A thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University
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2015

Abstract

Conditions, Behaviors, and Fecal Contamination of Nursery Schools in Four Low and Medium Income Neighborhoods of Accra, Ghana
By Benjamin Natkin

While under five deaths due to diarrhea remain high in Africa, little is understood of the role of nurseries in the transmission of fecal pathogens. Nurseries in four neighborhoods of Accra, Ghana were selected for a mixed methods investigation of conditions and child behaviors that could affect exposure to fecal bacteria and the presence of E. coli on hands, surfaces and in water stored on site. A high ratio of children to teachers was noted as well as poor latrine conditions and a lack of water designated for hand washing. The large majority of children showed E. coli contamination on their hands, along with frequent contamination of surfaces such as chairs, toys, and food wrappers. Linear models between nursery conditions and level of hand contamination showed significant relationships for the ratio of children to teachers and the presence of feces on latrine floors or walls.

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Thank you to Matt Freeman, for his infinite patience, boundless wisdom, and never ending supply of snack foods during office hours. Without him, none of this would have been possible. Thank you as well to everyone else involved in the Sanipath project for your hard work and help.

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Thank you to all of my family and friends for their love and encouragement. They were an as indispensable a resource as any database or library catalogue. A very special thank you to my parents and my sister for their belief in me in everything I do.

And finally, thank you to my late grandmother, Betty Natkin, for inspiring a lifelong passion for making people wash their hands and washing everything with bleach.

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Chapter I: Introduction and Literature review

Context of Project

Diarrhea is a major cause of under-five mortality, causing an estimated 11-19% of all global deaths in this age group (1-3). At least 40% of these deaths occur in Africa (1). While the rate of under 5 mortality caused by diarrhea is falling worldwide, it is falling slower in Sub-Saharan Africa than in nearly any other region (2). As of 2012, Millennium Development Goal target 4a, the reduction by two-thirds of under-5 mortality was achieved or on track for only 9 of 46 countries in the Africa region (4). Mortality is far from the only outcome of the high prevalence of childhood diarrhea. Frequent diarrheal episodes are associated with lifelong stunting, leading to further health and cognitive impairments (5). Children under 5 are not only at a higher risk of diarrheal disease themselves, but can be a significant factor in spreading disease to others even when asymptomatic (6, 7).

In the developing world, where this burden is the heaviest, urbanization and increased labor force participation by mothers has resulted in increasing numbers of children enrolled in group day care services (8). Care outside the home is associated with positive developmental outcomes, such as increased IQ and eventual socioeconomic status (9). However, these settings are frequently foci of diarrheal disease outbreaks (10), and children attending day care are more likely to become sick than those being cared for at home (11). Fecal contamination of food preparation surfaces (12), toys easily inserted in the mouth (13), faucets (14), and floors (15) can lead to increased risk of exposure and infection for children. While these outbreak studies include microbiological data, observational data on child and caregiver behaviors is much less common, and usually cursory.

Problem Statement

While numerous studies have explored the dynamics of hygiene and diarrheal disease at day care centers in the developed world, finding that they are common settings for disease transmission and that contamination is variable between settings (11-14, 16, 17), very few studies have looked at these same issues in the developing world, and outside of an outbreak context, almost none have looked at day care centers in sub-Saharan Africa. Facility design, behaviors, and other factors affecting pathogen transmission are all potentially different in resource constrained settings. Informal settlements in these countries are of particular concern, given that informality may be associated with increased environmental contamination (18) and failure to seek appropriate medical care for diarrhea (19). These institutions where children spend hours on a daily basis among other children are not well understood in low income settings, especially as they relate to fecal exposure.

The purpose of this study was to provide an estimate of the behaviors and conditions that could result in fecal pathogen exposure, quantify the microbiological contamination of surfaces, objects, and water in nurseries, and estimate the associations between behaviors and conditions and child hand contamination. This paper describes the above parameters of selected day care centers in four low and middle-income neighborhoods of Accra, Ghana. Approximately 11.7% of Accra's residents are under the age of 5 (20), and while previous research has investigated the importance of child care practices in the home (21, 22), no studies have examined the conditions this is the first study to look at Ghanaian day care centers through the lens of hygiene. To understand how and why children become sick, we must understand what happens in these spaces where children mingle outside of their immediate family. Additionally, we hope to

contribute to the development of methodologies to better understand the material conditions of developing world day care centers and their effect on health.

This study of nursery conditions is a part of the larger SaniPath study, which was undertaken to quantify fecal exposure in Accra and more generally to create a rapid assessment tool for creating this data for low income urban areas worldwide. These data were generated from a mixed methods approach, combining both microbiological and observational data.

Chapter II: Literature Review

Al-Ghamdi MA, Bentham G, Hunter PR. Environmental risk factors for diarrhoea among male schoolchildren in Jeddah City, Saudi Arabia. Journal of water and health. 2009;7(3):380-91.

Families of boys aged 7-12 in Jeddah were surveyed about the boys' health, demographic info, and WASH risk factors. A logistic model was then fitted using factors which have a $P < 0.2$ significant effect on diarrheal episodes. 14.9% of children had diarrhea in the previous month. Of these, 49.7% had missed school because of the disease, which frequently occurred along with vomiting (43.0%) and fever (33.8%). Problems noted in the public water network was associated with increased risk of illness, as were sewage spills near the home, as were hand washing behaviors (before eating, when coming into the home, after using the bathroom, and drying hands after washing), buying food outside the home, and use of dishrags or sponges while cleaning dishes.

Amugsi DA, Mittelmark MB, Lartey A, Matanda DJ, Urke HB. Influence of childcare practices on nutritional status of Ghanaian children: a regression analysis of the Ghana Demographic and Health Surveys. BMJ open. 2014;4(11):e005340.

While family SDS is well understood to affect infant and young child growth, the role of factors that families have more control over, including child care practices and clean water availability, is less well understood. Using Ghana's DHS survey, 1187 children for whom anthropometry data was available were analyzed for a child care practices score which was made of variables based on feeding practices and use of preventive health service. Additional variables including

demographics of children, mothers, and other household members and water/sanitation availability were also included. A significant, positive relationship between the child care practice score and HAZ was observed.

Barnes PM, Maddocks A. Standards in school toilets--a questionnaire survey. Journal of public health medicine. 2002;24(2):85-7.

A questionnaire regarding school toilets was administered to children in South Wales. Questions involved access, hygienic conditions, facilities available (such as hand washing facilities and toilet paper), privacy, and issues of bullying. Children's caretakers were asked about recent constipation. The ability to close and lock doors, cleanliness, and availability of toilet paper were all problematic. Additionally, only 28% of children said that they felt comfortable defecating at school, while the number willing to urinate was much higher. Roughly ten percent of children had recently experienced constipation, which could be tied to their lack of willingness to defecate in the bathroom.

Bartlett AV, Moore M, Gary GW, Starko KM, Erben JJ, Meredith BA. Diarrheal illness among infants and toddlers in day care centers. II. Comparison with day care homes and households. The Journal of pediatrics. 1985;107(4):503-9.

A prospective study of diarrheal illness comparing children in day care centers, home based paid day care, and children taken care of at home was undertaken in Maricopa County, Arizona. The day care center and home-based day care children were actively monitored for diarrheal outbreaks, with weekly visits from enumerators, whereas households were monitored passively. Questionnaires were administered at the beginning of the study, then stool samples were taken

from all ill children and children attending day care in places there were ongoing outbreaks. The most common pathogen found was Giardia. Children in day care centers, which had the highest number of children present, had a higher rate of illness compared to the other settings. Better hand washing was also associated with less illness.

Boschi-Pinto C, Velebit L, Shibuya K. Estimating child mortality due to diarrhoea in developing countries. Bulletin of the World Health Organization. 2008;86(9):710-7.

The authors conducted a systematic literature review of articles on under-five diarrhea related mortality from 1980 to 2007. The study was undertaken as a part of the Child Health Epidemiology Reference Group (CHERG), a UNICEF/WHO led group of experts attempting to create a uniform standard of knowledge across different diseases and conditions which may cause child death. Diarrhea was found to cause 19% of under 5 deaths worldwide, or 1.87 million deaths per year. Africa and Southeast Asia make up the bulk of these deaths. This estimated proportion of all under-five deaths is below that of other recent estimates, possibly due to the comprehensive nature of their review cutting out some sources of selection bias.

Carabin H, Gyorkos TW, Joseph L, Payment P, Soto JC. Comparison of methods to analyse imprecise faecal coliform count data from environmental samples. Epidemiology and infection. 2001;126(2):181-90.

Membrane filtration in order to measure bacteria frequently ends with either too many CFUs to count, or nothing at all in a given sample. Standard procedures for measuring bacteria can be affected by imprecision caused by clustering of bacteria in water or other reasons as well. While multiple tests and dilutions can correct for these problems, logistics and costs often prevent such

rigorous methods from being employed. Using samples originating from handrinses and swabs taken at Quebec area day care centers, the researchers compared statistic methods including multiple imputation and interval censored regression with more common methods such as using half of the lowest screening dilution used, dichotomizing results, or attributing a value of 1 to every imprecise value. Multiple imputation provided more conservative confidence intervals which may be more theoretically sound, though the difference was minimal, especially considering the way that bacteria counts are distributed.

Cosby CM, Costello CA, Morris WC, Haughton B, Devereaux MJ, Harte F, et al. Microbiological analysis of food contact surfaces in child care centers. Applied and environmental microbiology. 2008;74(22):6918-22.

Six Knoxville area day care centers were sampled monthly for 8 months to understand the presence of *E. coli* on food preparation and diaper changing surfaces. *E. coli* recovery was fairly consistent within each day care center with some always showing higher counts and some always showing lower counts. The counts were all generally low, with associations shown for different personnel, the time of day the sample was taken, and cleaning protocols in place.

Ekanem EE, DuPont HL, Pickering LK, Selwyn BJ, Hawkins CM. Transmission dynamics of enteric bacteria in day-care centers. American journal of epidemiology. 1983;118(4):562-72.

Five Houston area nursery schools were selected for long term evaluation. Schools were routinely sampled for fecal coliforms, shigella, and salmonella, with hand rinses and surface

swabs taken monthly. Additionally, when an outbreak of diarrheal disease occurred, the team came in for additional sampling. Though recovery was higher during outbreaks than routine sampling, the two values were fairly close. In general, recovery from surfaces was common, though with low plate counts. The exceptions were classroom floors, toys, and table tops, which all showed much more common fecal coliform presence during outbreaks than during routine sampling.

Fobil JN, Kraemer A, Meyer CG, May J. Neighborhood urban environmental quality conditions are likely to drive malaria and diarrhea mortality in Accra, Ghana. Journal of environmental and public health. 2011;2011:484010.

While rural incidences of malaria and exposure to enteric pathogens have been investigated, low income urban environments have lagged behind. Using a set of 65 variables to describe the built environment and water/sanitation conditions in neighborhoods across Accra, a classification of environmental quality in these neighborhoods was created. This classification was then compared to malarial and diarrheal mortality rates using a one way analysis of variance for each of these rates. Degraded environments were associated with higher incidence of malarial mortality, but diarrheal mortality did not differ significantly by environmental quality.

Guerrant RL, DeBoer MD, Moore SR, Scharf RJ, Lima AA. The impoverished gut--a triple burden of diarrhoea, stunting and chronic disease. Nature reviews Gastroenterology & hepatology. 2013;10(4):220-9.

The high incidence of diarrhea in the developing world has implications for its children beyond the headline number of mortality. Chronic malnutrition caused by childhood diarrhea, especially

in the poor, has lifelong consequences, including stunting and cognitive impairment, both of which can lead to lifelong poverty, inhibiting the ability of these people to ever break the cycle of poverty. Furthermore poor development in early life is increasingly being linked to later life non-communicable diseases such as CVD. These long acting diseases drain family resources not only through medical costs but through an inability to work. Multi-generational poverty is thus strongly linked to the prevalence of environmental enteropathy.

Heijnen M, Cumming O, Peletz R, Chan GK, Brown J, Baker K, et al. Shared sanitation versus individual household latrines: a systematic review of health outcomes. PloS one. 2014;9(4):e93300.

Shared sanitation has in the past been categorically excluded from improved sanitation definitions, regardless of service level. Nonetheless, hundreds of millions worldwide rely on shared sanitation, and this number is growing, especially in urban areas. In order to assess the validity of this assumption, a literature review of the relevant data was conducted. 22 documents were used in the final analysis. The data focused on urban areas with outcomes of diarrhea (general, watery, or bloody) as well as specific disease outcomes such as typhoid fever or intestinal parasites. A consistent and significant pattern of increased risk for negative health outcomes was observed, confirming the belief that shared sanitation cannot be considered equal to improved sanitation for the sake of the MDGs or other health related goals.

Holaday B, Pantell R, Lewis C, Gilliss CL. Patterns of fecal coliform contamination in day-care centers. Public health nursing (Boston, Mass). 1990;7(4):224-8.

Six day care centers in San Francisco were inspected for the presence of fecal indicator bacteria. Each center was visited four times over a six month period during which swabs were taken from relevant surfaces and hand rinses were taken from children and caregivers. 9.5% of surfaces sampled showed fecal coliform presence, along with 6% of children's hands and 16% of caregivers'. Presence of non-toilet trained children did not affect the presence of fecal indicators, nor did differing socioeconomic status. Toilets and toys did not have particularly high recovery rates, but surfaces in the kitchen, tables for children, and faucets outside the bathroom did. Time of year did not affect recovery rates. These rates remain similar to rates before major governmental endeavors were undertaken to improve daycare hygiene, showing the difficulty of changing these factors.

Hunter PR, Hughes S, Woodhouse S, Syed Q, Verlander NQ, Chalmers RM, et al. Sporadic cryptosporidiosis case-control study with genotyping. Emerging infectious diseases. 2004;10(7):1241-9.

A matched case control study of cryptosporidiosis was undertaken in northwest England and Wales. Questionnaires were administered to cases and controls and a chi-squared tests were used to ascertain associations between patient behaviors and an outcome of cryptosporidiosis. A logistic model was then created using all variables showing a $p < 0.2$ significance in a modified stepwise selection. International travel, contact with animals, and contact with a patient were all strongly associated, but interestingly contact (specifically toileting) with any child under 5, even one who hadn't been sick, was positively associated with cryptosporidiosis.

Itah AY, Ben AE. Incidence of enteric bacteria and Staphylococcus aureus in day care centers in Akwa Ibom State, Nigeria. The Southeast Asian journal of tropical medicine and public health. 2004;35(1):202-9.

Microbiological samples were taken from surfaces, water, and children's skin in four day care centers in Akwa Ibom state, Nigeria. The samples were tested through membrane filtration and broth incubation for total and fecal coliforms, *Staphylococcus aureus*, and for *Vibrio cholera*. Samples were taken one time without clear indication of systemic methods of sampling. Bacterial counts were classified as none, scanty, some, or profuse, though the precise definition of these levels is not made clear. Tables and door handles showed the highest concentrations of coliforms. Widespread antibiotic resistance was common.

Laborde DJ, Weigle KA, Weber DJ, Kotch JB. Effect of fecal contamination on diarrheal illness rates in day-care centers. American journal of epidemiology. 1993;138(4):243-55.

Day care attendees in Cumberland County, North Carolina, were followed for a period of 6 months with biweekly phone calls to the parents to determine incidents of diarrheal disease. Afterwards the day care centers attended by these children were sampled once for fecal coliforms on various surfaces including hands. FC presence and level at moist sites, including hands, sinks, and faucets, were both higher than other surfaces inspected and more strongly associated with diarrhea.

Liu L, Johnson HL, Cousens S, Perin J, Scott S, Lawn JE, et al. Global, regional, and national causes of child mortality: an updated systematic analysis for 2010 with time trends since 2000. Lancet. 2012;379(9832):2151-61.

In order to update the estimates of under-five mortality, the authors used vital information registration systems where available and a multinomial logistic regression was used. Neonatal and 1-59 month deaths were differentiated both in methods used and how the data was reported. Deaths were grouped into categories, namely pneumonia, diarrhea, meningitis, injury, malaria, congenital abnormalities, perinatal causes, and other, though several other estimates were also created such as measles. Of all deaths reported, 64% were from infectious sources, though in Africa this proportion is 73.2%. The number of deaths under five is falling in all regions, but in Africa in particular this number is not reducing nearly as fast as in other regions, and its under-five deaths are primarily from preventable causes.

Mattioli MC, Pickering AJ, Gilsdorf RJ, Davis J, Boehm AB. Hands and water as vectors of diarrheal pathogens in Bagamoyo, Tanzania. Environmental science & technology. 2013;47(1):355-63.

93 households in Bagamoyo, Tanzania with at least one under five child were sampled for presence of specific human pathogens in hand rinses or in stored drinking water. E. coli was tested for 7 pathogenic genes and the human specific Bacteriodales gene was sought in rotavirus, enterovirus, and adenovirus samples. An interview was also conducted with the female head of household regarding hygiene, water consumption, and demographic data. Chlorine was not found in the municipal water, though it was supposedly treated. Pathogenic E. coli was very common, showing up in 59% of stored water samples, and on 41% of hand rinses. Enteric viruses were more common on hands than in water, implying that hands are an important means of transmission.

Mukiira C, Ibisomi L. Health care seeking practices of caregivers of children under 5 with diarrhea in two informal settlements in Nairobi, Kenya. Journal of child health care : for professionals working with children in the hospital and community. 2013.

Delay in seeking care for severe diarrhea and other conditions is linked to increased under five mortality, especially in developing countries. In the slums of Nairobi, one major cause is the difficulty of accessing health care facilities, especially at night. Data from a prospective study in two informal neighborhoods of Nairobi wherein all children born within the study area were followed every 4 months for a total of 4 years. When contacting families, enumerators asked about any illnesses that the children had experienced within the previous two weeks and what the family did about it. Coding for appropriate or inappropriate health seeking behavior as the dependent variable, logistic models were fit to understand what led families to seek care. Taken individually, the age of the child and caregiver, household wealth and duration of illness were all significantly associated with appropriate care seeking behavior. When adjusted, child age, and formality of settlement were significant. Education was not found to significantly affect care seeking behavior.

Ruel MT, Levin CE, Armar-Klemesu M, Maxwell DG, Morris S. Good care practices can mitigate the negative effects of poverty and low maternal schooling on children's nutritional status: evidence from Accra. World Dev. 1999;27.

A representative survey of households with children 3 and under in Accra was undertaken to understand the role of child care and household type in the HAZ and WAZ scores for children. While maternal schooling and low income have previously been shown to negatively affect child growth, this study shows that this is only true when the mothers are poor carers. It disappears

with good care practices. In general, better care and better home facilities were shown to have positive effects on child growth.

Van R, Morrow AL, Reves RR, Pickering LK. Environmental contamination in child day-care centers. American journal of epidemiology. 1991;133(5):460-70.

Six Houston area day care centers were monitored for 13 weeks. The week prior to the study, all cleaning, diapering, and housekeeping procedures were recorded. In addition to monitoring the incidence of diarrhea among pupils, areas in each study room were swabbed twice a week throughout the study to test for fecal coliforms. Once per week, a caregiver and 5 children had their hand sampled for fecal coliforms as well. Pupils developing diarrhea during the study gave stool samples. Inanimate objects showed contamination 2-34% of the time depending on the week. Hand contamination was noted in a mean of 20% of pupils and 16% of caregivers. Hands of caregivers and children were more likely to be contaminated the week of a diarrheal event. Toys as well were a frequent carrier of fecal bacteria.

Zoritch B, Roberts I, Oakley A. Day care for pre-school children. The Cochrane database of systematic reviews. 2000(3):Cd000564.

The decision whether or not to send children to day care is an important and difficult decision for parents. A Cochrane review of the health effects of day care center attendance. Eight randomized control trials were selected from among several hundred possibilities. The studies primarily focused on the effects for low income and African-American students. IQ improvements were strongly noted across studies, as well as other school achievement measures. Behavioral

outcomes were mixed. The only study that included health outcomes found increased health issues at 3 years but not at 5 for children enrolled in day care

Chapter III: Manuscript

Title Page

Conditions, Behaviors, and Fecal Contamination of Nursery Schools in Four Low and Medium Income Neighborhoods of Accra, Ghana

Benjamin J Natkin

Contribution of Student

I did not participate in the design of the SaniPath study, nor the data collection, nor the overall management of the project. My role was to analyze and write up the nursery data once that data had been collected, cleaned, and separated. I created and performed all analysis once the database had been created. I was also responsible for writing the manuscript which follows, including all figures and tables with the exception of table 1 describing the selected neighborhoods which was adapted from the unpublished paper Peprah, et. al.

Abstract

While under five deaths due to diarrhea remain high in Africa, little is understood of the role of nurseries in the transmission of fecal pathogens. Nurseries in four neighborhoods of Accra, Ghana were selected for a mixed methods investigation of conditions and child behaviors that could affect exposure to fecal bacteria and the presence of E. coli on hands, surfaces and in water stored on site. A high ratio of children to teachers was noted as well as poor latrine conditions and a lack of water designated for hand washing. The large majority of children showed *E. coli* contamination on their hands, along with frequent contamination of surfaces such as chairs, toys, and food wrappers. Linear models between nursery conditions and level of hand contamination showed significant relationships for the ratio of children to teachers and the presence of feces on latrine floors or walls.

INTRODUCTION

Diarrhea is a major cause of under-five mortality, causing an estimated 11-19% of all global deaths in this age group (1-3). At least 40% of these deaths occur in Africa (1). While the rate of under 5 mortality caused by diarrhea is falling worldwide, it is falling slower in Sub-Saharan Africa than in nearly any other region (2). As of 2012, millennium development goal target 4a, the reduction by two-thirds of under-5 mortality was achieved or on track for only 9 of 46 countries in the Africa region (4). Mortality is far from the only outcome of the high prevalence of childhood diarrhea. Frequent diarrheal episodes are associated with lifelong stunting, leading to further health and cognitive impairments (5). Children under 5 are not only at a higher risk of diarrheal disease themselves, but can be a significant factor in spreading disease to others even when asymptomatic (6, 7).

In the developing world, where this burden is the heaviest, urbanization and increased labor force participation by mothers has resulted in increasing numbers of children enrolled in group day care services (8). Care outside the home is associated with positive developmental outcomes, such as increased IQ and eventual socioeconomic status (9). However, these settings are frequently foci of diarrheal disease outbreaks (10), and children attending day care are more likely to become sick than those being cared for at home (11). Fecal contamination of food preparation surfaces (12), toys easily inserted in the mouth (13), faucets (14), and floors (15) can lead to increased risk of exposure and infection for children. While these outbreak studies include microbiological data, observational data on child and caregiver behaviors is much less common, and usually cursory.

While numerous studies have explored the dynamics of hygiene and diarrheal disease at day care centers in the developed world, finding that they are common settings for disease transmission and that contamination is variable between settings (11-14, 16, 17), very few studies have looked at these same issues in the developing world, and outside of an outbreak context, almost none have looked at day care centers in sub-Saharan Africa. Facility design, behaviors, and other factors affecting pathogen transmission are all potentially different in resource constrained settings. Informal settlements in these countries are of particular concern, given that informality may be associated with increased environmental contamination (18) and failure to seek appropriate medical care for diarrhea (19). These institutions where children spend hours on a daily basis among other children are not well understood in low income settings, especially as they relate to fecal exposure.

The purpose of this study was to provide an estimate of the behaviors and conditions that could result in fecal pathogen exposure, quantify the microbiological contamination of surfaces, objects, and water in nurseries, and estimate the associations between behaviors and conditions and child hand contamination. This paper describes the above parameters of selected day care centers in four low and middle-income neighborhoods of Accra, Ghana. Approximately 11.7% of Accra's residents are under the age of 5 (20), and while previous research has investigated the importance of child care practices in the home (21, 22), no previous study has examined the conditions this is the first study to look at Ghanaian day care centers through the lens of hygiene. To understand how and why children become sick, we must understand what happens in these spaces where children mingle outside of their immediate family. Additionally, we hope to contribute to the development of methodologies to better understand the material conditions of developing world day care centers and their effect on health.

METHODS

This study of nursery conditions is a part of the larger SaniPath study, which was undertaken to quantify fecal exposure in Accra and more generally to create a rapid assessment tool for creating this data for low income urban areas worldwide. These data were generated from a mixed methods approach, combining both microbiological and observational data.

Study sites

Four neighborhoods in Accra were selected for observation in the SaniPath study: Alajo, Bukom, Old Fadama, and Shiabu. Study designers chose these neighborhoods to cut across several characteristics, namely formality of the settlement, location on the coast or inland, frequency of flooding, and proximity to a major market. Neighborhood characteristics are summarized in table 1.

Within each neighborhood, five nursery schools were chosen purposively by the community liaison for observation. Informed consent was obtained from the administrator in charge of the nursery, who then designated a class for observation. The enumerator then explained the purpose and procedures of the observation to that class's teacher.

Enumerators were recruited from local universities by TREND Group, the local research partner. Enumerators were taught data collection methods and research ethics in classes and field trials. During the study, enumerators were supervised by TREND Group and used community liaisons in the identification of nurseries and attainment of consent.

Child observation

Throughout the morning, one enumerator sat unobtrusively in each classroom and observed a single child for the duration of the observation period. The gender of the child to be observed was determined through coin flip, then the specific child was determined at random.

Enumerators used a child observations form (Appendix A) to count behaviors that could relate to exposure to environmental pathogens and mark the time and location of each behavior. These behaviors included contact with others, placement of fingers or objects in mouth, playing, sleeping, handwashing, bathing, defecating, and eating.

Nursery and latrine conditions

Following the observation period, the enumerator verbally administered the nursery questionnaire (Appendix B) to the teacher. This questionnaire covered basic administrative facts about the nursery (e.g., the number of children enrolled and management type) as well as specific questions about the water and sanitation services available. The enumerator asked to see the latrine available for the children's use and directly observed the conditions on the latrine observation form (Appendix C). Information recorded includes type of latrine, material condition of the latrine (e.g. slab type, presence of a door), apparent cleanliness (e.g. feces observed on floor, flies present, noticeable odor), and cleaning materials present (e.g. toilet tissue, soap).

Microbiological data

The enumerator gathered microbiological data from the nursery following observations. These included water samples, hand rinses of students (including the student observed and one or two others selected at random, though which sample was collected from the observed student was not labeled), and surface swabs of pertinent areas such as tables. Surface swabs of tables, benches, and chairs were taken over a 5 cm x 10 cm area, whereas other swabs were varied in area based

on the object. All surfaces swabbed were areas that the child being observed came into direct contact with. The samples were analyzed for *E. coli* using membrane filtration to determine colony forming units (CFU) per 100 mL. E.coli was used as an indicator of the presence of fecal contamination, and thus the potential for a pathogenic exposure (28). The actual efficacy of E. coli as an indicator is somewhat limited, though it is a cost effective and readily reproducible test across many circumstances (29). Each sample was tested at three dilutions; water and hand rinses were diluted to ratios of 1:1, 1:10, and 1:1000 (though three hand rinse samples were diluted to 1:10, 1:100, and 1:1000) and surface swabs were diluted to 1:100, 1:1000, and 1:10000.

If all three plates showed counts within the range of 20-200 CFU, then the average of all three was used to describe the level *E. coli*. If one or two plates were outside the countable range, then the average of the other plates was used. If all plates were outside of the countable range, but at least one is within the range of 1-20, then the average of all plates within that range was used. If all plates are too numerous or too dirty to count, then a count of 200 for the smallest dilution was used. If all plates show CFU counts of 0 or TNTC, then plates with a count of 0 were imputed a value of 0.5 and the average of these was taken.

Data Methods

Data were double entered in Microsoft Access then cleaned and exported to SAS 9.4. Demographic information was recorded, including student enrollment, number of children and teachers present (as well as their genders), and the ages of the youngest and oldest child present. Counts of child contact with other children or adults and times that children placed fingers or objects in their mouths were calculated as a number of incidents per hour of observation, and this rate was summarized with means and ranges. Children were classified as having washed their

hands zero, one, or two times during the observation period and their use of soap was also noted. Sources of child food were recorded, as well as their use of cutlery and whether they washed their hands immediately before eating. Time spent per location was taken from the difference between the time the child was first noted in that location and when the child was noted in another location, or until the end of the observation period.

Stored water was classified as clean if all three plates showed a zero count for *E. coli* and contaminated if any showed one or more CFUs. Once *E. coli* counts for hand rinses and surface swabs were calculated as detailed above, the counts were Log_{10} transformed to improve the normality of distribution.

Linear regression models were developed to assess which variables were associated with changes in levels of *E. coli* concentration on student hands. Because individual hand swabs were not fully independent but nested within schools, a multi-level random effects approach was used. Because observed children were not identified in the hand rinses, behavioral predictors such as hand washing were not included. For each predictor, a univariate model was fit to explain the transformed *E. coli* concentration from the hand rinses as a function of the variable using Satterthwaite's method of approximating degrees of freedom, followed by a full model.

RESULTS

Due to irregularities in data collection, not every school had data available for all aspects of the study. While all 20 schools had child observations available, only 16 had nursery and latrine conditions available and 16 had environmental data. Among these subsets, 12 had both environmental and nursery conditions available. Two schools were sampled twice for observational data and one was sampled four times.

Nursery and latrine characteristics

Nursery conditions are summarized in table 2. All schools are privately run, with tuition charged either daily or by term. Of the seven schools that charge a daily rate, the cost ranged from 0.7 to 1.4 cedis (0.18 to 0.37 USD) per day with most charging an even 1 cedi (0.26 USD). Among the nine that charged per term, the rate ranged from 45 to 74 cedis (11.73 to 19.30 USD) with a median of 60 (15.65 USD). All nurseries had been open for 2 or more years, with the oldest operating for 33 years. Of the 15 schools for which a floor type was noted, 13 (87%) had cement floors while 2 (13%) had ceramic tiles.

Of the 16 schools for which conditions were recorded, 11 s had latrines present, 9 of which the enumerator was able to fill out information for. 9 flush toilets were found (1 of which was a pour flush toilet) along with 1 bucket latrine. All latrines had a slab with a stance deemed to be secure, and 7 (78%) had a door. Of the 9 latrines observed, 5 (56%) had a noticeable odor, 1 (11%) had flies present, and 2 (22%) had feces on the floor or walls. All latrines had at least one means of anal cleansing available, most commonly toilet tissue (89%) though newspaper (11%), water (11%), and other (22%) were also noted.

Child behaviors

Of the 24 children observed for which demographics were noted, 17 (71%) were male; 1 (6%) was under 1 year of age, 7 (41%) were between 1 and 2 years, and 16 (67%) were between 2 and 5 years of age. All children were capable of walking, all were wearing shoes, and all but 1 were teething. Children were observed for a median of 2 hours and 59 minutes, with a range of between 1 hour and 57 minutes and a maximum of 4 hours and 10 minutes. Behaviors related to hygiene or possible exposure to environmental contamination are summarized in table 3.

Contact with other children was very frequent, averaging more than 17 times per hour. Contact with adults was much less frequent, with 2 children not coming into contact with an adult once during the observation period. The other most common occurrence was children placing fingers or objects in their mouths. The objects placed in mouths included nearly anything available, including clothing, pencils, sticks, chalk, and a broom. Of the children for whom data was available (n=23), more than half (52%) placed a food wrapper or plastic bag in their mouths during observation, with pencils or crayons as the next most common object (39%).

Among the 42 eating events observed, the child or caregiver feeding the child used cutlery 7 times, with the rest using hands only. Of the 22 meals for which the enumerator was able to ascertain the source of the food, 6 were prepared at home, whereas the rest were purchased, packaged food. Several children were noted eating crumbs from the floor or chairs. Only one child washed his or her hands immediately before eating.

Only 7 (28%) children were observed washing their hands at all during the observation period, 2 (8%) of whom used soap. No defecation events were noted during the observation period for any of the children, so it was not possible to assess hand washing at the latrine.

Child locations throughout the observation period are noted in Figure 1. Children spent the majority of their time on the floor. Only 4 children were noted on unimproved/dirt floors, and only one was noted in a standing water and trash area for a period of 10 minutes.

Environmental contamination

A majority of environmental samples taken from surfaces, drinking water, and hands contained microbiological contamination (Table 4). Three types of water were sampled: manufactured water sachets, the water from the public or private tap used to fill on site plastic storage

containers, and water from these containers. The five water sachets sampled were all different brands and taken from different schools, though no *E. coli* was detected in any of them. Water taken directly from the tap was either above or below the limits of detection for all 3 plates, and was therefore categorized as having any *E. coli* detected or having none. 5 of 16 samples taken (31%) showed *E. coli* contamination at the source.

Though *E. coli* data were not available for all tanks, 4 schools extracted water from their tanks with a tap, while the other 12 used a dip. While all schools used this water for drinking, 4 also used this water for hand washing, 3 of which had no tap and children presumably put their hands directly in the water. No schools reported any additional methods of treatment. Stored water had a median turbidity of 1.12 NTUs (range 0.32 – 2.23 NTUs) and a median free chlorine residual of 0.04 mg/L (range 0.03 – 0.10 mg/L). Even the maximum value observed does not come close to the WHO's recommendation of 0.5 mg/L for drinking water.

Multivariable associations between nursery conditions and E. coli concentration on pupil hands

Unadjusted and adjusted models were fitted for associations between nursery conditions and pupil hand contamination. Parameter estimates of each unadjusted model and the partial estimates for each parameter in the final model are included with confidence intervals in table 5. The data used in the models had an intra-class correlation of pupil vs. school variance of 0.77, showing that the variance in hand contamination was predominantly explained by individual schools, confirming the necessity of a multilevel model. Significant findings in the adjusted model included the ratio of children to teacher present, a noticeable odor from the latrine, and the

presence of feces on a latrine floor or wall. Having water designated for hand washing was the closest to significant of the non-significant variables ($p = 0.067$)

DISCUSSION

Behaviors and Conditions

The behaviors and conditions observed in the nursery showed numerous possible pathways to fecal pathogen exposure, including poor latrine conditions, including a lack of any latrine at all, and very little hand washing. The microbiological data confirmed that children were being exposed to fecal indicator bacteria with a large majority of hands and surfaces showing evidence of contamination. Significant associations were shown between several nursery conditions and level of E. coli found on hands, including children per teacher present and feces on latrine floors or walls. Taken together, these results show that fecal exposure in these nurseries is present and likely related to their conditions.

Key among the school conditions for understanding fecal exposure are latrines and hand washing stations. While no defecation was observed while enumerators were present (possibly due to observer effects), 45% of the nurseries lacked an on-site latrine, meaning that children would need to leave the nursery to defecate, either in a public latrine, which has been shown to be a health risk to be a risk factor for adverse health outcomes (23), or defecate openly. More importantly, with only 38% of nurseries had water that was designated for use with hand washing, 4 of which doubled as the school's drinking water, recommended hygienic behavior such as hand washing after defecation or before eating is impossible for many children. Hand washing with soap was even more limited. None of the latrines surveyed received the worst

marks possible for odor, flies, or presence of feces on the floor or walls, implying that at least some care was being taken to maintain these facilities. However, the frequent lack of doors in latrines or shoddy conditions of what doors there were could be a factor preventing children from feeling safe within them.

The surveyed nurseries varied in several demographic areas, such as years of operation, and number of children present. Studies of nurseries in high income settings revealed considerable fecal contamination and lack of attention to hygiene from caregivers in nurseries with as few as of 9 children present on average (13). The number of children present in our study was much higher than the levels seen in studies from the developed world, with as many as 81 children in one nursery, and as many at 37 children per teacher, making the potential for many children to be exposed at once much higher. The high number of children present is reflected in the number of times that children came into contact with each other, the most common behavior noted.

An important factor for understanding the role of child day care centers in the lives of children is the comparison to the lives of children in the household. In another part of the SaniPath study, children from the same 4 neighborhoods were observed at home, where they spent much more time on unimproved floors and in standing water and trash areas than children in nurseries did (27). <<This is fine, but could you add a few more sentences as comparison?>>

Of course, nursery attendance is not independent of possible confounding factors, most notably household wealth. The one cedi per day median rate charged is important because of the implied cost to families. Average household income in Ghana is 1,217 cedis per year (317.35 USD), with the lowest quintile only earning on average 728 cedis per year (189.84 USD)(20). Childcare is a

heavy cost on Ghanaian families, but even in informal and low income settlements, people are still sending their children to day care.

Fecal contamination and modeling

Presence fecal contamination was not unexpected, but quantifying the extent of potential exposure shows both how widespread this contamination is and the association between the potential risk factors and individual hand contamination. The consistency of hand contamination between different groups, with all groups showing a prevalence of *E. coli* presence on hands between 85% and 87%, taken along with the high recovery rate on surfaces and amount of contact between children shows that the contamination is not limited to a few children, but is being spread throughout the nurseries. Studies conducted in the United States have found varying levels of fecal contamination on children's hands in nurseries from as high as 57% (24) to as low as 6% (25). A study that found fecal coliforms on 57% of children's hands found contamination on only 24% of dry surfaces such as tables and chairs, a much lower recovery rate than was found in Accra. Whether because of more frequent cleaning, fewer children, or another factor, tables and chairs were less likely to be a possible pathway to fecal pathogen exposure in the study conducted in the United States than in ours conducted in Ghana.

While prevalence of any *E. coli* in hand samples was fairly uniform within the small sample size, we were able to draw distinctions based on the amount of *E. coli* recovered. In this context, the number of children per teacher revealed a significant association with *E. coli* level, and not the total number of children present. This model does not have the sample size draw conclusions with high confidence, but it describes some of the factors that influence hand contamination at

nursery schools and increases our understanding of how these spaces influence children's exposure to fecal pathogens.

Limitations

The already constrained sample size was further limited due to data loss, whether through enumerator error or loss of paperwork, making comparisons difficult. Additionally, some parts of the observation form were filled out inconsistently. For example, only two forms specified whether there was soap available at a hand washing station, both of which indicated a lack of soap, but we know that several children did wash their hands with soap during the observation period. Another inconsistency was the number of times a school was visited, with 3 schools being visited multiple times for unknown reasons. For some of these visits, missing information was completed on a follow up visit, but it is unclear if the multiple observations were due to a factor that could influence the results.

Surface swabs were not undertaken in a defined or consistent way, and while all areas swabbed were touched by the observed child, the lack of consistency makes these swabs of no use in a model. Furthermore, to avoid collecting identifiable information about the children involved, the observed child's hand rinse was not identified apart from that of the other children. Therefore while we can hypothesize about the role that child contact, hand washing, etc. played on hand hygiene, we cannot make any actual tests of these hypotheses.

Conclusions

Our data revealed that nurseries are an important piece in understanding childhood exposure to fecal contamination. These often forgotten settings may be a vital part of the ecology of childhood illness, mixing children and their associated microflora from across families and other

social groups, then sending them back home. Though children in these establishments may spend less time in risky areas than they would at home, such as drains or stagnant water, their hands show much more prevalent contamination than previous studies of nurseries have demonstrated in the developed world. The large number of children and relatively small number of adults caring for them appears to be an important factor in the dynamics of bacterial transfer. Further research should be undertaken to understand how nurseries in low income settings affect the health of the children that attend them and potential ways to mitigate that risk.

REFERENCES

1. Boschi-Pinto C, Velebit L, Shibuya K. Estimating child mortality due to diarrhoea in developing countries. Bulletin of the World Health Organization. 2008;86(9):710-7.

2. Liu L, Johnson HL, Cousens S, Perin J, Scott S, Lawn JE, et al. Global, regional, and national causes of child mortality: an updated systematic analysis for 2010 with time trends since 2000. Lancet. 2012;379(9832):2151-61.

3. UN. The Millenium Development Goals Report. New York: United Nations Department of Economic and Social Affairs, 2010.

4. World Health Organization. World Health Statistics 2014. 2014.

5. Guerrant RL, DeBoer MD, Moore SR, Scharf RJ, Lima AA. The impoverished gut--a triple burden of diarrhoea, stunting and chronic disease. Nature reviews Gastroenterology & hepatology. 2013;10(4):220-9.

6. Al-Ghamdi MA, Bentham G, Hunter PR. Environmental risk factors for diarrhoea among male schoolchildren in Jeddah City, Saudi Arabia. Journal of water and health. 2009;7(3):380-91.

7. Hunter PR, Hughes S, Woodhouse S, Syed Q, Verlander NQ, Chalmers RM, et al. Sporadic cryptosporidiosis case-control study with genotyping. Emerging infectious diseases. 2004;10(7):1241-9.

8. Engle PE. Urban Women: Balancing Work and Culture. International Food Policy Research Institute, 2000 Auguat 2000. Report No.: Contract No.: 8.

9. Zoritch B, Roberts I, Oakley A. Day care for pre-school children. The Cochrane database of systematic reviews. 2000(3):Cd000564.

10. Ekanem EE, DuPont HL, Pickering LK, Selwyn BJ, Hawkins CM. Transmission dynamics of enteric bacteria in day-care centers. American journal of epidemiology. 1983;118(4):562-72.

11. Bartlett AV, Moore M, Gary GW, Starko KM, Erben JJ, Meredith BA. Diarrheal illness among infants and toddlers in day care centers. II. Comparison with day care homes and households. The Journal of pediatrics. 1985;107(4):503-9.

12. Cosby CM, Costello CA, Morris WC, Haughton B, Devereaux MJ, Harte F, et al. Microbiological analysis of food contact surfaces in child care centers. Applied and environmental microbiology. 2008;74(22):6918-22.

13. Van R, Morrow AL, Reves RR, Pickering LK. Environmental contamination in child day-care centers. American journal of epidemiology. 1991;133(5):460-70.

14. Laborde DJ, Weigle KA, Weber DJ, Kotch JB. Effect of fecal contamination on diarrheal illness rates in day-care centers. American journal of epidemiology. 1993;138(4):243-55.

15. Itah AY, Ben AE. Incidence of enteric bacteria and Staphylococcus aureus in day care centers in Akwa Ibom State, Nigeria. The Southeast Asian journal of tropical medicine and public health. 2004;35(1):202-9.

16. Carabin H, Gyorkos TW, Soto JC, Joseph L, Payment P, Collet JP. Effectiveness of a training program in reducing infections in toddlers attending day care centers. Epidemiology (Cambridge, Mass). 1999;10(3):219-27.

17. Holaday B, Waugh G, Moukaddem VE, West J, Harshman S. Diaper type and fecal contamination in child day care. Journal of pediatric health care : official publication of National Association of Pediatric Nurse Associates & Practitioners. 1995;9(2):67-74.

18. Fobil JN, Kraemer A, Meyer CG, May J. Neighborhood urban environmental quality conditions are likely to drive malaria and diarrhea mortality in Accra, Ghana. Journal of environmental and public health. 2011;2011:484010.

19. Mukiira C, Ibisomi L. Health care seeking practices of caregivers of children under 5 with diarrhea in two informal settlements in Nairobi, Kenya. Journal of child health care : for professionals working with children in the hospital and community. 2013.

20. Population and Housing Census - Summary Report of Final Results. In: Service GS, editor. Accra, Ghana: Sakoa Press Limited; 2012.

21. Amugsi DA, Mittelmark MB, Lartey A, Matanda DJ, Urke HB. Influence of childcare practices on nutritional status of Ghanaian children: a regression analysis of the Ghana Demographic and Health Surveys. BMJ open. 2014;4(11):e005340.

22. Ruel MT, Levin CE, Armar-Klemesu M, Maxwell DG, Morris S. Good care practices can mitigate the negative effects of poverty and low maternal schooling on children's nutritional status: evidence from Accra. World Dev. 1999;27.

23. Heijnen M, Cumming O, Peletz R, Chan GK, Brown J, Baker K, et al. Shared sanitation versus individual household latrines: a systematic review of health outcomes. PloS one. 2014;9(4):e93300.

24. Laborde DJ, Weigle KA, Weber DJ, Sobsey MD, Kotch JB. The frequency, level, and distribution of fecal contamination in day-care center classrooms. Pediatrics. 1994;94(6 Pt 2):1008-11.

25. Holaday B, Pantell R, Lewis C, Gilliss CL. Patterns of fecal coliform contamination in day-care centers. Public health nursing (Boston, Mass). 1990;7(4):224-8.

26. Peprah D, Baker K, Moe C, Robb K, Wellington N, Yakubu H, Null C. Public Toilets and their Customers in Low-Income, Urban Accra, Ghana. Unpublished

27. Banta Z. Conditions, Behaviors, and Fecal Contamination of Homes with Under Five Children in Four Low and Medium Income Neighborhoods of Accra, Ghana

28. Gómez-Aldapa, C. A., Rangel-Vargas, E. and Castro-Rosas, J. (2013), Frequency and Correlation of Some Enteric Indicator Bacteria and Salmonella in Ready-to-Eat Raw Vegetable Salads from Mexican Restaurants. Journal of Food Science, 78: M1201–M1207.

29. Bain R, Cronk R, Wright J, Yang H, Slaymaker T, Bartram J. Fecal contamination of drinking-water in low- and middle-income countries: a systematic review and meta-analysis. PLoS Med. 2014 May 6;11(5):e1001644.

TABLES AND FIGURES

Table 1: Neighborhood characteristics[1]

	Alajo	Bukom	Old Fadama	Shiabu
Type of settlement	Formal	Formal	Squatter	Mixed
Location	Inland	Coastal	Inland	Coastal
Near major market	No	Yes	Yes	No
Population estimate (people/~1km sq)	14,161	8,917	7,511	12,103

Table 2 Nursery Characteristics

Demographics	**n**	**Measure***
Average number of children present	15	46 [15, 81]
Female	15	20 [8, 43]
Average number of children enrolled	13	42 [29, 194]
Female	13	23 [11, 107]
Average age of children		
Youngest present	15	1.9 [1, 4]
Oldest present	15	4.5 [2, 10]
Youngest enrolled	13	2.0 [1, 4]
Oldest enrolled	14	4.9 [2, 10]
Average number of teachers present	16	2.5 [1, 8]
Children per teacher present	15	19 [5.9, 37]
Water	**n**	**Measure****
Primary source of drinking water	16	
Sachet/Water Bottle		1 (6.25%)
Tap from pipe network		14 (87.5%)
Tap from polytank/bucket		1 (6.25%)
Drinking water storage container in class	16	16 (100%)
Container covered		15 (94%)
Safe water extraction methods		4 (25%)
Water designated for use in hand washing	16	6 (37.5%)

[1] Adapted from Peprah, et. al (unpublished)

*Data reported median [range] values
**Data reported number (percentage) values

Table 3 - Child behavior counts and rates

Event	N	Count (range)*	n	Count/hr (SD)**
Contact with other children	23	53 (8, 98)	22	17.5 (7.9)
Contact with adult	22	3.5 [0, 30]	21	2.3 (3.2)
Fingers in mouth	23	21 [3, 62]	22	9.1 (6.7)
Objects in mouth	23	10 [1, 21]	22	4.1 (2.7)
Child washes hands	25	0 [0, 2]	24	0.1 (0.2)
Child eats	25	2 [0, 5]	24	0.6 (0.4)

*Data reported median [range] events
**Data reported mean (standard deviation) events in person-hours
Median hours of observation: 2.9

Table 4 - E. coli concentrations in the environment

Source	N	Number of contaminated samples*	Log10 E. coli concentration**
Surface swabs	38	26 (68%)	2.04 (1.6)
Toys	9	5 (56%)	2.21 (1.8)
Tables, chairs and benches	24	19 (79%)	2.39 (1.6)
Food/drink containers	6	3 (50%)	0.80 (0.5)
Water sachets	5	0 (0%)	-
Stored drinking water	15	13 (87%)	1.67 (1.2)
Dip extraction	11	9 (82%)	1.61 (1.2)
Tap extraction	2	2 (100%)	0.67 (0.3)
Source is public tap	10	9 (90%)	1.80 (1.1)
Source is private tap	4	4 (100%)	1.83 (1.0)
Source contains E. coli	6	5 (83%)	1.53 (1.1)
Handrinses	53	46 (87%)	2.46 (1.3)
Female	28	24 (86%)	2.21 (1.2)
Male	25	22 (85%)	2.72 (1.3)
Age < 5	46	40 (87%)	2.49 (1.3)
Age >= 5	7	6 (86%)	2.24 (0.6)
Dirt visible on hands	21	18 (86%)	2.62 (1.2)
No dirt visible on hands	32	28 (88%)	2.35 (1.3)

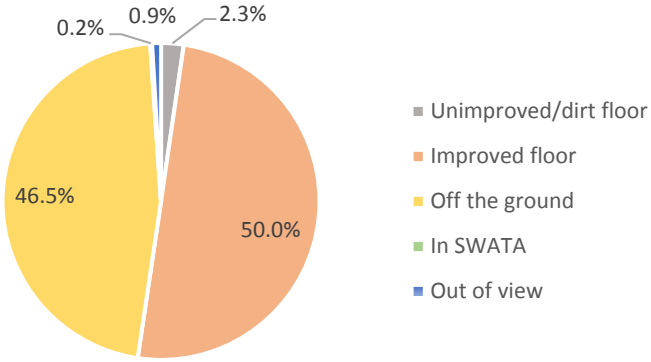
* Data reported number (percent) values
**Data reported mean (standard deviation) values

Table 5 –Hand contamination regression

Variable	n	Unadjusted model*	p value	Adjusted model*	p value
Neighborhood formality	35	-0.6 (-1.5, 0.4)	0.240	-0.8 (-2.0, 0.5)	0.227
Latrine Presence	32	-1.9 (-3.0, -0.8)	0.001	1.8 (-1.2, 4.8)	0.223
Presence of feces on any latrine floor or walls	23	-0.7 (-2.1, 0.6)	0.280	-3.1 (-4.7, -1.4)	0.001
Latrine has a door	23	0.5 (-0.9, 1.9)	0.456	0.8 (-0.1, 1.8)	0.654
Latrine has an odor	23	0.1 (-1.1, 1.3)	0.844	5.0 (2.8, 7.2)	< 0.001
Water designated for hand washing	53	0.1 (-0.6, 0.9)	0.682	-1.4 (-3.0, 0.1)	0.067
Child is male	53	0.5 (-0.2, 1.2)	0.130	0.3 (-0.2, 0.9)	0.245
Child under five	53	0.3 (-0.8, 1.3)	0.627	0.5 (-0.4, 1.4)	0.230
Total children present	35	-0.0 (-0.0, 0.0)	0.481	-0.0 (-0.1, 0.0)	0.462
Children per teacher present	35	-0.1 (-0.1, -0.0)	0.002	-0.3 (-0.4, -0.2)	< 0.001

*Data reported Beta (95% confidence interval) values

Figure 1 - Percent of child time by location



Chapter IV: Conclusions and Public Health Implications

Conclusions

This study has demonstrated that nurseries are an important piece in understanding childhood exposure to fecal contamination. These often forgotten settings may be a vital part of the ecology of childhood illness, mixing children and their associated microflora from across families and other social groups, then sending them back home. Though children in these establishments may spend less time in risky areas than they would at home, such as drains or stagnant water, their hands show much more prevalent contamination than previous studies of nurseries have demonstrated in the developed world. The large number of children and relatively small number of adults caring for them appears to be an important factor in the dynamics of bacterial transfer. Further research should be undertaken to understand how nurseries in low income settings affect the health of the children that attend them.

Public Health Implications

This is the first study of both nursery conditions and microbiological contamination to take place in a low income country. Additionally, while several studies have noted a few child and caretaker behaviors during observation, this was the first to do so systematically and thoroughly. Though some aspects of the study could be tweaked, this study is an example of how future research can be built to look into how child behaviors and fecal contamination interact in the real world. Whereas previous research has tied the existence of bacteria or other microorganisms to outbreaks of disease, the actual processes by which the children become exposed are left to assumption. With this methodology, we can narrow the gap in our understanding of how the

intermediate parts of the fecal-oral route function in reality, namely the role of fomites in carrying pathogens from host to host.

Additionally, the descriptions of conditions, behaviors and levels of contamination are useful for quantifying how nurseries function in low income settings. Most currently existing research covers the developed world, where resources and knowledge are more readily available and the expectations of parents and government regulations may have a strong effect on how these nurseries function. The developing world until this point has largely remained a blind spot, even as urbanization and increased workforce participation drive more and more children into nurseries. By showing the high levels of fecal contamination, poor conditions of latrines, and large numbers of children with very little supervision, this study has demonstrated that nurseries may be an important focal point for future efforts at reducing childhood diarrhea. Governments should focus on improving these conditions, whether through education, regulation, or subsidy, in order to improve rates of childhood illness and all of the long term conditions that have been linked to chronic childhood diarrhea.

Future research should focus not only on replicating these results in different settings, but on how these results compare to children who do not attend day care. My results show that a high ratio of children to caregivers is correlated with higher levels of hand contamination, a situation that is not likely to be found in the household. However, the situations cannot be assumed to be otherwise equal. Comparing children in nurseries and in the home would answer the question of what level of exposure to fecal contamination is a direct result of being enrolled in a nursery school.

References

1. Boschi-Pinto C, Velebit L, Shibuya K. Estimating child mortality due to diarrhoea in developing countries. Bulletin of the World Health Organization. 2008;86(9):710-7.

2. Liu L, Johnson HL, Cousens S, Perin J, Scott S, Lawn JE, et al. Global, regional, and national causes of child mortality: an updated systematic analysis for 2010 with time trends since 2000. Lancet. 2012;379(9832):2151-61.

3. UN. The Millenium Development Goals Report. New York: United Nations Department of Economic and Social Affairs, 2010.

4. World Health Organization. World Health Statistics 2014. 2014.

5. Guerrant RL, DeBoer MD, Moore SR, Scharf RJ, Lima AA. The impoverished gut--a triple burden of diarrhoea, stunting and chronic disease. Nature reviews Gastroenterology & hepatology. 2013;10(4):220-9.

6. Al-Ghamdi MA, Bentham G, Hunter PR. Environmental risk factors for diarrhoea among male schoolchildren in Jeddah City, Saudi Arabia. Journal of water and health. 2009;7(3):380-91.

7. Hunter PR, Hughes S, Woodhouse S, Syed Q, Verlander NQ, Chalmers RM, et al. Sporadic cryptosporidiosis case-control study with genotyping. Emerging infectious diseases. 2004;10(7):1241-9.

8. Engle PE. Urban Women: Balancing Work and Culture. International Food Policy Research Institute, 2000 Auguat 2000. Report No.: Contract No.: 8.

9. Zoritch B, Roberts I, Oakley A. Day care for pre-school children. The Cochrane database of systematic reviews. 2000(3):Cd000564.

10. Ekanem EE, DuPont HL, Pickering LK, Selwyn BJ, Hawkins CM. Transmission dynamics of enteric bacteria in day-care centers. American journal of epidemiology. 1983;118(4):562-72.

11. Bartlett AV, Moore M, Gary GW, Starko KM, Erben JJ, Meredith BA. Diarrheal illness among infants and toddlers in day care centers. II. Comparison with day care homes and households. The Journal of pediatrics. 1985;107(4):503-9.

12. Cosby CM, Costello CA, Morris WC, Haughton B, Devereaux MJ, Harte F, et al. Microbiological analysis of food contact surfaces in child care centers. Applied and environmental microbiology. 2008;74(22):6918-22.

13. Van R, Morrow AL, Reves RR, Pickering LK. Environmental contamination in child day-care centers. American journal of epidemiology. 1991;133(5):460-70.

14. Laborde DJ, Weigle KA, Weber DJ, Kotch JB. Effect of fecal contamination on diarrheal illness rates in day-care centers. American journal of epidemiology. 1993;138(4):243-55.

15. Itah AY, Ben AE. Incidence of enteric bacteria and Staphylococcus aureus in day care centers in Akwa Ibom State, Nigeria. The Southeast Asian journal of tropical medicine and public health. 2004;35(1):202-9.

16. Carabin H, Gyorkos TW, Soto JC, Joseph L, Payment P, Collet JP. Effectiveness of a training program in reducing infections in toddlers attending day care centers. Epidemiology (Cambridge, Mass). 1999;10(3):219-27.

17. Holaday B, Waugh G, Moukaddem VE, West J, Harshman S. Diaper type and fecal contamination in child day care. Journal of pediatric health care : official publication of National Association of Pediatric Nurse Associates & Practitioners. 1995;9(2):67-74.

18. Fobil JN, Kraemer A, Meyer CG, May J. Neighborhood urban environmental quality conditions are likely to drive malaria and diarrhea mortality in Accra, Ghana. Journal of environmental and public health. 2011;2011:484010.

19. Mukiira C, Ibisomi L. Health care seeking practices of caregivers of children under 5 with diarrhea in two informal settlements in Nairobi, Kenya. Journal of child health care : for professionals working with children in the hospital and community. 2013.

20. Population and Housing Census - Summary Report of Final Results. In: Service GS, editor. Accra, Ghana: Sakoa Press Limited; 2012.

21. Amugsi DA, Mittelmark MB, Lartey A, Matanda DJ, Urke HB. Influence of childcare practices on nutritional status of Ghanaian children: a regression analysis of the Ghana Demographic and Health Surveys. BMJ open. 2014;4(11):e005340.

22. Ruel MT, Levin CE, Armar-Klemesu M, Maxwell DG, Morris S. Good care practices can mitigate the negative effects of poverty and low maternal schooling on children's nutritional status: evidence from Accra. World Dev. 1999;27.

23. Heijnen M, Cumming O, Peletz R, Chan GK, Brown J, Baker K, et al. Shared sanitation versus individual household latrines: a systematic review of health outcomes. PloS one. 2014;9(4):e93300.

24. Laborde DJ, Weigle KA, Weber DJ, Sobsey MD, Kotch JB. The frequency, level, and distribution of fecal contamination in day-care center classrooms. Pediatrics. 1994;94(6 Pt 2):1008-11.

25. Holaday B, Pantell R, Lewis C, Gilliss CL. Patterns of fecal coliform contamination in day-care centers. Public health nursing (Boston, Mass). 1990;7(4):224-8.

26. Peprah D, Baker K, Moe C, Robb K, Wellington N, Yakubu H, Null C. Public Toilets and their Customers in Low-Income, Urban Accra, Ghana. Unpublished

27. Banta Z. Conditions, Behaviors, and Fecal Contamination of Homes with Under Five Children in Four Low and Medium Income Neighborhoods of Accra, Ghana

28. Gómez-Aldapa, C. A., Rangel-Vargas, E. and Castro-Rosas, J. (2013), Frequency and Correlation of Some Enteric Indicator Bacteria and Salmonella in Ready-to-Eat Raw Vegetable Salads from Mexican Restaurants. Journal of Food Science, 78: M1201–M1207.

29. Bain R, Cronk R, Wright J, Yang H, Slaymaker T, Bartram J. Fecal contamination of drinking-water in low- and middle-income countries: a systematic review and meta-analysis. PLoS Med. 2014 May 6;11(5):e1001644.

Appendix A – Child Observation Form

Children Under Five
Structured Observation- Tallies

Child Behavior Tallies Child ID

Contact with other children	Contact with adults (≥12 years)	Fingers in mouth	Objects in mouth	List of objects in mouth

Child Behavior Tallies Child ID

Contact with other children	Contact with adults (≥12 years)	Fingers in mouth	Objects in mouth	List of objects in mouth

Child Behavior Tallies Child ID

Contact with other children	Contact with adults (≥12 years)	Fingers in mouth	Objects in mouth	List of objects in mouth

Enumerator code

Location ID

Children Under Five
Structured Observation- Behavior Events

Child ID _____ **Start Time** _____ : _____

Child Location 1) On unimproved ground (dirt) ☐ 2) On improved ground (floor) ☐ 3) Off ground (with caregiver/on chair, etc) ☐ 4) In SWATA ☐ 5) In drain ☐ 6) Out of view ☐

A) Touching location with hands: 1) Yes ☐ 2) No ☐ 3) N/A ☐

B) Wearing shoes in location: 1) Yes ☐ 2) No ☐ 3) N/A ☐

Child Behavior

☐ A) Playing/sitting

☐ B) Sleeping

☐ C) Handwashing 1) With soap ☐ 2) Without soap ☐

☐ D) Bathing: 1) With soap ☐ 2) Without soap ☐

☐ E) Defecating: 1) On ground ☐ 2) In latrine ☐ 3) In bag ☐ 4) In potty ☐ 5) In drain ☐

- Child's bottom is: 1) Cleaned ☐ 2) Not cleaned ☐
- Feces are: 1) Put in latrine ☐ 2) Put in drain ☐ 3) Put in trash ☐ 4) Left on ground ☐

☐ F) Eating: 1)Food prepared at home ☐ 2) Bought food ☐ 3) Raw produce ☐ 4) DK ☐

- Eating with: 1) Cutlery ☐ 2) Hands ☐

Notes _____

Child ID _____ **Start Time** _____ : _____

Child Location 1) On unimproved ground (dirt) ☐ 2) On improved ground (floor) ☐ 3) Off ground (with caregiver/on chair, etc) ☐ 4) In SWATA ☐ 5) In drain ☐ 6) Out of view ☐

A) Touching location with hands: 1) Yes ☐ 2) No ☐ 3) N/A ☐

B) Wearing shoes in location: 1) Yes ☐ 2) No ☐ 3) N/A ☐

Child Behavior

☐ A) Playing/sitting

☐ B) Sleeping

☐ C) Handwashing 1) With soap ☐ 2) Without soap ☐

☐ D) Bathing: 1) With soap ☐ 2) Without soap ☐

☐ E) Defecating: 1) On ground ☐ 2) In latrine ☐ 3) In bag ☐ 4) In potty ☐ 5) In drain ☐

- Child's bottom is: 1) Cleaned ☐ 2) Not cleaned ☐
- Feces are: 1) Put in latrine ☐ 2) Put in drain ☐ 3) Put in trash ☐ 4) Left on ground ☐

☐ F) Eating: 1)Food prepared at home ☐ 2) Bought food ☐ 3) Raw produce ☐ 4) DK ☐

- Eating with: 1) Cutlery ☐ 2) Hands ☐

Notes _____

Enumerator code _____

Location ID _____

Children Under Five
Structured Observation- Caregiver

Caregiver ID ☐ Start Time ☐ : ☐

Caregiver Behavior

☐ A) Handwashing 1) With soap ☐ 2) Without soap ☐
☐ B) Preparing or handling food
☐ C) Sullage disposal
☐ D) Latrine use
☐ E) Handling money
☐ F) Sweeping

Caregiver ID ☐ Start Time ☐ : ☐

Caregiver Behavior

☐ A) Handwashing 1) With soap ☐ 2) Without soap ☐
☐ B) Preparing or handling food
☐ C) Sullage disposal
☐ D) Latrine use
☐ E) Handling money
☐ F) Sweeping

Caregiver ID ☐ Start Time ☐ : ☐

Caregiver Behavior

☐ A) Handwashing 1) With soap ☐ 2) Without soap ☐
☐ B) Preparing or handling food
☐ C) Sullage disposal
☐ D) Latrine use
☐ E) Handling money
☐ F) Sweeping

Caregiver ID ☐ Start Time ☐ : ☐

Caregiver Behavior

☐ A) Handwashing 1) With soap ☐ 2) Without soap ☐
☐ B) Preparing or handling food
☐ C) Sullage disposal
☐ D) Latrine use
☐ E) Handling money
☐ F) Sweeping

Caregiver ID ☐ Start Time ☐ : ☐

Caregiver Behavior

☐ A) Handwashing 1) With soap ☐ 2) Without soap ☐
☐ B) Preparing or handling food
☐ C) Sullage disposal
☐ D) Latrine use
☐ E) Handling money
☐ F) Sweeping

Caregiver ID ☐ Start Time ☐ : ☐

Caregiver Behavior

☐ A) Handwashing 1) With soap ☐ 2) Without soap ☐
☐ B) Preparing or handling food
☐ C) Sullage disposal
☐ D) Latrine use
☐ E) Handling money
☐ F) Sweeping

Enumerator code ☐

Location ID ☐

Appendix B – Nursery Questionnaire

Nursery Description and Conditions
Structured Observation

Ques #	Description	Indicators
A	What is the managment type?	1) Public ☐ 2) Private ☐
B	How many years has this nursery been in operation?	
C	What is the cost of attending this nursery? (Write number, check 'pesewas' or 'cedis' and check if cost is per 'day' or per 'term'.)	1) Pesewas ☐ 1) Day ☐ 2) Cedis ☐ 2) Term ☐
D	What hours is the nursery open each day?	: until :
E	Does this nursery have a latrine?	1) Yes ☐ 2) No ☐
F	What days of the week is the latrine open?	1) Sunday ☐ 5) Thursday ☐ 2) Monday ☐ 6) Friday ☐ 3) Tuesday ☐ 7) Saturday ☐ 4) Wednesday ☐
G	How many children are present today at this nursery? Number of MALE children Number of FEMALE children Age range of children: (Write age in years if 2 years or older, and in months if under 2 years old.)	 1) Mo ☐ to 1) Mo ☐ 2) Yrs ☐ 2) Yrs ☐
H	How many children are enrolled at this nursery? Number of MALE children Number of FEMALE children Age range of children: (Write age in years if 2 years or older, and in months if under 2 years old.)	 1) Mo ☐ to 1) Mo ☐ 2) Yrs ☐ 2) Yrs ☐
I	How many teachers work at this nursery? Number of MALE teachers Number of FEMALE teachers	
J	Children's food sources: (Check all that apply)	1) Brought from home ☐ 2) Purchased from vendors ☐ 3) Provided by the nursery ☐

Enumerator code

Location ID

Nursery Description and Conditions
Structured Observation

Ques #	Description	Indicators
K	Children's primary source of drinking water:	1) Sachet/water bottle ☐ 2) Tap from pipe network ☐ 3) Tap from polytank/bucket ☐ 4) Well ☐ 5) Water trucks ☐ 6) Rainwater ☐ 7) Other ☐ 8) Don't know ☐ 9) No response ☐
L	Is there a container in the classroom where drinking water is stored? Type of container Is container covered or uncovered? How is water taken from the stored container?	1) Yes ☐ 2) No ☐ **If 'No'-> M** 1) Narrow mouth (≤6cm) ☐ 2) Wide mouth (>6cm) ☐ 1) Covered ☐ 2) Uncovered ☐ 1) Dip ☐ 2) Pour ☐ 3) Tap ☐ 4) Sachet water used ☐ 5) No water available ☐
M	Latrine options (use latrine condition form to observe conditions)	1) Traditional pit latrine ☐ 2) KVIP (double) ☐ 3) VIP (single) ☐ 4) Bucket/pan ☐ 5) Pour flush ☐ 6) Flush toilet ☐
N	Characteristics of physical space (room under observation): Approximate square meters Flooring type Number of windows	 1) Cement ☐ 4) Carpeted ☐ 2) Linoleum ☐ 5) Ceramic tiles ☐ 3) Terrazzo ☐ 6) Dirt/unfinished ☐
O	List objects that children are able to touch (chairs, toys, etc.)	

Enumerator code

Location ID

Appendix C Latrine Observations

Latrine Conditions
Structured Observations and Tallies

Observation start time : Observation end time :

Ques #	Description	Indicators
A	Latrine setting	1) Nursery school ☐ 4) Public latrine beach ☐ 2) Basic school ☐ 5) Public latrine community ☐ 3) Public latrine market ☐
B	Are there handwashing stations at this latrine?	1) Yes ☐ 2) No ☐ **If 'No' -> C**
	How many?	
	How many have soap?	
	How many have water?	
C	Are cleansing materials provided?	1) Water ☐ 4) Other ☐ 2) Newspaper ☐ 5) None ☐ 3) Toilet tissue ☐
D	What is the managment type?	1) Municipal ☐ 2) Private ☐ 3) Community ☐
E	How many years has the latrine been in operation?	
F	What is the cost of using this latrine? (Write number and check 'pesewas' or 'cedis')	1) Pesewas ☐ 2) Cedis ☐
G	What is the cost of cleansing materials? (If 'extra', write amount and check 'pesewas' or 'cedis')	1) Included ☐ 1) Pesewas ☐ 2) Extra ☐ 2) Cedis ☐
H	What are the open hours each day?	until Total hours
I	What days of the week is the latrine open?	1) Sunday ☐ 5) Thursday ☐ 2) Monday ☐ 6) Friday ☐ 3) Tuesday ☐ 7) Saturday ☐ 4) Wednesday ☐
J	Is there a shower associated with this latrine?	1) Yes ☐ 2) No ☐ **If 'No' -> Tallies on page 3**
	If yes, how often are feces found in shower?	1) Never ☐ 3) At least once a week ☐ 2) Less than once a week ☐ 4) Every day ☐
	Cost of shower. (Write number and check 'pesewas' or 'cedis')	1) Pesewas ☐ 2) Cedis ☐

Enumerator code

Location ID

Latrine Conditions
Structured Observations and Tallies

Note: Use tick mark sheet for individual tallies. Provide summary numbers of the tallies in the table below.

	Adult females	Adult males	Age 13-18 girls	Age 13-18 boys	Age 5-12 girls	Age 5-12 boys
Total number of people						
Shoes worn into latrine						
Handwashing						
Handwashing with soap						
Child feces brought (in bag or potty) to dispose of at latrine						

Mark only 'handwashing with soap' when hands are washed with soap. Don't mark both 'handwashing' and 'handwashing with soap'.

Please note times latrine cleaning is observed!

Notes

Enumerator code

Location ID