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Everyone Poops (But Where?): Assessing Feces Disposal Practices for Children Under-Five in Low- and Middle-Income Countries

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Global Health

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Everyone Poops (But Where?): Assessing Feces Disposal Practices for Children Under-Five in Low- and Middle-Income Countries

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Abstract

Everyone Poops (But Where?): Assessing Feces Disposal Practices for Children Under-Five in Low- and Middle-Income Countries

By Heather Reese

Background: Sanitation is a global priority, with estimated 2.6 billion worldwide still lacking access to improved sanitation. This estimate is solely based on surveys of adults even though a key argument for the focus on improving sanitation is the potential reduction in child deaths attributable to diarrheal disease. Children are at greater risk in both contraction and the severity of diarrheal diseases than adults, representing 68% of the diarrheal disease burden. Given that over 9% of the world's population of 7 billion is under 5years old, there is a need to systematically assess sanitation for children under-five in the same way that adult sanitation is being analyzed.

Objective: This study aims to expand the knowledge base for sanitation and feces disposal behavior for children under-five in low- and middle-income countries, focusing on whether children's feces are disposed of in an improved method and whether disposal method varies regionally.

Methods: DHS Individual Module and MICS Child Module survey data from 78 low- and middle-income countries was extracted to estimate sanitation statistics and to develop an exploratory model for improved disposal, defined as use of a toilet/latrine or feces put or rinsed into a toilet/latrine.

Results: Globally, an estimated 47.0% of households report using an improved method to dispose of children's feces, with urban dwellers more likely to use an improved method than rural dwellers (51.8% v. 44.7%, $p<0.01$). The practice is highly variable by world region and urban/rural residence within a given country. Using disposable diapers or throwing feces in garbage is the dominant practice for children 6 months old and younger (30.4%). Putting or rinsing feces into a toilet or latrine is the most common disposal method for children 7-60 months old (31.0-34.8%). Unsurprisingly, since by definition improved disposal requires access to a toilet/latrine the strongest predictor of improved disposal is household access to an improved toilet/latrine.

Discussion: Although children under 6 months and rural residents are at increased risk of diarrheal disease, these caregivers are less likely to use improved disposal. Further analysis of these data will help to focus on improving coverage of sanitation solutions that are effective for children under-five and to better target those populations who do not practice improved disposal of children's feces.

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Introduction

Sanitation is a global priority, with billions of people worldwide lacking adequate access to appropriate sanitation solutions. In 2000, the United Nations adopted the Millennium Declaration to reduce extreme poverty through global dedication to eight Millennium Development Goals (MDGs). The seventh MDG, to ensure environmental sustainability, includes the target of halving the proportion of people without sustainable access to basic sanitation by 2015.

The Joint Monitoring Programme for Water Supply and Sanitation (JMP), a partnership between WHO and UNICEF, was formed to monitor global and national progress towards the drinking-water and sanitation MDG. To more meaningfully describe changes in access to sanitation, all sanitation technologies were categorized as improved or unimproved. Improved sanitation includes flush and pour-flush toilets that drain to a piped sewer system, septic tank, or pit latrine; ventilated improved pit (VIP) latrines; pit latrines with slabs; and composting toilets. In contrast, unimproved sanitation is defined as flush and pour-flush toilets that drain to all locations not included in the improved category, pit latrines without slabs, buckets, hanging toilets or latrines, shared facilities, and lack of any facilities [1].

As measured by the JMP, there has been substantial improvement in access to improved sanitation since 1990, however, an estimated 2.6 billion still lack access to improved sanitation, including 1.1 billion without any facilities at all [2]. If the progress in sanitation coverage continues at the current rate, the world will fail to reach the Millennium Development Goal of a reduction to 23% of the population without access to improved sanitation by 2015.

Nevertheless, there is a significant difference between the concept of access to improved sanitation and use of improved sanitation. The MDGs only specify access to improved sanitation. Access to sanitation is concerned with the provision of a safe place to defecate, which can encompass a variety of defecation options; it does not ensure that people actually use it. While the JMP states that it measures reported use of sanitation, the international survey programs such as the Demographic and Health Surveys (DHS), Multiple Indicator Cluster Surveys (MICS), World Health Surveys (WHS), and Living Standards Measurement Surveys (LSMS) used by JMP only provide data on the type of sanitation facility each household has access to. No data is collected on where adults usually defecate. Employing an indicator measuring use of sanitation facilities instead of access would provide JMP with a more informative estimate of trends in sanitation.

Moreover, there is a large subset of the population that is not explicitly included in these estimates: children under-five. Due to a variety of reasons, including developmental differences between children under-five years old and adults, there is reason to believe that the same sanitation options that succeed for adults[1] may not be as applicable for young children. Given that over 9% of the world's population of 7 billion is under-five years old, there is a clear need to systematically assess sanitation for children under-five in the same way that the status of adult sanitation is being analyzed [3]. Fortunately, the DHS and MICS surveys provide data on where children's excreta is disposed of, providing the link between access to sanitation facilities and use of the facilities by or for children. Using this wealth of available data, this study aims to expand the knowledge base for child sanitation and feces disposal behavior in low- and middle-

[1] Ventilated improved pit latrines and flush toilets are improved sanitation solutions that are applicable for adults, but may not be as successful for children under-five years old due to initial age at potty training and safety concerns.

income countries. The primary focus is to determine both whether children's feces are disposed of by an improved method and whether disposal method varies regionally. Secondary research objectives include the evaluation of factors which may affect improved disposal behavior and the development of an exploratory model.

Sanitation for young children usually involves a two-step process: choice of primary defecation site and final disposal behavior. Unless the child is using the same sanitation facilities used by adults, defecation occurs at one site, and disposal of the feces is a separate decision. For example, if a child defecates in a washable diaper, the caregiver needs to wash the diaper free of feces and then needs to decide where to dispose of the dirty wash-water; if the child instead defecates on the ground, the caregiver needs to remove the feces from the ground and decide where to dispose of them. This two-stage process requires an adult or older child to act as caregiver and both dispose of the child's feces appropriately and clean the child's bottom. If the caregiver does not safely dispose of the feces and hand-wash with soap afterwards, then the rest of the household is put at risk through water collection, water storage and food preparation tasks.[2] The time interval between the first and second step of this process, defecation and disposal, also influences the risk to the household: the longer the interval, the more likely fecal contamination will occur, regardless of whether the child's feces ultimately are disposed of in an improved location such as a VIP (ventilated pit latrine).

In high income countries, the sanitation solution for young children usually involves disposable diapers thrown out with the solid waste and eventually disposed of in a landfill, until the child is

[2] Fecal exposure pathways are often described through use of the "F-diagram" in which feces can directly contaminate fluids such as drinking water, fields /floors of homes, flies, fingers, and food. Feces can also indirectly contaminate food through contaminated fluids, fields, flies and fingers, ultimately exposing a new host to fecal pathogens.

potty trained. Assuming the caregiver responsible for removing the child's diaper and cleaning the child's bottom washes their hands with soap afterwards, this is a safe process. Developmentally, children are considered able to begin toilet training at 18 months and are able to use a toilet without assistance by as early as 2-3 years old [4]. However, in the U.S. there are discrepancies in both the timing of toilet training and parental beliefs of the appropriate age at which to initiate toilet training. Both race and income are predictors of the timing of toilet training and parental beliefs, likely due in part to the expense of diapers.

For the minimum of 18 months that the child is not even developmentally ready to begin training, not including the months during toilet training, an estimated 4,800 diapers are needed per child at a cost of over USD 1,500 [5]. This breaks down to over USD 2 per day for diapers, clearly unaffordable for the 27% percent of the population in low-income countries who live on less than USD 1.25 a day [6]. Even if disposable diapers were available at reduced pricing, it is apparent that the sanitation solutions used in high income countries are not necessarily appropriate or adequate in low income settings. Unlike high-income countries, middle and low-income countries do not necessarily have the consistent, efficient and well-maintained sanitation systems and solid waste infrastructure necessary for disposable diapers to be a safe option. In addition, it's important to note the difference between a toddler demonstrating competency in safely and hygienically using a modern flush toilet (often with a potty training seat), and demonstrating a similar competency with a pit latrine. Pit latrines are rarely lit, often only a crack of sunlight available during daylight hours and moonlight during the night, while the size of the hole can vary from the size of a thin bike seat to large enough for there to be legitimate concern over a small children falling in. The combination of poor or no lighting and

the variable size hole make safe and hygienic use of a pit latrine a substantially more impressive feat than the same level of competency with a modern flush toilet and potty training seat.

Ironically, the importance of children as an important driver for appropriate sanitation solutions has already been acknowledged. Indeed, a key argument for the focus on improving sanitation is the potential reduction in child deaths attributable to diarrheal disease [6]. Children are at greater risk in both contraction and the severity of diarrheal diseases than adults, representing 68% of the diarrheal disease burden [7]. This is in part due to their still developing immune systems. An estimated 1.3 million children under-five years die annually due to diarrheal disease-- the second largest single cause of under-five death globally [8]. While the introduction of improved case management measures and increased access to health care over the last couple decades has substantially reduced mortality due to diarrhea, morbidity has remained relatively unchanged, and is currently estimated at four billion cases annually [9].

There has been limited study of disposal of children's excreta; the majority of interventions aimed at improving sanitation focus simply on increasing latrine coverage in communities- which may not be an applicable sanitation solution for children under-five. Even community-led total sanitation (CLTS), an approach championed by UNICEF, World Bank, Plan International, and Water Aid among others, overlooks sanitation for children under-five [10]. The CLTS methodology facilitates communities to take collective action to become open defecation free, usually through increasing latrine coverage. While this approach acknowledges the large role school age children can have in influencing their families to improve sanitation practices, assessments of CLTS programs appear to forget sanitation for children under-five [11-14].

In addition, due to crawling, toddling, and other developmental behaviors, young children are more likely to come into contact with fecal matter left on the ground or otherwise not adequately disposed of, increasing the risk of oral-fecal transmission. Increased risk of transmission results in increased burden of diarrheal disease among children. As a result, children's feces are more pathogenic than adults', exacerbating the risks stemming from unsafe defecation practices by children. This cycle of increased exposure, transmission and burden of disease highlights the importance of determining where children's feces are ultimately disposed of and interrupting the cycle.

Background

Impact of Improved Sanitation

While water, sanitation and hygiene interventions and combinations of interventions have been demonstrated to reduce morbidity and mortality due to diarrheal disease, sanitation alone arguably provides the greatest reduction in morbidity due to diarrheal diseases. Esrey *et al.* (1991) systematically analyzed 144 studies to assess the impact of improved water supply and sanitation facilities on presence and severity of infection by several causes of infectious diarrhea. For the more methodologically rigorous studies, findings indicated that improvements in sanitation alone were associated with the greatest reduction in morbidity due to diarrheal diseases as well greater health and nutritional outcomes [15, 16]. However, as many of the studies are observational, there are significant and substantial methodological weaknesses, as admitted by Esrey [17].

Another review focused on thirteen rigorous control studies from six countries measuring the reduction in diarrhea attributable to sanitation interventions [18]. The interventions generally involved increased coverage and promotion of sanitation facilities such as pit latrines, VIP latrines, and pour-flush toilets. Overall, there is sufficient evidence that sanitation interventions provide a protective health impact, although the inconsistent quality of data makes it difficult to unequivocally quantify the impact.

A recent systematic review argues that hand-washing with soap after key behaviors, such as after disposing of a child's feces or cleaning a child's bottom, provides a similar reduction in morbidity due to diarrheal disease regardless of setting. Improved hygiene has a similar effect both in developed and developing countries in which access to water-supply and improved

sanitation varies greatly [19]. There is some evidence that hand-washing may be more effective after certain key behaviors than after others. Washing at least one hand with soap after defecation and before preparing food is significantly associated with a reduction in child diarrhea while no significant relationship was found between hand-washing after cleaning a child's bottom and child diarrhea [20]. This may be due more to a child already having been exposed to the pathogens in their own feces, and the many other fecal exposure pathways, than to hand-washing at this key time being unimportant. However, there is still debate as to which intervention or combination of interventions, improved water-supply, sanitation, or hygiene, provides the greatest impact.

Although a firm relationship has been established between water-supply, sanitation and hygiene interventions and resulting reductions in diarrheal disease, this association has primarily been demonstrated in finite-length research trials concerned with increasing access to the targeted water-treatment or sanitation technology. There is little evidence of the continued effectiveness of the programming in a more long-term, naturally scaled-up process; there is a substantial difference between increased access and consistent, community-wide use. Lack of appropriate health knowledge and socio-economic factors both influence behavior. For children under-five, the knowledge and perceptions of their parents, especially their mothers, influences both the sanitation options available to them and their risk of contracting diarrheal disease [21]. Both adequate sanitation and hygiene are essential to ensuring safe disposal of children's excreta.

Disposal of Children's Feces

While there is worldwide focus on sanitation, there has been limited assessment of how children's feces are disposed and the determinants of safe or improved disposal. What even constitutes improved disposal of children's feces has not been defined, let alone internationally accepted, unlike adult sanitation. Of the limited research which even mentions child sanitation, the majority is intervention studies and is thus likely to be biased toward improved sanitation behaviors. Most sanitation literature does not distinguish between adult and child excreta; it is only explicitly discussed when children have been directly targeted [18, 22]. When children are the focus of the research, emphasis has been placed on developing appropriate hygiene practices for caregivers responsible for disposing of the child feces, not on where the feces are disposed of [23]. For many studies, children are only mentioned in the introductory paragraphs of the paper, citing diarrheal disease burden as a justification for the public health focus on sanitation. While the recent review of sanitation intervention by Clasen *et al.* (2010) includes several studies focusing on young children, all include latrine coverage as the main intervention without providing evidence that young children primarily use latrines [18]. Without evidence that children under-five use latrines, improving latrine coverage could be an inappropriate and ultimately ineffective intervention for improving child sanitation practices.

Gil *et al.* (2004) provides the most comprehensive review of children's feces disposal practices, although focus is placed on the primary defecation site, not final disposal behavior. In fact, only 11 of the studies even reported disposal behavior. It gives a systematic analysis of 33 studies in 16 countries, with methodologies including questionnaires on hygiene behavior (20 studies), spot observations (15), structured observations (10), focus groups (6) and in-depth interviews

(4). The most common defecation practice and disposal of feces varied both by developmental age of child as well as by region of the world.

Among the 11 studies that considered feces disposal, reported and observed disposal behaviors varied by study. Recorded disposal behaviors included “washing diapers”, “removed from soil”, “buried”, “thrown in latrine or toilet”, “eaten by dog”, “thrown outside”, “thrown in rivers”, and “not disposed of”. At least two of the disposal options, “removed from soil” and “not disposed of”, don’t describe the final disposal location. Feces were reported as “not disposed of” if they were left at the defecation site during the observation period or disposal behavior was not reported. Results from these studies were not synthesized, making it difficult to draw any overall conclusions. However, “thrown in a latrine or toilet” was the most variable of the locations, ranging from 0 to over 75% prevalence depending on study while “not disposed of” ranged from 0 to just under 50% [24].

This review is substantially limited due to the small sample of studies over a wide range of settings (i.e. almost all studies in the Africa region were completed in Burkina Faso and studies in Latin America were mainly conducted in urban and peri-urban communities), the lack of standardization and consistency in methodology, and limited synthesis of study results. In addition, the majority of the studies were conducted over two decades ago as evaluations of sanitation interventions, and there has been no similarly comprehensive follow-up review. One of the greatest contributions of the Gil *et al.* review is to highlight the need for a more in-depth analysis of how the feces of children under-five years are disposed of.

Some studies not included in the Gil *et al.* review also measure similarly variable latrine use among children. In the follow-up of a five year hygiene education, hand-pump and latrine installation intervention in rural Bangladesh Hoque *et al.* observed a difference in latrine use by age of child: the majority of children between 36-59 months were reported to use the latrine, while few children under 36 months did so [25]. An evaluation of defecation and disposal practices in the second largest town in Burkina Faso also reported a disparity in disposal in the latrine by child age [23]. Overall, 67% of caregivers reported throwing feces in the latrine, 26% outside the compound, 7% in the yard, 0.4% burying feces in the yard, and 0.3% reported that the child used the latrine. However, suspected human feces were still sometimes observed on the ground of households claiming children's feces are disposed of in the latrine.

Comparison of Methodologies for Analysis of Sanitation Practices

There are a variety of methodologies for collecting data on sanitation practices, all with their intrinsic benefits and limitations. Some of the most common are observation and questionnaire surveys. Observation includes spot observations occurring while the observer is briefly visiting the household, as well as structured observations occurring over a defined time frame at specified intervals. Due to the time frame and observer skill necessary, observation is expensive, usually involves a small sample size, and is subject to extensive intra- and inter-observer bias[3]. Other limitations include the Hawthorne effect[4] and social desirability bias[5]—especially in effect when the studied behavior is a sensitive and often private one, such as

[3] Inter-observer bias describes the difference in measurements between observers. Intra-observer bias describes the differences among repeated measurements by the same observer.
[4] The Hawthorne effect refers to study participants modifying or improving behavior that is being experimentally studied simply due to their knowledge that their behavior is being monitored.
[5] Social desirability bias refers to study participants altering their responses to be viewed favorably by others. This can result in under-reporting of socially undesirable behavior and over-reporting of socially desirable behavior.

defecation and sanitation practices [26]. However, observation is more likely to accurately capture a sensitive behavior than relying on the individual to truthfully report their behavior.

The other main method is use of a survey, such as the nationally representative household-level DHS and MICS surveys. Due to its relative cost-effectiveness and simplicity, a survey can be applied to assess a very large sample of individuals or households in a wide range of settings. Unlike observation, it can be more systematically and consistently used to apply the same methodology to communities regardless of timeframe or country. Similar to observation, self-reporting a behavior to someone administering a survey is also subject to social desirability bias—although to a greater extent. Surveys are also limited by what is asked; if the correct question isn't asked, data won't be collected on the behavior of interest. For example, if the time elapsed between defecation and disposal is not asked, risk can't accurately be assessed. Or in a more extreme example, if defecation location but not disposal location is asked then it is even more difficult to determine. However, several wide-scale nationally representative surveys including most of the data needed to assess disposal methods for children's feces are publically available, making survey data preferable to observation for the purposes of this study.

Methods

Data Sources

Using Rosa and Clasen's (2010) review of household water treatment in low- and middle-income countries as a model for methodology, the Demographic and Health Surveys (DHS), funded in part by the United States Agency for International AID (USAID), and UNICEF's Multiple Indicator Cluster Surveys (MICS) were the main data sources for this research [27]. A compilation of this survey data was selected to estimate sanitation statistics. Questionnaire survey data were used to provide a large sample size, consistent methodology over a wide-range of settings and time, and to reduce intra- and inter-observer bias. The likelihood of social desirability bias was considered an acceptable limitation.

Standard DHS and MICS surveys usually sample between 5,000 and 30,000 households in a stratified two-stage cluster design, and are representative at the national, residence (urban/rural), and regional levels. MICS surveys similarly capture a large sample of households and use a stratified cluster design to give representativeness at the national, residence (urban/rural), and regional levels. The MICS surveys were developed with technical support from the DHS program to provide similarity between survey questions and implementation and thus ensure comparability while reducing duplication. MICS surveys are completed in developing countries, and DHS surveys are completed in less-developed countries or countries receiving U.S. foreign aid. Each survey is divided into modules. For the purposes of this study, the MICS Child Module and the DHS Individual Modules were selected. The MICS Child Module surveys are administered to women who act as caregivers of children under-five; the DHS Individual Module surveys are administered to women who may or may not be caregivers of children under-five.

Inclusion factors used to select surveys were as follows:

- The dataset must be publically available as of August 2011 and not restricted.
- The survey must give a cross-sectional view of the population at one point in time and not be continuously administered.
- The dataset must include all necessary identifying information such as cluster, household and child identification numbers, and sampling weights.
- The survey must include the following or a similar question: "The last time your child defecated, where were the stools disposed of?"

Officially, the disposal of children's stools question was included in DHS surveys starting in 1997 and in MICS surveys by 2000, thus all DHS IV (1997-2003), DHS V (2003-2008), DHS IV (2008-2013), MICS2 (2000-2001) and MICS3 (2005-2006) surveys were originally identified for a total of 374 datasets from 94 different countries. Although these identified surveys were supposed to include the disposal question, the variable was either empty or missing entirely from many datasets; and they were excluded. Several other datasets were excluded due to empty or unclear coding of water and sanitation, identification or weighting variables, and finally, the most recent datasets from each country were selected for this study for an end total 78 datasets (Table 1).

IRB approval was not required for this study since it relies on secondary data analysis.

Data Management

All DHS datasets were obtained as STATA files, and MICS datasets were converted from SPSS datasets to a file type compatible with STATA. A key group of variables was subset from the MICS Child Module for each dataset, and a similar subset of variables was subset from the DHS Individual Module for each dataset. These variables included all identification, basic demographics (religion, ethnicity, child's sex, child's age, rural/urban residence, wealth quintile, maternal education, number of people in household, number of children in household, etc.) and water and sanitation (access to toilet/latrine type, drinking water source, distance to water source, etc.) variables. Reduced datasets were then appended, including information on country, survey type and WHO defined world region (Table 2).

Although DHS and MICS surveys are supposed to be standardized both across time and countries, this was not the case. Both phrasing of questions and responses varied substantially. For the purpose of this study, responses to key variables were standardized across surveys. Standardization of household access to a toilet/latrine and disposal of children's feces were the most complicated (Tables 3 and 4). Access to a latrine/toilet was standardized using the JMP classification for improved and unimproved (see Introduction), and unless characterized as unimproved, toilets and latrines were assumed to be improved.

Disposal of children's feces was standardized using as similar a process as possible to the toilet/latrine JMP classification, with one large difference. Disposal of children's feces in a toilet or latrine was considered improved regardless of whether the toilet or latrine was improved, providing a conservative estimate of unimproved disposal. In addition, disposal with solid waste or in the garbage was grouped with use of a disposable diaper and with burning since these

options all have a substantial time lag between defecation and disposal, and since solid waste and garbage is often burned in low- and middle-income countries. Burning was only a possible disposal option for surveys administered in Colombia, Peru and Maldives. Although disposal with solid waste or in the garbage may be a safe option in some countries and contexts, it was assumed unsafe for the majority, and was classified as unimproved (see Table 3 for full classification of improved/unimproved disposal).

Religion was categorized as Traditional/Spiritualist, Judeo-Christian, Muslim, Buddhist, Hindu, other religion, or none/Atheist. Regional religions that did not fit into the major religions were placed in the traditional category. Maternal education was categorized as none, at least some primary, at least some secondary or vocational school, or higher level education. Developmental age was categorized using development of gross motor skills that may have some impact children's autonomy and help determine where they defecate, as described below. By 0-6 months the child can sit up, by 7-9months the child can creep and cruise furniture, by 10-12 months the child can crawl and take their first steps, by 13-24 months the child can walk and run stiffly, and by 25-60 months the child can walk, run, and will likely begin toilet training [28].

Survey questions were also not standardized across datasets. In the MICS2 and MICS3 surveys, caregivers of children under-five were asked: "What is done to dispose of children's stools?". Some MICS3 surveys prefixed this question with: "The last time ---- [child under three] passed stools …". The DHS4 surveys asked "The last time ---- [the youngest child] passed stools, what was done to dispose of the stools?". These questions were considered similar enough to combine into one variable.

Analysis

Data were analyzed with Stata/SE version 11 (Stata Corp., College Station, TX). Dataset specific sample weights were used to restore representativeness to country-level datasets and to calculate dataset summary statistics. Country-year specific population weights were used to calculate regional summary statistics and in model development. Population estimates were obtained from the United Nations (2010 Revision) using medium variant estimates for the year closest to the time each survey was administered, i.e. 2000 estimates were used for surveys administered in 1999-2002, 2005 estimates were used for surveys in 2003-2007, and 2010 estimates were used for 2008-2011 [29]. The complex stratified cluster sample design was taken into account by use of Stata *svy* and *svy,subpop()* commands, using cluster as the primary sampling unit and urban/rural as the strata. Finite population correction was assumed to approach 1 for all populations sampled.

Multivariate logistic regression was used to develop exploratory models for improved disposal of children's feces. Sex of child, developmental age of child, religion, maternal education, wealth quintile, urban/rural designation, household access to an improved toilet/latrine, and WHO region were considered possible covariates for improved disposal. All covariates are categorical and with the exception of sex and access to an improved toilet/latrine, were coded with dummy variables. Due to the complex survey design, the likelihood ratio test could not be used and instead, the Wald test was used to test for the overall effect of categorical variables. While there is possible interaction between predictors such as urban/rural residence and wealth quintile, ultimately effect modifiers were not included in the models due to the resulting complexity and thus difficulty in interpretation.

Model 1:

logit (improved disposal)= intercept + β_1(sex of child) + β_2(access to toilet/latrine) + β_3(urban/rural residence) + β_4(wealth quintile) + β_5(religion) + β_6(world region) + β_7(developmental age) + β_8(maternal education)

Sex and urban/rural residence were not significant and were dropped from the model; no other potential confounders were dropped. The most parsimonious model is:

Model 2:

logit (improved disposal)= intercept + β_2(access to toilet/latrine) + β_4(wealth quintile) + β_5(religion) + β_6(world region) + β_7(developmental age) + β_8(maternal education)

Results

Data Management

Of the entire survey population, 30.28% (ranging from 0% to 72.15%) of respondents did not have children under-five and so were excluded. No MICS surveys were missing children under-five while the highest percent without children under-five was 72.15% for DHS in Armenia. Observations were also excluded from analysis if the response for the disposal of children's feces was "no applicable children".

Not unexpectedly for such a sensitive topic, 29.8% (ranging from 0% to 47.79%) of household observations were missing data on disposal of children's feces. There were several significant differences between those who responded to the question of where children's feces are disposed of and those who did not respond. Globally, rural dwellers were less likely to respond than urban dwellers, the poorest were less likely to respond than those belonging to the higher wealth quintiles, and caregivers of older children were less likely to respond than caregivers of younger children. Respondents in the Americas were less likely and respondents in Africa were more likely to respond than in other regions.

Overall, 5.9% (ranging from 0.2%, Vietnam to 52.2%, Benin) responded "don't know" to the question of where children's feces are disposed of, while 2.9% (0% to 14.5%) of households responded "other". Household's responding "other" or "don't know" to disposal of children's feces were combined and assumed to use an unimproved method of disposal.

Of caregivers reporting that the child regularly uses the toilet/latrine or that the child's feces are thrown in the toilet/latrine, 2.53% also reported that the household does not have access to a

toilet or latrine. Since access to a toilet is likely reported more accurately than the more sensitive topic of feces disposal, these observations were transferred to the "don't know" category for disposal.

A comparison of basic demographics shows similarity between world regions for sex of child, child's age in months, the number of household members and the number of children under-five in the household (Table 5). However, there are large differences between regions for all other characteristics compared. Thus, further analysis takes this regional variation into account.

Reported Disposal by Country and Region

Globally, an estimated 47.0% of households report using an improved method to dispose of children's feces (Table 6). All of the world regions except the Western Pacific have similar total improved disposal prevalences (41.2-55.7%); the Western Pacific is significantly lower with 22.2% improved disposal. There are also substantial differences between countries and within countries by urban/rural characterization (Figure 1). Only Moldova has improved disposal over 90%, improved disposal ranges from 76-90% for six countries (Egypt, Rwanda, Armenia, Azerbaijan, Belarus and Comoros), improved disposal ranges from 50-75% for 14 countries, while 57 countries have less than 50% improved disposal.

In the African region, "put/rinsed into toilet/latrine" is the most common response (34.1%). Among countries in the region, "always use toilet/latrine" ranges from 0%, Burkina Faso and Mozambique to 21.4%, Zimbabwe. Prevalence of "put/rinsed into toilet/latrine" ranges from 0%, Mozambique to 69.7%, Rwanda. Prevalence of "put/rinsed into drain/ditch/sink/gutter" ranges from 0%, multiple countries to 30.6%, Niger. Prevalence of "buried" ranges from 0.2%,

the Gambia to 38.5%, Namibia. Prevalence of "thrown in garbage/burned/disposable diapers" ranges from 0%, multiple countries to 47.5%, Niger. Prevalence of "washable diapers/put in washing place/rinsed" ranges from 0%, multiple countries to 33.3%, Senegal. Prevalence of "thrown outside/not disposed of" ranges from 0%, multiple countries to 64.2%, Chad.

In the Americas, "thrown in garbage/burned/disposable diapers" is the most common response (30.8%). Among countries in the region, "always use toilet/latrine" ranges from 0%, Bolivia to 37.6%, Colombia. Prevalence of "put/rinsed into toilet/latrine" ranges from 0%, Bolivia to 67.8%, Guyana. Prevalence of "put/rinsed into drain/ditch/sink/gutter" ranges from 0%, multiple countries to 26.5%, Honduras. Prevalence of "buried" ranges from 0%, multiple countries to 7.0%, Suriname. Prevalence of "thrown in garbage/burned/disposable diapers" ranges from 2.9%, Nicaragua to 67.1%, Belize. Prevalence of "washable diapers/put in washing place/rinsed" ranges from 0%, multiple countries to 14.4%, Nicaragua. Prevalence of "thrown outside/not disposed of" ranges from 0.1%, Suriname to 26.2%, Peru.

In the Eastern Mediterranean, "put/rinsed in to toilet/latrine" is the most common response (28.0%). Among countries in the region, "always use toilet/latrine" ranges from 0.3%, Somalia to 40.1%, Egypt. Prevalence of "put/rinsed into toilet/latrine" ranges from 1.7%, Morocco to 46.4%, Egypt. Prevalence of "put/rinsed into drain/ditch/sink/gutter" ranges from 0%, Morocco to 26.5%, Iraq. Prevalence of "buried" ranges from 0.2%, Morocco to 9.8%, Somalia. Prevalence of "thrown in garbage/burned/disposable diapers" ranges from 8.3%, Egypt to 36.9%, Iraq. Prevalence of "washable diapers/put in washing place/rinsed" ranges from 0%, multiple countries to 37.1%, Morocco. Prevalence of "thrown outside/not disposed of" ranges from 0.4%, Egypt to 20.0%, Somalia.

In Europe, “thrown in garbage/burned/disposable diapers” is the most common response (33.5%). Among countries in the region, “always use toilet/latrine” ranges from 0%, multiple countries to 37.6%, Albania. Prevalence of “put/rinsed into toilet/latrine” ranges from 0%, multiple countries to 91.5%, Moldova. Prevalence of “put/rinsed into drain/ditch/sink/gutter” ranges from 0%, multiple countries to 37.1%, Tajikistan. Prevalence of “buried” ranges from 0%, multiple countries to 15.1%, Uzbekistan. Prevalence of “thrown in garbage/burned/disposable diapers” ranges from 0%, multiple countries to 74.9%, Macedonia. Prevalence of “washable diapers/put in washing place/rinsed” was 0% for all countries. Prevalence of “thrown outside/not disposed of” ranges from 0%, Armenia to 36.5%, Belarus.

In Southeast Asia, “put/rinsed into toilet/latrine” is the most common response (21.3%). Among countries in the region, “always use toilet/latrine” ranges from 1.0%, Bangladesh to 28.4%, Maldives. Prevalence of “put/rinsed into toilet/latrine” ranges from 7.6%, India to 40.2%, Thailand. Prevalence of “put/rinsed into drain/ditch/sink/gutter” ranges from 0.3%, Maldives to 22.3%, Bangladesh. Prevalence of “buried” ranges from 0.8%, multiple countries to 9.1%, Thailand. Prevalence of “thrown in garbage/burned/disposable diapers” ranges from 6.8%, Timor-Leste to 52.2%, Maldives. Prevalence of “washable diapers/put in washing place/rinsed” was 0% for all countries except Timor-Leste (5.6%). Prevalence of “thrown outside/not disposed of” ranges from 7.2%, Thailand to 44.6%, Timor-Leste.

In the Western Pacific, “buried” is the most common response (30.8%). Among countries in the region, “always use toilet/latrine” ranges from 3.0%, Vanuatu to 29.5%, Philippines. Prevalence of “put/rinsed into toilet/latrine” ranges from 3.7%, Lao PDR to 35.7%, Vietnam. Prevalence of

"put/rinsed into drain/ditch/sink/gutter" ranges from 1.6%, Mongolia to 21.1%, Vanuatu. Prevalence of "buried" ranges from 2.9%, Mongolia to 41.7%, Cambodia. Prevalence of "thrown in garbage/burned/disposable diapers" ranges from 1.3%, Lao PDR to 33.0%, Philippines. Prevalence of "washable diapers/put in washing place/rinsed" is 0% for all countries. Prevalence of "thrown outside/not disposed of" ranges from 2.8%, Vanuatu to 63.2%, Lao PDR.

Reported Disposal by Urban/Rural Residence

Globally, urban dwellers are more likely to use an improved method than rural dwellers (51.8% v. 44.7%, $p<0.01$), and are more likely to use both improved methods, "use of toilet/latrine" and "put/rinsed into a toilet/latrine" (17.4% and 34.4% v. 14.3% and 30.4%, Table 6). This trend is true for most world regions. The African region varies from 53.6% in urban areas to 35.8% in rural; the Americas vary from 41.9% to 40.5%; the Eastern Mediterranean varies from 57.6% to 33.7%; Europe varies from 45.0% to 40.1%; the Western Pacific region varies from 40.4% to 17.3%. However, Southeast Asia shows a not significant reverse trend, varying from 55.5% to 55.9%. Prevalence of improved disposal among urban compared to rural dwellers ranges from 0%, regardless of urban/rural residence, in Mozambique, Bolivia, Montenegro and Serbia to 98.4% v. 93.8% in Moldova. Chad, Niger, Somalia, Zambia, and Zimbabwe have an over 50% increase in improved disposal in urban compared to rural residence. In contrast, Belize ($p<0.05$), Egypt ($p<0.01$), Jamaica ($p<0.01$), and Maldives ($p<0.01$) all have a decrease in improved disposal in urban compared to rural residence.

Globally, "put/rinsed into toilet/latrine" was the most common disposal method for both urban and rural dwellers. This practice was also the most common for urban dwellers in the African and the Eastern Mediterranean regions, as well as for rural dwellers in Africa, the Americas,

Europe and Southeast Asia (range: 29.5-41.7%). "Thrown in garbage/burned/disposable diapers" was the dominant method among urban dwellers in the Americas, Europe, Southeast Asia and the Western Pacific, as well as for rural dwellers in the Eastern Mediterranean region (range: 25.7-40.1%). "Buried" was the most common disposal method among rural dwellers in the Western Pacific region (25.1%).

Reported Disposal by Household Wealth

Reported improved disposal of children's feces show an increasing trend with increasing household wealth both globally and in each world region except Southeast Asia (Figure 2). The average regional gross national income (GNI) for each region varies greatly from USD 677 in Africa to USD 3371 in the Americas and should be taken into account during regional comparisons. In Africa and the Eastern Mediterranean, the difference in disposal between the poorest and richest quintiles is the greatest (25.79% to 67.34%, 26.33% to 75.59%, $p<0.05$ for both).

Globally, "put/rinsed into toilet/latrine" is the most common disposal method regardless of wealth quintile. There is no difference in dominant disposal method between wealth quintiles in Europe. "Thrown in garbage/burned/disposable diapers" is the dominant method among the poorest and the poorer quintiles in Africa, the richest quintiles in Southeast Asia, and all except the richer and richest in Eastern Mediterranean. "Put/rinsed into toilet/latrine" is the dominant method among the poorest quintiles in the Americas and the richer and richest quintiles in the Western Pacific.

Reported Disposal by Developmental Age of Child

Globally, reported improved disposal of children's feces increased with increasing developmental age of the child (Figure 3). Improved disposal increased across developmental age category in each world region, although it is consistently low among youngest ages in all regions. The greatest improvement is generally between 13-24 months and 25-60 months. The Americas show the greatest difference between age categories, ranging from 10.80% for 0-6 months to 80.95% for 25-60 months.

In the African region, "put/rinsed into toilet/latrine" is the most common disposal method regardless of developmental age (Table 7). In the Americas, "buried" is most common from 0-24 months, and "use toilet/latrine" is most common for ages 25-60 months. In the Eastern Mediterranean region, "thrown in garbage/burned/disposable diapers" is most common from 0-12 months, "put/rinsed into toilet/latrine" is most common for 13-24 months, and "use toilet/latrine" is most common for ages 25-60 months. In Europe, "thrown in garbage/burned/disposable diapers" is most common from 0-24 months; "put/rinsed into toilet/latrine" is most common for ages 25-60 months. In Southeast Asia, "thrown in garbage/burned/disposable diapers" is most common for ages 0-6 months, "put/rinsed into toilet/latrine" is most common for 7-24 months, and "use toilet/latrine" is most common for 25-60 months. In the Western Pacific, "put/rinsed into drain/ditch/sink/gutter" is most common for 0-12 months and "buried" is most common for ages 13-60 months.

Modeling Improved Disposal of Children's Feces

Regardless of the model used, analysis across the full set of surveys found increased odds of improved disposal of children's feces with increasing wealth, with at least some primary, secondary or higher level formal maternal education compared to none, and with the children aged 10-60 months compared to 0-6 months old, adjusting for all other covariates (Table 8). There are also decreased odds of improved disposal associated with residing in all WHO world regions compared to Europe, except in Africa and the Eastern Mediterranean where there are increased odds (OR=3.44 and OR=7.56)). Unsurprisingly, the strongest determinant of improved disposal, adjusting for all other covariates, is household access to an improved toilet or latrine (Model 1: OR=52.90, $p<0.00$ and Model 2: OR=52.84, $p<0.00$). Controlling for access to an improved toilet or latrine, world region and the developmental age of the child appear to be the next strongest determinants of improved disposal.

Discussion and Conclusion

The Millennium Development Goals include the target of halving the proportion of people without sustainable access to basic sanitation by 2015 [6]. Currently, the JMP reports that 61% of the global population uses improved sanitation solutions [2]. However, this only estimates adult access to improved facilities and does not include the subpopulation at greatest risk for diarrheal disease, children under-five years old with 47.03% improved disposal of feces in low- and middle-income countries. These findings contribute to the existing literature on the global sanitation situation by providing a first comprehensive look at how the feces of children under-five years are disposed of. While some previous literature has touched upon disposal of children's feces, it has not taken advantage of the globally administered standardized household surveys which allow greater comparability between countries and regions of the world.

Questions on child feces disposal are now included in two of the internationally implemented, large-scale household level surveys, DHS and MICS, making it possible to track sanitation behaviors for children under-five years, and differentiate it from adult sanitation. This study includes DHS and MICS surveys from 47.3% of all low- and middle-income countries. Due to the great variance in disposal behavior within WHO world regions and even within countries, it is difficult to generalize to those countries without available data.

This study identified demographic characteristics which are associated with use of improved feces disposal: household access to an improved toilet/latrine, urban/rural residence, wealth quintile, maternal education, religion, WHO world region and developmental age of the child. Unsurprisingly, access to an improved toilet or latrine was the greatest predictor of improved feces disposal for children, controlling for other covariates.

The Western Pacific region reports significantly lower improved disposal than all other world regions (22.2%). However, this cannot solely be due to differences in demographic characteristics or household access to an improve toilet/latrine; there is likely another influencing factor aside from geography that was not covered by this study. Overall, the vast majority of countries (74%) countries have less than 50% improved disposal, even given the conservative definition of unimproved disposal used, implying that sanitation for children is a real concern. There was significant urban/rural disparity in improved disposal practices, both regionally, and in almost every country surveyed. Whether this is in part due to interaction between urban/rural residence and wealth was unfortunately not covered by this analysis. The use of improved feces disposal methods was especially low among the poorest households and for those where the mother had no formal education. As there is some evidence of the influence of maternal education on diarrheal incidence in children, it follows that mothers have a significant impact on use of appropriate sanitation solutions for children not developmentally capable of caring for their own sanitation needs [21]. Especially for those children not developmentally able to use a latrine or toilet, even if there was household access to one, use of improved disposal methods was uniformly low (31.7%).

Although the findings of this study are plausible in the context of sanitation research and the socio-physical development of children, there are several limitations. One clear limitation is the categorization of children's feces disposal to improved and unimproved. While every attempt was made to appropriately assign disposal practices, this relied on several assumptions.

A main assumption was that solid waste disposal was unsafe. Municipal waste collection and safe disposal vary greatly between high-income countries (~100% collection and safe disposal),

middle-income countries (60% collection, 30% safe disposal) and low-income countries (40% collection, 5% safe disposal)[30]. Uncollected and unsafe disposal of solid waste leads to leaching into soil and water sources, contaminating food, drinking water and soil. Although waste disposal and the sewage system vary in effectiveness and safety by world region, country, and urban/rural designation, disposal of feces with solid waste, including the use of disposable diapers, was assumed to be unsafe in low and middle-income countries [31]. In addition, it was assumed that the wash water used to clean cloth diapers was thrown in the yard, drain, river, or some other unsafe location.

In addition, the large percent of respondents who did not answer the disposal question is also a clear limitation of this study, though it is not unexpected due to the sensitive nature of the topic. Due to the significant differences between the responsive and non-responsive populations, both non-response and social-desirability biases are of concern possibly limiting the accuracy and generalizability of study results. The complex sample survey design and large number of categorical covariates also limited the scope of analysis possible.

In further studies, a wider selection of countries should be assessed and a more precise characterization of improved versus unimproved disposal of children's feces should be determined on a country and regional basis. This would require additional country specific data on assumptions made in this study, such as safety and consistency of solid waste management. Further analysis of these data will help focus on improving coverage of sanitation solutions that are effective for children under-five and to better target those populations who do not practice improved disposal of children's feces.

Appendix: Tables and Figures

Tables

Table 1. Selected surveys by survey year, country, and survey type (number of observations).

Country/WHO Region	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Africa											
Benin							DHS5 (17794)				
Burkina Faso							MICS3 (5677)				
Burundi						MICS3 (6934)					
Cameroon							MICS3 (6495)				
Central African Republic							MICS3 (9820)				
Chad	MICS2 (5384)										
Comoros	MICS2 (4870)										
Congo								DHS5 (9995)			
Cote d'Ivoire							MICS3 (8604)				
Equatorial Guinea	MICS2 (2949)										
Ethiopia						DHS5 (14070)					
Gambia						MICS3 (6641)					
Ghana									DHS5 (4916)		
Guinea						DHS5 (7954)					
Guinea-Bissau							MICS3 (6570)				
Kenya									DHS5 (8444)		
Lesotho										DHS6 (7624)	
Liberia								DHS5 (7092)			
Madagascar									DHS5 (17375)		
Malawi							MICS3 (23238)				
Mali							DHS5 (14583)				
Mauritania								MICS3 (8981)			
Mozambique									MICS3 (11818)		
Namibia							DHS5 (9804)				
Niger							DHS5 (9223)				
Nigeria									DHS5 (33385)		
Rwanda	DHS4 (10421)										
Sao Tome and Principe									DHS5 (2615)		
Senegal						DHS4 (14602)					
Sierra Leone									DHS5 (7374)		
Swaziland							DHS5 (4987)				

Country/WHO Region	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Tanzania											DHS6 (10139)
Togo							MICS3 (4154)				
Uganda							DHS5 (8531)				
Zambia								DHS5 (7146)			
Zimbabwe						DHS5 (8907)					
Americas											
Belize							MICS3 (796)				
Bolivia									DHS5 (16939)		
Colombia											DHS6 (53521)
Dominican Republic								DHS5 (27195)			
Guyana								MICS3 (2541)			
Haiti						DHS5 (10757)					
Honduras						DHS5 (19948)					
Jamaica						MICS3 (1444)					
Nicaragua		DHS4 (13060)									
Peru	DHS4 (27843)										
Suriname							MICS3 (2354)				
Eastern Mediterranean											
Egypt									DHS5 (16527)		
Iraq							MICS3 (16570)				
Morocco				DHS4 (16798)							
Somalia							MICS3 (6305)				
Europe											
Albania									DHS5 (7584)		
Armenia						DHS5 (6566)					
Azerbaijan	MICS2 (1890)										
Belarus						MICS3 (3051)					
Bosnia and Herzegovina							MICS3 (3209)				
Georgia						MICS3 (2196)					
Kazakhstan							MICS3 (16570)				
Kyrgyzstan						MICS3 (2987)					
Macedonia						MICS3 (4545)					
Moldova	MICS2 (1655)										
Montenegro						MICS3 (1072)					
Serbia						MICS3 (3838)					
Tajikistan						MICS3 (4370)					

Country/WHO Region	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Uzbekistan							MICS3 (5039)				
Southeast Asia											
Bangladesh							MICS3 (34710)				
India						DHS5 (124385)					
Indonesia								DHS5 (32895			
Maldives										DHS5 (7131)	
Nepal							DHS5 (10793)				
Thailand						MICS3 (9444)					
Timor-Leste										DHS6 (13137	
Western Pacific											
Cambodia						DHS5 (16823)					
Lao PDR							MICS3 (4204)				
Mongolia						MICS3 (3568)					
Philippines									DHS5 (13594)		
Vanuatu								MICS3 (1741)			
Vietnam							MICS3 (2680)				

Table 2. Regional distribution of country surveys included in analysis.

WHO Region	Total number of low- and middle- income countries	Countries included in analysis	Percent of countries included in analysis
Africa	46	36	82.6
The Americas	33	11	33.3
Eastern Mediterranean	22	4	18.2
Europe	25	14	56
Southeast Asia	10	7	70
Western Pacific	27	6	22.2
Total	**165**	**78**	**47.3**

Table 3. Standardization of indicator for disposal of children's feces.

Dataset	Common responses	Additional country specific responses	Standardized responses used in analysis
MICS 2	-always use toilet -thrown in toilet -thrown outside in yard -buried in yard -not disposed/left on ground -other -N/A (no applicable children)	-thrown in garbage	
MICS 3	-always use toilet/latrine -put/rinsed into toilet/latrine -put/rinsed into drain/ditch -thrown into garbage/solid waste -buried -left in open -other -DK	-thrown outside yard	**Improved:** -always use toilet/latrine -put/rinsed into toilet/latrine **Unimproved:** -put/rinsed into drain/ditch/sink/gutter -buried -thrown in garbage/solid waste/burned or use disposable diapers -use washable diapers/thrown in washing place area/rinse away (no location specified) -thrown outside (household/yard)/left in open/not disposed of -other -don't know
DHS 4	-always use toilet -thrown in toilet/latrine -thrown outside dwelling -thrown outside yard -buried in yard -rinse away -use disposable diapers -use washable diapers -not disposed -other	-thrown in garbage/trash -open field/river -thrown in sink -burned in yard	
DHS 5 & DHS 6	-always use toilet -put/rinsed into toilet -put/rinsed into drain/ditch -thrown in garbage -buried -rinsed away -use disposable diapers -use washable diapers -left in open/not disposed -other -DK	-thrown outside yard -thrown outside dwelling -burned in yard -thrown in washing place -collected in cloth and washed -thrown on field -disposed on field with water -buried by water -river/stream/beach/sea, etc. -gutter/drain -bush/forest	**Excluded from subpopulation analyzed:** -no applicable children

Table 4. Standardization of indicator for household access to toilet/latrine.

Dataset	Common responses	Additional country-level responses	Standardized responses used in analysis
MICS 2	-flush to sewage system/septic tank -pour flush -improved pit (VIP) -traditional pit -open pit/hole -bucket -no facilities/bush/field	- broken septic tank -a little broken septic tank -dry pour flush -river/ocean -evacuation latrine -soak away pit -flush to pit	
MICS 3	-flush to sewer -flush to septic tank -flush to pit -flush to somewhere else -flush to don't know -VIP -pit with slab -pit without slab -bucket -hanging toilet -no facilities -other	-composting toilet -pour flush -pit with slab and cover - pit with slab cover and footrest	**Improved:** -flush/pour-flush to sewer/septic pit/pit latrine -VIP -pit with slab/traditional pit/closed pit/own pit -composting toilet **Unimproved:** -flush/pour-flush to all other locations, including toilet to open water and yard -pit without slab/open pit -bucket -hanging toilet -shared facilities of any type -no facilities/field/bush/river/drain, etc. -other
DHS 4	-own flush -traditional pit -VIP -no facilities -other -not a resident	-toilet to pit -toilet to creek/open space -shared traditional pit -shared VIP -shared flush -river/stream/canal -flush to rainwater sewer -hanging latrine -drop or overhang toilet -flush to rainwater sewer	
DHS 5 & DHS 6	-flush to piped sewer system -flush to septic tank -flush to pit latrine -flush to somewhere else -VIP -pit with slab -pit latrine without slab/open pit -no facilities -composting toilet -bucket -other -not a resident -hanging latrine	-traditional latrine to sea/river -latrine with siphon -dry toilet -inside dwelling -outside dwelling -latrine over river/lake -stream/river/canal/beach/sea -gutter/drain -bush/forest	

Table 5. Demographics of population by world region.[6]

	Africa	The Americas	Eastern Mediterranean	Europe	Southeast Asia	Western Pacific	**Total**
Maternal education, % (n=646,272)							
No education	43.29	4.34	32.93	0.20	10.91	6.25	**11.54**
Primary	31.69	31.53	20.07	13.11	45.90	31.28	**45.34**
Secondary	21.63	48.68	39.47	76.66	41.93	43.86	**41.93**
Higher	3.40	15.45	7.53	10.04	1.19	18.61	**1.19**
Access to an improved toilet/latrine, % (n=623, 446)	42.50	85.00	94.33	94.07	88.19	71.24	**87.40**
Religion, % (n=430,361)							
None/Atheist	1.89	6.59	0.00	0.22	0.00	19.62	**0.13**
Traditional/Spiritualist	2.02	0.73	0.00	31.40	0.27	0.20	**0.30**
Judeo-Christian	52.28	91.04	4.53	32.10	1.10	62.21	**2.09**
Muslim	43.23	0.22	95.47	36.07	10.89	0.24	**11.71**
Buddhist	0.00	0.00	0.00	0.00	87.42	13.73	**85.48**
Hindu	0.00	1.32	1.32	0.00	0.14	3.78	**0.15**
Other	0.58	0.00	0.00	0.20	0.13	0.22	**0.14**
Female child, % (n=586,497)	49.40	49.08	47.76	48.92	48.53	47.76	**48.54**
Urban residence, % (n=656,761)	27.66	68.43	42.32	48.88	28.23	41.52	**28.58**
Child's age in months, $\bar{x}$ (std err) (n=471,307)	25.99 (0.12)	29.00 (0.18)	27.99 (0.12)	30.38 (0.19)	28.61(0.24)	28.02 (0.37)	**27.92 (0.13)**
Number of people in household, $\bar{x}$ (std err) (n=632,613)	7.70 (0.04)	6.23 (0.05)	7.07 (0.04)	6.31 (0.06)	5.92 (0.06)	6.03 (0.14)	**6.48 (0.04)**
Number of children under 5 in household, $\bar{x}$ (std err) (n=637,483)	1.89 (0.01)	1.60 (0.01)	1.90 (0.01)	1.60 (0.01)	1.39 (0.01)	1.57 (0.03)	**1.59 (0.01)**
Time to water source in hours, $\bar{x}$ (std err) (n=506, 184)	1.90 (0.5)	5.27 (0.10)	1.44 (0.07)	3.18 (0.11)	7.04 (0.08)	2.23 (0.21)	**4.50 (0.07)**

[6] All regional estimates are population-weighted.

Table 6. Urban (U), rural (R), and total (T) percent disposal of children's feces by country and world region.

Country/WHO Region	Improved						Not improved																		Overall Improved		
	Always use toilet/ latrine			Put/rinsed into toilet/ latrine			Put/rinsed into drain/ditch/ sink/gutter			Buried			Thrown in garbage/ Burned/ Disposable diapers			Washable diapers/ Put in washing area/Rinse away			Thrown outside/ Not disposed of			Other/ Don't know					
	U	R	T	U	R	T	U	R	T	U	R	T	U	R	T	U	R	T	U	R	T	U	R	T	U	R	T
Africa	**12**	**5**	**8**	**42**	**30**	**34**	**4**	**5**	**5**	**2**	**6**	**5**	**14**	**15**	**14**	**2**	**2**	**2**	**12**	**22**	**18**	**13**	**16**	**15**	**54**	**36**	**42**
Benin	6	1	3	41	6	18	19	35	29	2	2	2	19	43	35	11	10	10	0	0	0	4	3	3	**46**	**7**	**21**
Burkina Faso	0	0	0	2	0	1	16	14	15	0	3	3	13	44	38	0	0	0	6	31	26	62	8	18	**2**	**0**	**0**
Burundi	0	1	1	32	24	24	4	6	6	4	9	9	3	3	3	0	0	0	4	5	5	54	53	53	**32**	**24**	**25**
Cameroon	3	1	2	40	8	22	5	5	5	0	2	1	5	20	14	0	0	0	2	14	9	45	51	48	**43**	**9**	**24**
Central African Republic	3	1	2	45	24	32	6	11	9	1	1	1	14	37	28	0	0	0	3	4	3	27	23	24	**49**	**25**	**34**
Chad	6	1	2	63	8	20	0	0	0	2	9	8	0	0	0	0	0	0	19	77	64	10	6	7	**69**	**8**	**21**
Comoros	17	11	12	69	62	64	0	0	0	1	1	1	0	0	0	0	0	0	4	13	11	9	13	12	**86**	**73**	**76**
Congo DR	5	4	4	64	49	55	3	10	7	1	2	2	5	16	11	11	5	7	5	9	8	7	6	6	**69**	**53**	**59**
Cote d'Ivoire	1	0	1	68	20	38	4	3	3	0	0	0	13	40	30	0	0	0	4	11	8	11	25	20	**69**	**20**	**39**
Equatorial Guinea	17	4	9	55	36	44	0	0	0	2	5	3	0	0	0	0	0	0	18	45	34	9	11	10	**71**	**40**	**53**
Ethiopia	3	1	1	21	2	4	0	0	0	2	2	2	0	0	0	3	4	3	42	66	64	30	26	26	**24**	**3**	**5**
Gambia	1	1	1	86	61	70	3	6	5	0	0	0	3	15	11	0	0	0	0	1	0	7	17	14	**87**	**62**	**70**
Ghana	6	3	4	43	18	28	13	11	12	4	6	5	28	42	37	0	0	0	1	5	3	5	15	11	**48**	**6**	**32**
Guinea	5	1	2	43	5	14	0	0	0	0	2	2	0	0	0	15	24	22	8	50	40	28	18	20	**48**	**6**	**16**
Guinea Bissau	3	2	2	56	21	31	14	4	7	0	2	1	11	22	19	0	0	0	7	37	28	9	13	12	**59**	**23**	**33**
Kenya	14	6	7	65	24	32	3	5	5	1	6	5	4	7	6	0	0	0	1	12	10	14	41	35	**78**	**29**	**39**
Lesotho	14	4	6	35	14	19	3	6	5	2	5	4	3	14	12	4	3	3	3	33	26	37	34	25	**49**	**18**	**25**
Liberia	4	1	2	17	7	10	20	14	16	11	14	13	18	28	25	0	0	0	7	22	17	24	14	17	**20**	**8**	**12**
Madagascar	4	1	1	11	1	2	11	16	16	7	6	6	7	7	7	0	0	0	10	33	30	51	35	37	**16**	**2**	**3**
Malawi	4	1	1	31	11	14	7	9	9	1	4	4	1	4	4	0	0	0	0	2	2	56	69	67	**35**	**12**	**15**
Mali	13	8	9	58	25	35	9	22	18	0	1	1	7	29	23	11	12	12	0	0	0	2	2	2	**71**	**33**	**44**
Mauritania	3	0	1	26	3	12	2	2	2	3	8	6	41	26	33	0	0	0	12	54	37	13	7	10	**29**	**3**	**14**
Mozambique	0	0	0	0	0	0	4	3	4	22	34	30	10	19	17	0	0	0	6	14	12	58	29	37	**0**	**0**	**0**
Namibia	23	2	11	24	3	12	7	5	5	16	54	39	18	7	11	0	0	0	9	21	16	4	9	7	**47**	**5**	**22**
Niger	7	1	2	57	3	11	9	35	31	0	1	1	15	54	48	9	6	6	0	0	0	3	2	2	**64**	**3**	**13**
Nigeria	7	2	4	57	29	37	6	10	9	1	4	3	15	28	24	0	0	0	3	9	7	12	29	17	**63**	**31**	**41**
Rwanda	10	9	9	70	70	70	0	0	0	0	2	2	1	0	0	16	13	14	1	3	3	2	3	3	**80**	**79**	**79**
Sao Tome and Principe	18	9	14	14	10	12	0	0	0	2	6	4	28	33	30	0	0	0	29	31	30	9	11	10	**32**	**19**	**25**

Country/WHO Region	Improved						Not improved																		Overall Improved		
	Always use toilet/ latrine			Put/rinsed into toilet/ latrine			Put/rinsed into drain/ditch/ sink/gutter			Buried			Thrown in garbage/ Burned/ Disposable diapers			Washable diapers/ Put in washing area/Rinse away			Thrown outside/ Not disposed of			Other/ Don't know					
	U	R	T	U	R	T	U	R	T	U	R	T	U	R	T	U	R	T	U	R	T	U	R	T	**U**	**R**	**T**
Senegal	9	3	5	50	31	38	0	0	0	0	0	0	2	0	1	32	34	33	3	28	19	4	4	4	**59**	**33**	**43**
Sierra Leone	1	1	1	22	27	24	19	13	16	0	1	1	24	20	22	0	0	0	0	1	1	34	38	36	**23**	**27**	**25**
Swaziland	27	13	16	53	36	39	8	9	9	1	8	7	6	6	6	0	0	0	4	24	20	1	5	4	**80**	**49**	**55**
Tanzania	11	4	5	40	18	23	2	1	1	2	6	5	3	6	5	6	8	8	2	10	8	35	48	45	**50**	**22**	**28**
Togo	2	0	1	49	4	20	7	3	5	5	11	9	15	46	35	0	0	0	4	19	14	17	17	17	**51**	**4**	**21**
Uganda	11	2	3	41	11	15	5	6	6	5	8	7	2	11	10	0	0	0	2	6	6	35	57	54	**52**	**13**	**17**
Zambia	16	3	7	47	10	22	5	9	8	1	12	9	2	10	7	0	0	0	1	7	5	29	50	43	**63**	**12**	**28**
Zimbabwe	46	11	21	50	21	30	1	7	5	0	18	13	0	7	5	0	0	0	0	16	11	2	21	15	**96**	**32**	**51**
The Americas	**19**	**10**	**15**	**23**	**30**	**27**	**4**	**7**	**5**	**1**	**4**	**2**	**40**	**21**	**31**	**2**	**1**	**2**	**2**	**12**	**7**	**10**	**14**	**12**	**42**	**41**	**41**
Belize	12	11	11	5	17	12	2	3	2	0	1	1	79	57	67	0	0	0	0	3	2	2	9	5	**17**	**27**	**23**
Bolivia	0	0	0	0	0	0	4	14	8	2	5	3	37	18	29	0	0	0	3	27	13	55	35	47	**0**	**0**	**0**
Colombia	41	30	38	16	12	15	0	0	0	0	0	0	30	25	29	0	0	0	12	25	16	1	8	3	**66**	**42**	**52**
Dominican Republic	34	23	31	22	25	23	1	2	1	0	0	0	25	23	27	0	0	0	0	2	1	13	24	17	**57**	**48**	**54**
Guyana	8	7	7	66	68	68	4	7	6	0	1	1	16	9	11	0	0	0	1	4	3	4	4	4	**74**	**76**	**75**
Haiti	4	1	2	37	11	20	2	1	1	0	3	2	6	13	10	0	0	0	6	34	24	45	37	40	**41**	**12**	**23**
Honduras	33	18	25	23	13	18	21	31	27	1	3	2	16	7	11	0	0	0	3	23	14	2	5	4	**57**	**31**	**43**
Jamaica	13	9	11	14	37	24	0	2	1	1	3	2	70	39	56	0	0	0	0	0	0	3	9	6	**26**	**46**	**35**
Nicaragua	32	14	23	42	26	35	0	0	0	0	1	0	2	4	3	17	12	14	5	36	19	3	8	5	**73**	**40**	**58**
Peru	24	12	19	30	12	23	0	0	0	0	0	0	20	5	14	6	9	8	9	51	26	11	11	11	**54**	**24**	**42**
Suriname	13	8	11	20	18	19	2	4	3	2	15	7	56	25	44	0	0	0	0	0	0	7	30	16	**33**	**26**	**30**
Eastern Mediterranean	**20**	**14**	**17**	**38**	**20**	**28**	**6**	**6**	**6**	**1**	**6**	**4**	**26**	**26**	**26**	**4**	**5**	**5**	**2**	**18**	**10**	**4**	**5**	**4**	**58**	**34**	**45**
Egypt	44	40	42	42	49	46	1	1	1	0	1	0	12	6	8	0	0	0	0	1	0	1	3	3	**86**	**89**	**88**
Iraq	15	11	14	30	21	26	8	22	14	0	1	1	44	26	37	0	0	0	1	16	7	2	4	3	**45**	**32**	**40**
Morocco	45	26	36	2	1	2	0	0	0	0	1	0	24	3	15	28	48	37	0	13	6	1	9	5	**57**	**27**	**37**
Somalia	1	0	0	67	9	30	8	2	4	3	14	10	8	41	29	0	0	0	3	29	20	12	4	7	**67**	**9**	**30**
Europe	**14**	**11**	**12**	**31**	**30**	**30**	**5**	**13**	**9**	**1**	**3**	**2**	**38**	**29**	**34**	**0**	**0**	**0**	**1**	**3**	**2**	**11**	**12**	**12**	**45**	**40**	**43**
Albania	42	35	38	11	14	13	1	4	3	0	2	2	45	40	42	0	0	0	0	1	1	1	4	3	**53**	**49**	**50**
Armenia	25	18	23	54	56	55	0	6	2	0	0	0	19	6	14	0	0	0	0	0	0	2	15	7	**79**	**73**	**77**
Azerbaijan	4	3	3	84	64	74	0	0	0	0	1	1	0	0	0	0	0	0	3	5	4	9	28	19	**88**	**66**	**77**
Belarus	9	6	8	69	66	68	2	13	5	0	0	0	18	13	17	0	0	0	0	0	37	3	3	15	**78**	**72**	**76**

Country/WHO Region	Improved						Not improved																		Overall Improved		
	Always use toilet/ latrine			Put/rinsed into toilet/ latrine			Put/rinsed into drain/ditch/ sink/gutter			Buried			Thrown in garbage/ Burned/ Disposable diapers			Washable diapers/ Put in washing area/Rinse away			Thrown outside/ Not disposed of			Other/ Don't know					
	U	R	T	U	R	T	U	R	T	U	R	T	U	R	T	U	R	T	U	R	T	U	R	T	**U**	**R**	**T**
Bosnia & Herzegovina	8	8	8	27	28	28	2	2	2	0	0	0	62	59	60	0	0	0	0	1	1	2	2	2	**35**	**36**	**36**
Georgia	2	2	2	61	50	56	3	20	11	1	1	1	16	9	13	0	0	0	0	1	1	16	18	17	**63**	**52**	**58**
Kazakhstan	15	11	14	30	21	26	8	22	14	0	1	1	44	26	37	0	0	0	1	16	7	2	4	3	**45**	**32**	**40**
Kyrgyzstan	7	8	8	50	20	32	29	38	34	3	12	9	8	10	10	0	0	0	2	3	2	1	8	5	**57**	**28**	**40**
Macedonia	26	14	20	25	33	29	2	6	4	0	0	0	38	38	75	0	0	0	0	0	0	9	9	9	**51**	**47**	**49**
Moldova	6	3	4	93	91	92	0	0	0	0	1	1	0	0	0	0	0	0	1	3	2	1	3	2	**98**	**94**	**95**
Montenegro	0	0	0	0	0	0	2	10	4	0	0	0	65	45	58	0	0	0	0	1	0	33	45	38	**0**	**0**	**0**
Serbia	0	0	0	0	0	0	3	4	3	0	0	0	60	57	59	0	0	0	0	0	0	37	39	38	**0**	**0**	**0**
Tajikistan	11	8	8	39	13	19	25	41	37	6	15	13	8	14	12	0	0	0	0	2	2	10	8	8	**50**	**20**	**28**
Uzbekistan	4	3	3	66	51	55	14	22	20	8	18	15	5	4	10	0	0	0	0	0	0	4	2	3	**70**	**54**	**58**
Southeast Asia	**23**	**23**	**23**	**33**	**33**	**33**	**2**	**3**	**2**	**2**	**11**	**9**	**36**	**15**	**21**	**0**	**1**	**1**	**4**	**12**	**10**	**1**	**2**	**2**	56	56	56
Bangladesh	2	1	1	32	7	14	21	23	22	0	1	1	8	12	11	0	0	0	21	42	37	15	15	15	**35**	**8**	**15**
India	26	5	10	19	3	8	10	6	7	0	1	1	17	29	26	0	0	0	25	52	45	3	4	4	**45**	**8**	**18**
Indonesia	31	15	21	29	22	25	6	17	12	3	5	4	9	8	9	0	0	0	12	26	20	10	9	9	**60**	**36**	**46**
Maldives	26	29	28	4	11	9	0	0	0	0	11	8	70	45	52	0	0	0	0	2	1	1	1	1	**30**	**40**	**37**
Nepal	27	7	10	27	7	10	13	14	14	1	2	2	16	38	35	0	0	0	11	27	25	5	6	6	**54**	**14**	**19**
Thailand	23	25	24	40	40	40	2	1	1	2	12	9	3	11	16	6	0	0	2	9	7	35	2	2	**63**	**65**	**64**
Timor-Leste	13	5	7	23	8	11	8	15	13	10	6	7	14	5	7	2	7	6	28	50	45	4	5	5	**35**	**12**	**18**
Western Pacific	**15**	**3**	**6**	**25**	**14**	**17**	**11**	**18**	**17**	**7**	**25**	**21**	**28**	**5**	**10**	**0**	**0**	**0**	**3**	**12**	**10**	**10**	**22**	**20**	40	17	22
Cambodia	17	4	6	30	6	9	5	5	5	22	45	42	8	9	9	0	0	0	11	30	27	7	3	4	**47**	**9**	**15**
Lao PDR	25	4	8	16	1	4	6	4	5	17	12	13	3	1	1	0	0	0	25	71	63	8	6	7	**41**	**5**	**11**
Mongolia	31	8	20	44	25	35	1	3	2	1	5	3	11	12	12	0	0	0	4	34	18	9	14	11	**75**	**33**	**55**
Philippines	36	24	30	10	11	10	3	10	7	4	13	8	41	25	33	0	0	0	5	15	10	2	3	2	**45**	**34**	**40**
Vanuatu	7	2	3	17	16	16	18	22	21	8	26	23	40	5	11	0	0	0	0	3	3	11	26	24	**24**	**18**	**19**
Vietnam	16	2	5	61	28	36	4	18	15	2	5	5	5	1	2	0	0	0	0	18	14	12	28	24	**77**	**30**	**41**
Total	**17**	**14**	**15**	**34**	**30**	**32**	**3**	**5**	**5**	**2**	**9**	**7**	**28**	**16**	**20**	**1**	**1**	**1**	**6**	**15**	**12**	**8**	**10**	**9**	52	45	47

Table 7. Percent disposal of child's feces by developmental age of the child (n=376,644).

	Improved		Unimproved						**Overall Improved Disposal**
Developmental Age	Always use toilet/latrine	Put/rinsed into toilet/latrine	Put/rinsed into drain/ditch/ sink/gutter	Buried	Thrown in garbage/ Burned/ Disposable diapers	Washable diapers/Put in washing area/Rinse away	Thrown outside/Not disposed of	Other/Don't Know	
0-6 months	2.65	29.12	7.68	5.97	30.43	1.9	11.44	10.71	**31.77**
7-9 months	4.11	31.17	7.52	6.61	29.32	1.22	11.21	8.83	**35.28**
10-12 months	5.32	34.81	5.22	7.7	26.7	0.99	10.62	8.64	**40.13**
13-24 months	12.69	34.32	3.9	8.11	21.15	0.57	11.74	7.5	**47.01**
25-60 months	28.77	30.97	2.36	6.26	9.91	0.34	13.15	8.24	**59.74**

Table 8. Exploratory multivariate regression models for improved disposal of children's feces, OR (95% CI) (n=228,211).

	Model 1		Model 2	
Variable (Referent)	**OR (95% CI)**	**p>[t]**	**OR (95% CI)**	**p>[t]**
Sex of child (Male)	1.01 (0.91-1.11)	0.91	-	-
Access to an Improved Toilet/Latrine	52.90 (43.89-63.76)	0.00	52.84 (43.85-63.67)	0.00
Urban Residence	1.05 (0.92-1.20)	0.47	-	-
Wealth quintile (Poorest)*				
Poor	1.11 (0.92-1.34)	0.32	1.10 (0.91-1.34)	0.33
Middle	1.22 (0.99-1.51)	0.06	1.21 (0.98-1.49)	0.07
Rich	1.31 (1.06-1.61)	0.01	1.29 (1.05-1.58)	0.02
Richest	1.37 (1.09-1.72)	0.01	1.33 (1.07-1.67)	0.01
Religion (None/Atheist)*				
Traditional/Spiritualist	1.87 (1.18-2.96)	0.01	1.89 (1.19-2.99)	0.01
Judeo-Christian	1.01 (0.71-1.44)	0.96	1.02 (0.71-1.45)	0.93
Muslim	2.02 (1.38-2.96)	0.00	2.03 (1.39-2.98)	0.00
Buddhist	4.61 (3.01-7.05)	0.00	4.62 (3.02-7.06)	0.00
Hindu	1.69 (1.17-2.57)	0.01	1.69 (1.12-2.57)	0.01
Other religion	0.65 (0.33-1.30)	0.22	0.66 (0.33-1.31)	0.23
WHO region (Europe)*				
Africa	3.44 (2.70-4.40)	0.00	3.46 (2.72-4.42)	0.00
Eastern Mediterranean	7.56 (5.97-9.57)	0.00	7.62 (6.03-9.63)	0.00
Latin America and the Caribbean	0.53 (0.39-0.70)	0.00	0.53 (0.39-0.70)	0.00
Western Pacific	0.72 (0.51-0.99)	0.05	0.72 (0.52-1.01)	0.06
Southeast Asia	0.74 (0.53-1.04)	0.09	0.75 (0.54-1.06)	0.10
Developmental Age (0-6 months) *				
7-9 months	1.17 (0.93-1.46)	0.17	1.17 (0.93-1.46)	0.17
10-12 months	1.56 (1.24-1.95)	0.00	1.56 (1.24-1.95)	0.00
13-24 months	2.45 (2.08-2.88)	0.00	2.45 (2.08-2.88)	0.00
25-60 months	4.62 (3.86-5.53)	0.00	4.62 (3.86-5.53)	0.00
Maternal Education (None)				
Primary	1.22 (1.02-1.46)	0.03	1.22 (1.02-1.46)	0.03
Secondary/vocational	1.37 (1.14-1.65)	0.00	1.37 (1.14-1.64)	0.00
Higher	1.79 (1.40-2.30)	0.00	1.78 (1.39-2.27)	0.00
Goodness of fit (p>F)	**0.004**		**0.002**	

*Although categories of these predictor variables are not significant at a significance level of p<0.05, the variables as a whole are significant and so were retained in the model.

Figures

Figure 1. Percent prevalence of improved disposal of children's feces by country.

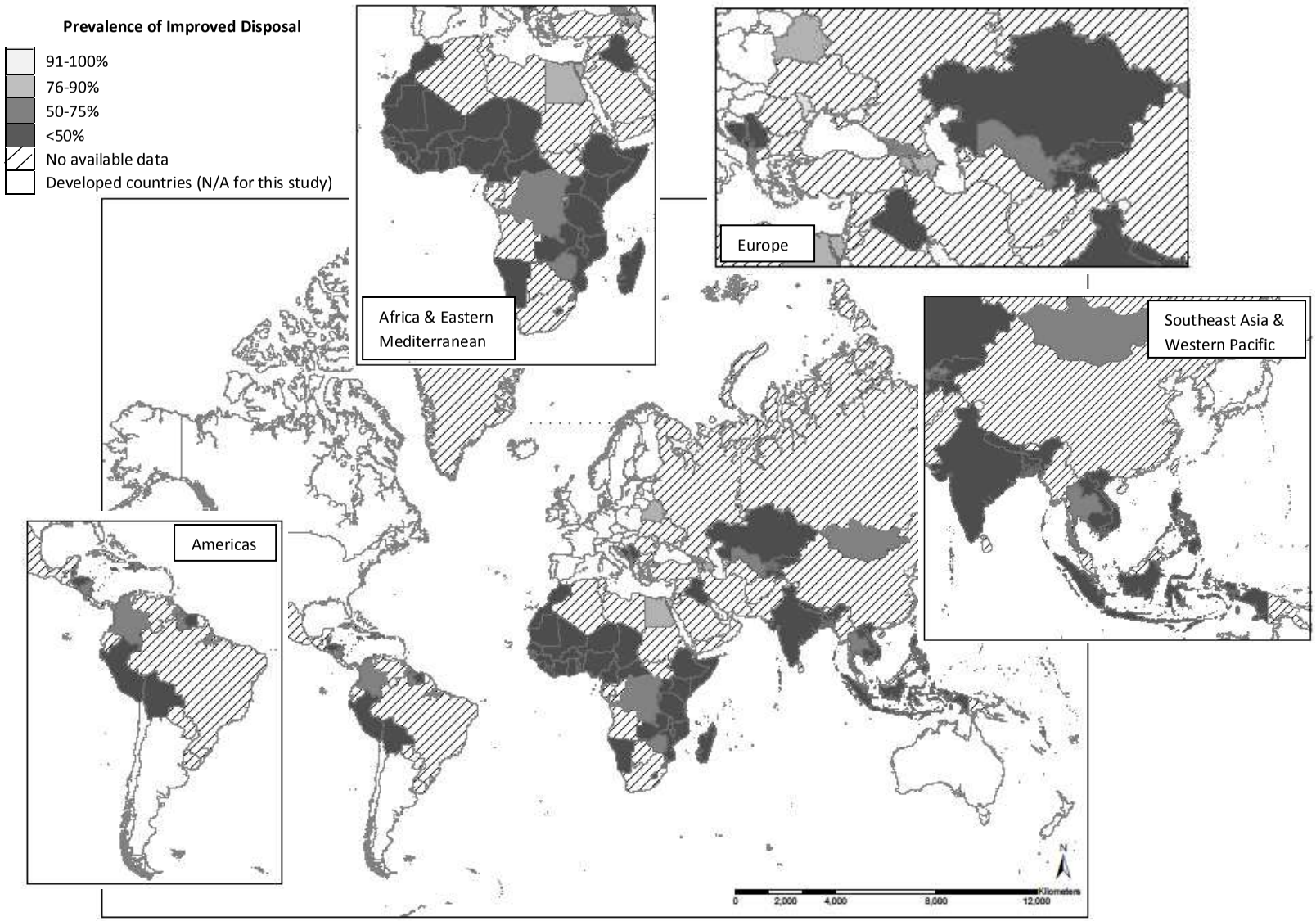


Figure 2. Percent improved disposal of child's feces by household wealth quintile for each world region (n=387,907). Population-weighted regional GNI in USD is shown above disposal statistics.

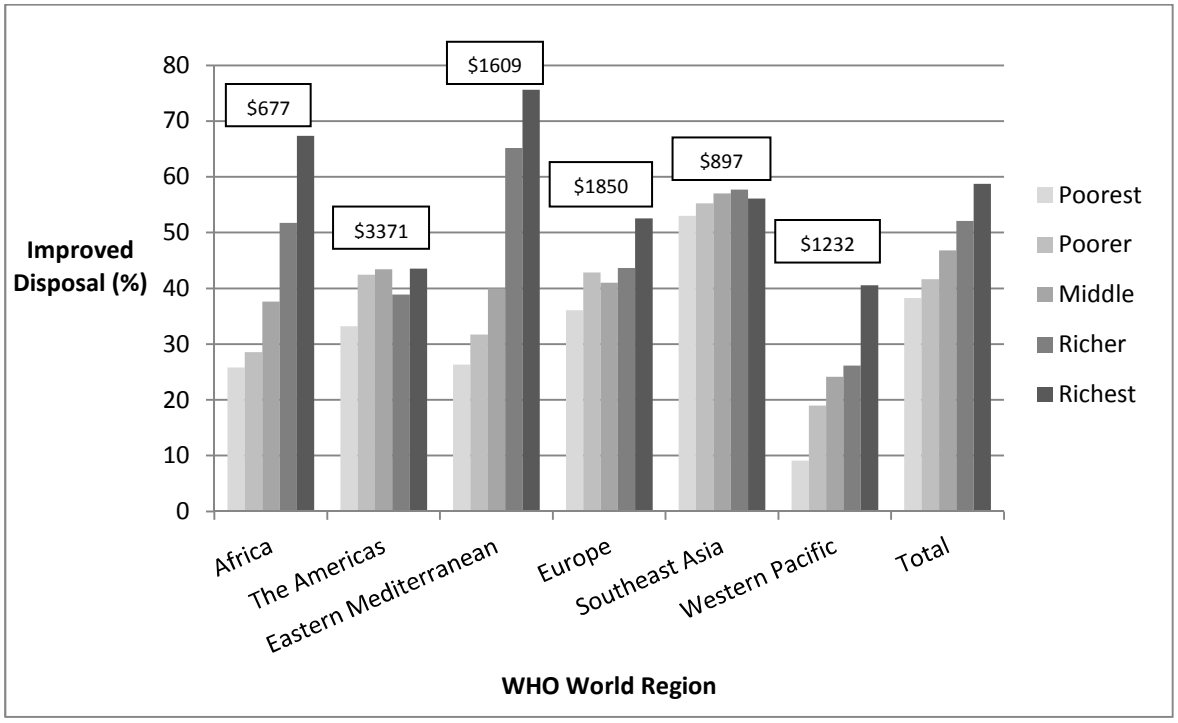
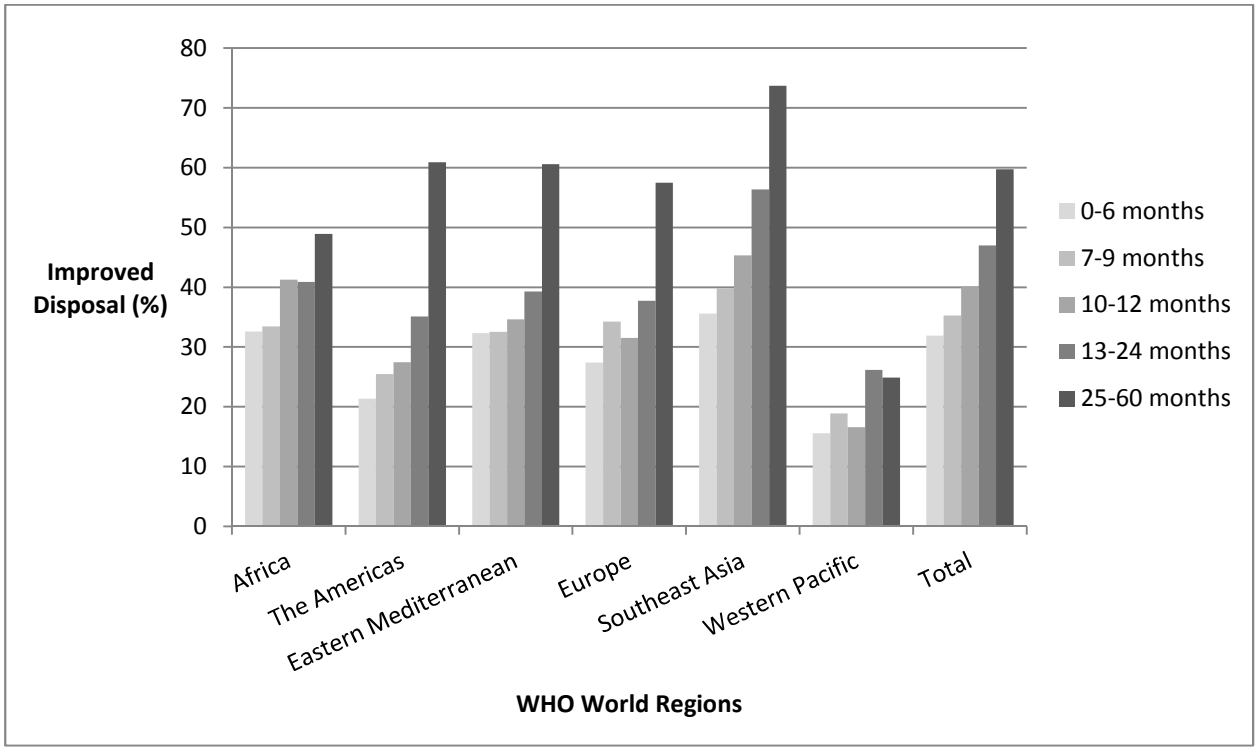


Figure 3. Percent improved disposal of child's feces by developmental age of child for each world region (n=376,644).



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