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Abstract	This chapter presents recent research in latrine use measurements—a challenging element of sanitation service delivery. The research used quantitative and qualitative methods to contribute to new understanding of sanitation practices and meanings in rural India. We estimated latrine usage behavior through ethnographic interviews and sensor monitoring, specifically the latest generation of infrared toilet sensors. Two hundred and fifty-eight rural households in West Bengal (WB) and Himachal Pradesh, India, participated in the study by allowing PLUMs to be installed in their houses for a minimum of 6 days. Six hundred interviews were taken in these households, and in others, where sensors had not been installed. Ethnographic and observational methods were used to capture the different defecation habits and their meanings in the two study sites. Those data framed the analysis of the PLUM raw data for each location. PLUMs provided reliable, quantitative verification. Interviews elicited unique information and proved essential to understanding and maximizing the PLUM data set. The combined methodological approach produced key findings that latrines in rural WB were used only for defecation, and that low cost, pit latrines were being used sustainably in both study areas.

Keywords (separated by “ - ”)	Behavior change - Ethnography - India - Policy - Sanitation - Sensor monitoring

Chapter 13
Combining Sensors and Ethnography to Evaluate Latrine Use in India

Kathleen O'Reilly, Elizabeth Louis, Evan A. Thomas, and Antara Sinha

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13.1 Introduction

Increased latrine coverage has generally been the primary metric used to evaluate the impact of sanitation interventions in Bangladesh, India and elsewhere. In this regard, many programs have been successful. In one recent study, the intervention increased latrine coverage from 9 to 63 %, compared to a control group that increased from 8 to 12 %. However, the intended health impact was not subsequently realized. The prevalence of diarrhea in the intervention was 8.8 %, while the control group was 9.1 %, and mortality estimates were roughly similar as well (Clasen et al. 2014). This study suggested that latrine coverage was an insufficient metric, and that utilization of latrines is a more appropriate measure that is more closely aligned with health impacts.

Measuring use has historically been challenging. Numerous studies have shown a respondent bias, and structured observations, previously the gold standard approach, have now been demonstrated to be highly reactive. Therefore, improved, objective utilization methods are required. For example, data from a recent study conducted in Bangladesh demonstrated an upward bias in the difference between respondent-reported 'likely defecation' events and sensor instrument-recorded events relative to the average between the measures. These findings indicate an over-estimation of respondent-reported latrine utilization relative to instrument-recorded use. The average difference between respondent-reported and instrument-recorded events indicated an average of 11 excess respondent-reported events (95 % CI 53, -30). The concordance correlation coefficient (CCC) between respondent-reported and instrument-recorded utilization was 29 (95 % BCa CI 0.15, 0.43). This CCC indicated that respondent-reported 'likely defecation' events were only weakly correlated with instrument-recorded 'likely defecation' events. While there was a moderately high level of accuracy in the measures, the data were imprecise, as indicated by the broad spread of observations from the reduced major axis (Delea et al. 2015).

This exaggerated self-reported use raises serious questions about the accuracy of self-reported data often used for policy and programmatic decision-making. Critically, the metrics used by program funders and implementers must at minimum narrow the gap between inputs and impact. While use may not be a sufficient measure, it is clear that measuring coverage alone is insufficient. Electronic sensors may improve the objectivity of latrine use measurement, and enable more continuous monitoring. Sanitation studies have yet to resolve the question of how to measure toilet usage with accuracy and sensitivity, leaving open the question of whether current policy is effective (Cousens et al. 1996; Rodgers et al. 2007). As Thomas et al. (2013) recommended, more rigorous, innovative evaluations are needed to guide best practices and improve future programs. Without clarity on why sanitation is adopted in some places and not others, programming and policy development is made more difficult.

This paper intends to fill a gap in studies of rural sanitation by demonstrating the combined strengths of quantitative and qualitative methods. We used Passive Latrine Use Monitors (PLUMs; instrumented monitoring) to quantify toilet usage. We used ethnography to learn about users, their beliefs about sanitation, and how beliefs influenced practices (Rheinlander et al. 2010). Ethnography is judged methodologically by different criteria than quantitative methods (Small 2009), leading to some tensions in research design. However, combining the two methods enabled insights into everyday sanitation behavior, including key findings that: (1) toilets across the WHO/UNICEF Joint Monitoring Program for Water Supply and Sanitation (JMP) spectrum were sustainably used in both study areas; and (2) beliefs of impurity limited toilet use to defecation in West Bengal. We discuss these findings below, after a brief review of the literature.

13.2 Understanding and Monitoring Sanitation Adoption

Studies deploying ethnographic methods, especially in-depth interviews, have uncovered a number of non-health related reasons motivating toilet building, e.g., social prestige, protection of women family members, desire to be modern, desire to take advantage of something given with little opportunity cost to the family, and rising household incomes (Jenkins and Curtis 2005; Jenkins 2004; Srinivas 2002; O'Reilly and Louis 2014). Interviews and focused group discussions have illuminated geographic variations in meanings of waste and hygiene; local norms for gendered, age-relevant defecation practices; and socio-religious rules about waste disposal matter for sanitation uptake (Drangert and Nawab 2011; McFarlane 2008; O'Reilly 2010). As Rheinlander et al. (2010) argued, knowledge of communities' beliefs about defecation is critical, as practices derive from beliefs. Insights into beliefs, values and meanings may be learned by asking people about them, and by observing their practices as a reflection of their beliefs. We used ethnography to illuminate geographically-specific toilet use behaviors and beliefs behind them.

Researchers have tackled the problem of assessing toilet usage (Olsen et al. 2001; Montgomery et al. 2010), but as yet, no single observational solution manages to be accurate, sensitive and non-intrusive. Structured observation at peak times of toilet usage is intrusive and may alter users' behavior (Clasen et al. 2012; Ram et al. 2010). It is also time-consuming, costly, and therefore difficult to scale up, while only providing a limited snapshot of potentially biased behavior. Observational methods such as looking for fresh feces in the pit or in open defecation areas, presence of materials for anal cleansing, and/or a wet toilet floor are subjective, lack sensitivity and specificity, and may be impossible given the toilet technology (Clasen et al. 2012). Self-reporting is also problematic as individuals may over-report in an effort to please the data collector, and gender of the evaluator has been shown to cause under-reporting (Manun'Ebo et al. 1997).

Cellular phone network-based monitoring technology has been field-tested to record usage and behavior change in WASH and other public health interventions, e.g., the provision of household water filters, hand washing stations, and cookstoves (Thomas et al. 2013). Effective use of remote monitoring is made possible by improved cellular networks, low cost of electronic components, and improved battery technology (Thomson et al. 2012; Thomas et al. 2013). The main argument for using electronically instrumented monitoring technologies is that they provide cost-effective, objective, accurate, regular, and continuous data thereby filling a critical gap in the ability to monitor health interventions effectively (Thomas et al. 2013; Clasen et al. 2012).

Below we discuss the study site and population selection rationale before moving into the specific methods guiding the quantitative and qualitative portions of the research. An analytical section follows, including a description of our iterative process, and discussion of findings. We conclude that, despite the challenges of integrating disparate methodological tools, combined methods offer new understandings of sanitation behavior in rural India.

13.3 Site Selection and Study Population

Our goal was to contribute new insights into effective sanitation by studying unique places where sanitation was adopted at rates of almost 100 % in parts of rural India. Therefore, the research was conducted in rural villages areas of West Bengal (WB) and Himachal Pradesh (HP)—two geographically and economically different states that have made some of the greatest improvements in sanitation coverage in the past 20 years (Table 13.1).

We chose Gram Panchayats (GPs; i.e., political subdivisions comprising multiple small villages) that won the Clean Village Award (NGP; a cash award for open defecation free status) in the past 3–5 years and that were well-known locally and extra-locally as areas of high toilet usage. Selected GPs were of mixed caste and class composition to enable a broad, socio-demographic cross-section of participants. Several individual household latrine (IHL) types were observed at each site; most were improved sanitation. Toilet cabins ranged from plastic sheeting to brick and mortar walls with slab roofs. Almost all toilets were built at a distance from the main dwelling. In HP, some households had attached (to the house) toilets in a room large enough for bathing (hereafter, toilet/bathroom).

13.4 Quantitative Methods – Sensor monitoring

The technology employed in this study, Portland State University Passive Latrine Use Monitors (PLUMs), is described in technical detail in other publications, including Thomas et al. 2013. A simple infrared motion detector was used, identical

Table 13.1 Percentage of households without toilets in WB and HP – 1992/1993–2011

State	1992/1993	2001	2011
WB	59.6	56.3	41.2
HP	87.4	66.6	30.9
All India			54.3

to the commercial sensor selected in the Clasen et al. (2012) study. A comparator circuit was linked with the motion detector, and recorded each detected motion. One or more times per day, the comparator board relayed logged data events to the internet via GSM cellular technology. A handheld cell phone was used to determine if a signal could be located at the household, indicating the PLUM could communicate with the cell phone tower. If a strong signal was unavailable, it was switched into "local" logging mode on a micro-SD card and data was manually uploaded after removal from the toilet. PLUMs were fastened with zip ties (aka cable ties) within 5 ft of the toilet pan.

Forty PLUMs were utilized and were rotated between 291 households. In related studies, PLUMs suggested low behavioral reactivity after the first several days, so PLUMs were installed for 7–10 days to capture behavior for at least 6 days of data. PLUM installations occurred based on willingness to accept, and the presence of the household head. The PLUM installation sample illustrates one of the tensions arising from combining qualitative and quantitative methods: we do not claim a representative, random, or unbiased sample of households with PLUMs installed. Ethical obligations prevented the installation of PLUMs in households that refused them, which may have biased the data if refusal was due to toilet non-use. However, respondents were forthcoming in interviews about household members who went for open defecation whether they accepted PLUMs or not, nor was there a noticeable difference in PLUM acceptance across the study sites once we routinized our installation strategy. Informants' honesty also enabled us to better calculate the number of toilet users per household, refining PLUM data analysis. It is possible that interviewing before installation and the initial presence of the PLUM may have influenced household behavior. This potential reactivity has not been rigorously characterized to date.

The PLUM online software system contains several data correction, reduction and analysis routines. Subsequently, an R code is run to interpret the raw data and generate estimates of 'usage events'. The algorithm employed is largely based on Clasen et al. 2012, with some adjustments to account for technological differences between the sensors.

13.5 Qualitative Methods – Ethnography

We conducted over 600 in-depth semi-structured interviews with household members and key informants. The rationale for 600 interviews was to insure saturation (i.e., interviews produced no new data) and to interview across socio-economic characteristics and toilet type in each of the four GPs. We only interviewed in households where toilets were present and householders reported that they were being used. Respondents were adults, but not necessarily the household head. Household interviews covered: family composition, general usage, household toilet building history, and their understandings of human waste, sanitation, and hygiene. We did not ask respondents about their usage habits because we found early in the field period that respondents grew suspicious that we were 'checking' (i.e., official record keeping that may have negative repercussions for households) on toilet usage. Households were reassured that we were not 'checking,' but seeking to confirm our information that these were GPs where most households used their toilets. This strategy of reassuring interviewees highlights again the tensions between qualitative and quantitative methods—in order to allay subjects' fears, the research team informed subjects of the research goals in ways that may have biased their answers. The size of the interview sample may have compensated for bias, but ethnography also depends on the research team's ability to sense if informants lie or prevaricate. We omitted such interviews from our analysis. Once PLUMs were installed the time and date of installation was logged in a field notebook. At the final study site, on the day the PLUM was removed, interviewees were questioned about their toilet use habits of the day before. It was only after extensive fieldwork that we felt confident that (a) we could install PLUMs even if we asked about individual usage and (b) that asking would not bias PLUM data beyond expected reactivity.

The research team lived in the GPs while the research was conducted. This facilitated unstructured participant observation events in the form of multiple, informal visits to households to observe household sanitation practices and to triangulate interviews and PLUM data. We also assembled participant households' photographic data sets of toilet type, cabin construction, PLUM installation, and path to toilet from house. Fieldnotes on unstructured participant observation and interview transcripts were coded by recurring themes and analyzed for significant patterns. Household socioeconomic data were entered into a spreadsheet. The photographic record was organized by household and referred back to during the iterative analytical process described in the discussion section. Key informant interviews were used to create a history of sanitation interventions for each study site. After the first round of PLUM data analysis, the research team returned to the field during September 2013 for results' dissemination with stakeholders. We now turn to results and a discussion of findings from each method and as part of an iterative process.

13.6 Results

13.6.1 Qualitative Results

In brief, successful sanitation depended on three factors: political will, political ecology, and proximate social pressure. Each forms one leg of the "toilet tripod," united by political economy—the 'seat' of the toilet tripod. Political will encompassed long-term, multi-scalar government and NGO efforts to facilitate toilet building and usage. Political ecology included the complex human-environment relationships that changed over time to support toilet adoption. Proximate social pressure comprised the informal encounters that influenced neighbors and family members to build and use toilets. All four study sites had different economies, types of government intervention, NGO involvement, and environmental resources. Nevertheless, the framework of the toilet tripod comprehended the success of sanitation in each location. Below we address specific behavior, values and patterns that emerged through combining ethnography and sensor monitoring (O'Reilly and Louis 2014).

13.6.2 Quantitative Results

Of the 291 household data sets, a total of 258 households' data were included in the analysis. These households had PLUM readings for at least 6 days. 33 households were excluded for having less than 6 days of data, usually due to PLUM failure, and occasionally because households covered or removed PLUMs. A specialized R code for this study parsed interpreted sensor data for each household deployment across the four sites. For each sensor, outliers were removed based on 1.5 times the interquartile range for that data set, a standard outlier removal approach (Weinberg and Abramowitz 2002). For per person usage calculations, the algorithm relied on recorded household toilet user data. Children too young to use a toilet were not counted, as their feces were not generally disposed of in IHLs (O'Reilly and Louis 2014).

The data sets at each site were not normally distributed, likely due to clustered low-end recorded behavior. Therefore, groups were compared using the Wilcox ranked sum test that is less sensitive to non-normal data than the t-test. The Wilcox ranked sum difference may be interpreted as a comparable mean difference value as often presented in a t-test. Figure 13.1 and Table 13.2 show the mean per capita usage events at each of the four sites.

According to Clasen et al. (2012), a 3 min separation between usage events was arbitrarily chosen for the algorithm. We repeated this 3 min separation between usage events. If separate usage events occurred within less than 3 min of each other, the algorithm would analyze them as one usage event. Thus, underreporting during high traffic times may occur with the current analytical algorithm.

Across all four study sites, usage frequency per capita per day averaged 1.51, which is in keeping with norms for Western and non-Western populations (Palit et al. 2012). There was a slightly significant difference between WB1 (1.14) and WB2 (1.46), of about 0.245 uses per person per day. Between the two states, there was slight significance to WB (1.29) and HP (1.71) of about 0.34 uses per person per day. No statistically significant differences in per capita usage events by study site were recorded with the exception of the two sites within HP. The influence of the high per-capita toilet use in HP1 likely influenced both the state differences *and* the intra-HP differences.

13.7 Discussion

In this section, we discuss the insights on mean per capita usage, toilet type, and time of day of usage gained by using combined quantitative and qualitative methods.

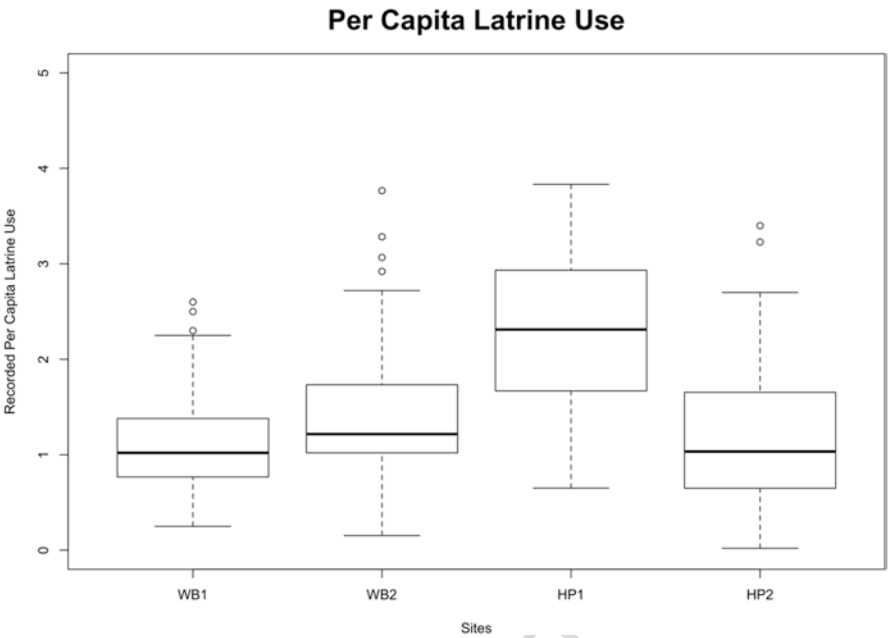

Fig. 13.1 Per capita latrine use per day by GP

Table 13.2 Mean per capita per day latrine use

GP	Recorded per capita use	Wilcox ranked sum difference
West Bengal	1.29	
WB1	1.14	0.25
WB2	1.46	
Himachal Pradesh	1.71	
HP1	2.27	1.13
HP2	1.18	
Overall average	1.51	

13.7.1 Mean Per Capita Usage

Initially, the data analysis suggested that WB2 per capita toilet usage was lower than WB1, but interviews led us to expect that WB2 toilet use should have been the same or higher. In WB2 the majority of households owned toilets for more than 10 years, while in WB1 the majority owned toilets for less than 10 years (see Fig. 13.2). Length of time of sustained intervention and toilet ownership meant that WB2 informants were more likely than those in WB1 to speak in terms of having a 'toilet habit.' We recalculated PLUM installations using fractions of days (as recorded in fieldnotes) to get a more accurate per capita reading than the initial calculation that

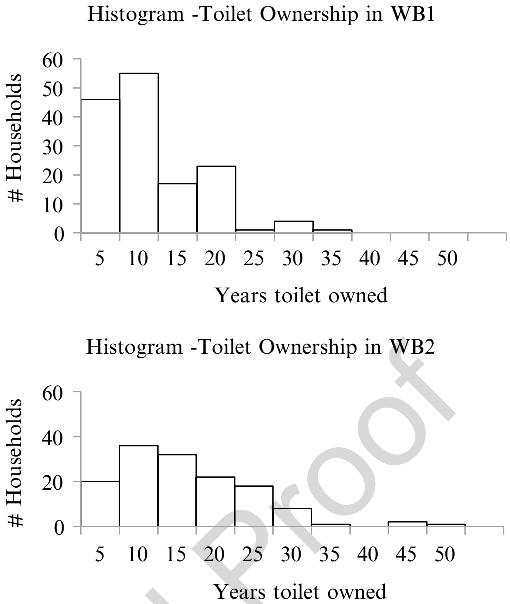

Fig. 13.2 Histogram of toilet ownership in WB

used whole numbers for days reported. With this adjustment, WB2 (1.46) per capita use was higher than WB1 (1.14)—a slight significant difference. Ethnography alerted us to subtleties in reported toilet usage within NGP villages, and the discrepancy between partial days and full days of installation for PLUM analysis.

The differences in mean per capita toilet usage between WB and HP were expected. In WB1 and WB2, toilets were only used for defecation and bathing after defecation. This was due to the ritual impurity of the toilet cabin, we were told, necessitating bathing and changing one's clothing after defecating inside the cabin. Urination took place outside in the family compound or nearby jungle. Family compounds nearly always had a pond, so most members bathed in the pond. For modesty's sake, some women would wash in the cabin itself. As this woman explained her reason for needing a taller, brick and mortar toilet cabin, "*My daughter cannot stand in the cabin and change her clothes now. People passing by will watch. Is this not a problem? She has to come with wet clothes inside the house.*" Previous research has noted the ways in which beliefs about impurity/disgust around feces in the South Asian context (Srinivas 2002). Our ethnography brings to light a geographically-specific, toilet-using behavior related to ritual impurity beliefs.

Using PLUM data to calculate 'total time in toilet,' HP recorded about 32 % more movement in a toilet on average than WB. This was consistent with our ethnographic research indicating that HP households use their toilet/bathrooms for other hygiene activities besides defecation. HP respondents did not report that toilet cabins were ritually impure. Instead, IHLs in both HP study sites were often built to take advantage of the single tap in family compounds, serving several purposes: toilet; bathroom; water filling station; and laundry. These larger rooms with easy access to water meant there was more traffic in and out of them, especially by women, for whom gender norms required them to do these tasks.

The differences in mean per capita usage between HP1 and HP2 were also expected. In HP1, 65 % of PLUM-accepting households had toilet/bathroom combinations. In HP2, only 23 % had toilet/bathroom combinations. When comparing usage events between toilet and toilet/bathrooms across all sites there was a significant difference (p value .00003) indicating that toilet type is important data when using PLUM technology. The difference in per capita toilet use based on toilet type indicated 0.6 fewer uses if the toilet type was 'toilet only'—validating our observations that participants spent less time in these toilet types.

We asked household members in HP1 (our last study site) on the day we removed their PLUM to recall the number of times they defecated the previous day. There was a significant difference between the sensor recorded use average of 2.27 uses per person per day, and the reported use of 1.38 for a Wilcox ranked sum mean difference of 0.85 uses. One sensor monitoring weakness is that it does not detect if the IHL is being used for the deposition of human feces. Ethnography supplied an explanation for the difference: HP1 had more toilet/bathrooms and women reported accessing stored water in the toilet/bathroom space multiple times daily. The photographic record verified that the PLUMs were installed close to toilets, but they were likely capturing non-usage events as well as usage events.

13.7.2 Toilet Type

We disaggregated PLUM data based on toilet quality in WB: (1) cement pan in cement slab; or (2) porcelain pan in cement slab using the photographic data set and interview data to determine whether lower cost toilets were used less than higher cost ones. Differences in toilet quality showed no significant difference in per capita usage in WB, where most low cost toilets were located across the four study areas. This result agreed with WB interviews; householders reported that low cost toilets were acceptable and in use. Using Barnard et al.'s (2013) criteria for 'functional latrine' (i.e., walls over 1.5 m; door; unbroken, unblocked pan; and functioning connection to pit (if any)), in WB, latrines were functional, even if those latrines had only plastic sheeting for walls and a door, no roof, and a cement pan. If feces could be flushed, these low cost latrines were used; this was verified by PLUM data. This key finding indicates that basic, low cost models that function are acceptable in communities where toilet use is the social norm.

In West Bengal, a GP had to achieve 90 % toilet coverage to win an NGP award. At the time that the NGP toilet drive started in the two study areas, a majority of the households could not afford to build toilets on their own. Availability of low cost cement slabs (250 INR, approximately US$5), free or subsidized pit digging, and walls of plastic sheeting supported widespread, rapid building. In WB2, 50–55 % of the households were still using cement pans. In WB1, 40–45 % had cement pans or largely subsidized porcelain pans.

There was a clear trajectory of toilet habituation in the region as one elderly man in WB2 explained, "*Earlier people used to go for open defecation OD, then khata paikhana* (pit latrine, wooden slab) *was built, then plate* (pour flush to pit latrine, cement pan) *came into existence. Now as people are making money, they are building sanitary paikhana* (pour flush to pit latrine, porcelain pan)" As his brief history relates, a significant factor in getting people to stop defecating in the open was enabling them to build pour flush latrines, even those considered temporary, as cement pan latrines were. 'Plate' latrines were a great improvement over pit latrines with wooden slabs or having to practice open defecation. Low cost latrines were less than ideal because they needed periodic reconstruction of toilet cabins, high water tables meant shallow pits (usually 3–4 rings deep) needed to be re-dug, composted, or emptied, but they did not stink, as drop pit toilets did (see also (Barnard et al. 2013; Kvarnstroem et al. 2011)). Families in WB that could afford better toilets built with porcelain pans and brick walls built them, but for those who could not, '*plate'* latrines were acceptable and were still in use decades after being built.

Pit latrines in HP were larger and had the advantage of well-draining soils and a low water table; few families had ever emptied their pits. Most latrines had porcelain pans with a cement slabs, and many families spent disposable income on tanks with piped water supply, decorative tiles, and occasionally, toilet seats.

13.7.3 Peak Usage Times and Occupation

PLUM data verified our ethnographic finding that most household members primarily defecated in the morning (Fig. 13.3). Data also showed a smaller but distinct peak in the evening hours. Sensors do not detect who is using the unit, a problem for per capita usage figures if household numbers fluctuate daily, but the reason households consented to installation. Using ethnography to establish family members' out-of-house routines can narrow the range of individual users throughout the day. For example, men in WB who worked as cycle-cab drivers left their houses early in the mornings and reported defecating elsewhere. Eliminating members of certain occupations as toilet users during peak hours could give more accurate mean per capita usage figures. Information on peak usage times can also assist with: knowing when to station structured observation in future studies verifying toilet usage (e.g., HP peak times were later in the morning than WB peak times (Clasen et al. 2012); capturing off-peak, high usage times (e.g., incidences of diarrhea); and informing shared toilet policy by providing information on peak time, mean per capita per hour figures (i.e., 'turnover rates').

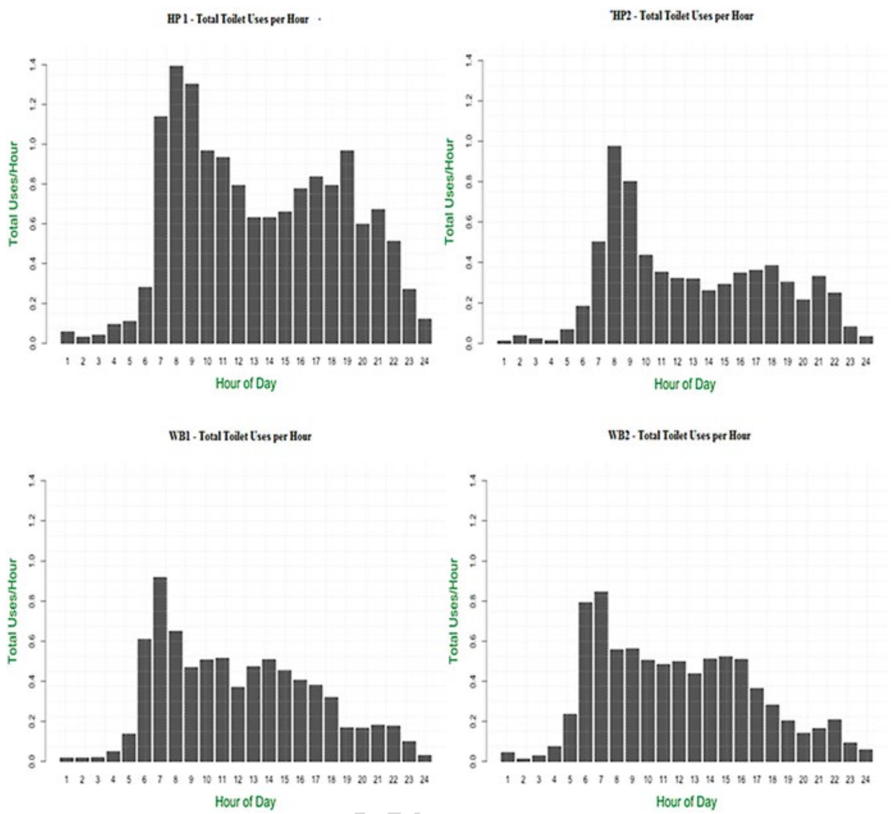

Fig. 13.3 Time of day usage for all GPs

13.8 Conclusions

A failure to understand sanitation behavior can result in policies that do not meet the needs of target populations. Given high rates of open defecation in India and recently revitalized efforts to end the practice, more research is needed that measures toilet usage and explains the reasons for use and non-use. We purposefully selected unique cases to study successful sanitation uptake, intending our findings to provide new insights, guide further research, and inform interventions. We used ethnography to 'get at' the everyday lived context of study populations' toilet practices by asking people about their values, meanings, and routines. PLUMs counted 'practices,' validated interviewees' reporting, and highlighted the significance of specific behaviors.

Our mixed method approach facilitated the general findings that political will, political ecology, and social pressure supported the building and sustained usage of toilets in the study sites. Specifically, subsidies were necessary for poor households in WB to build, but these subsidized, low cost toilets were still in use decades after they were built. Contrary to findings that Indians believe latrines are expensive (Coffey et al. 2014), or that pit latrines are not sustainable (Kvarnstroem et al. 2011), low cost, improved sanitation was used sustainably. We attribute their sustainability to local governments and NGOs in WB that invested in educating families how to manage pit latrines after they filled. As Barnard et al. (2013) also found, length of time of ownership mattered for toilet use; users spoke of developing a ‘toilet habit’ that both supported, and was supported by, social norms in the study areas.

PLUM analysis brought to light our finding that in rural WB toilets were used only for defecation. Due to our immersion in WB, using toilets only for defecating became normalized. In seeking to explain the differences in mean per capita usage based on PLUM results, we re-discovered WB beliefs of pollution that limited toilet use to defecation. Without the ethnography we could not have explained the PLUM results for WB; without the PLUMs, defecation-only toilet use would have been overlooked. An understanding that a toilet cabin is a polluting space presents new challenges for solving problems such as the disposal of child feces (Jenkins et al. 2014) or needed privacy for urination. Currently, PLUMs detect motion in and out of the toilet cabin without information on what occurred inside. Rural WB also presents itself as a place where the PLUM algorithm for ‘usage events’ might be further refined to assess ‘defecation events’ since toilets are used only for defecation. Other instruments including audio signal analysis or pressure pads placed near the toilet could also be field tested in WB as further improvement to PLUMs.

As in other studies, we found that not all family members regularly used toilets (Coffey et al. 2014; Jenkins et al. 2014) but interview data can enable refinement of PLUM data analysis by collecting information on the age and occupation of non-users. This serves the purpose of refining mean per capita usage, and thereby letting us know if the toilet is being used, by how many, and at what time. Standard large-scale survey methods could provide some of the same data (Barnard et al. 2013; Jenkins et al. 2014) and be verified by sensor monitoring, but without knowledge of norms and meanings, solutions to problems of non-usage due to occupation and age remain out of reach.

Ethnography relies on trust between the research team and the study community, not just individual interviewees. In small villages in WB and HP occupied by extended families, a misstep could have ended our research at those sites. The question of trust when using combined methodology raises the question as to whether people would be willing to install if they did not live in NGP villages? As stated above, we learned early on that PLUM installations were possible when households were informed that we chose their GP because it was an NGP village—because we knew their toilets were in use. Given the difficulty of installation in places of successful sanitation, installation in locations where populations were informed that they should use toilets but did not, would likely have low PLUM acceptance and could undermine the trust necessary for a rich ethnography.

Ethnography is seldom undertaken as it requires extended field periods and linguistic and cultural fluency, but its strengths lie in discovering new practices, and the surprising, subtle motivations for behaviors. Such discoveries are critical in their own right, but they also can inform other assessment tools. Findings can only be scaled up with caution, because 'scaling up' requires removing norms and meanings from the geographic context where they arose—in this case, tantamount to ignoring the very multi-scalar and intersecting factors (e.g., governance, changing environmental conditions, and processes of social norm development) that produced the conditions of successful sanitation. Similarly, PLUMs are not appropriate for wide-scale measurement of toilet usage in India, given the diversity of behaviors and beliefs across small geographic areas. Nevertheless, the findings from our combined methodology indicate that ethnography and sensor monitoring are important tools in the search for methods to assess toilet usage and behavior.

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