Area, Village, and Household Response to Arsenic Testing and Labeling of Tubewells in Araihazar, Bangladesh

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Abstract

Two years after the Bangladesh Arsenic Mitigation and Water Supply Project (BAMWSP) tested and labeled private tubewells for arsenic concentration (painted green if at or below the country standard of 50 ug/l or red if above), surveys of some 4,000 wells show that less than one-third of unsafe well owners in a 100-km^2 area of Araihazar have switched to an alternate well. In contrast, previous surveys of some 6,000 wells show that two-thirds of unsafe well owners had switched following testing and labeling by BAMWSP and Columbia University. This 25-km^2 area also received 50 low arsenic community wells prior to surveys and has been studied and surveyed by Columbia University earth, health, and social scientists since 2000. As the primary difference between mitigation efforts in these two socially and geographically similar locations, additional academic presence (with safe well installations and regular reminders of arsenic hazards) seems to have positively influenced switching behavior. Yet when switching behavior is examined on a village level, other factors clearly play a role in the success or failure of testing and labeling programs. Easily measured physical factors, such as the village proportion of unsafe wells or the distance to the nearest safe well, are boundary conditions that limit or encourage switching behavior. Yet less predictable factors, like the presence of an "arsenic activist" or social barriers to switching to the nearest safe well, can help overcome physical limitations or work against favorable ones. A comparison of distance to chosen well and the nearest safe well at the household level provides evidence that these social barriers exist and play a significant role in preventing a switch to the closest safe well.

1. Introduction

The Arsenic Crisis

Naturally occurring groundwater arsenic in Bangladesh is threatening the country's public health as its people greatly depend on well water for drinking and cooking. Bangladesh once depended on surface water, but switched to groundwater sources in the 1970's to reduce the incidence of water-borne bacterial diseases. The country is now estimated to have more than 10 million shallow tube wells, with up to 90% of their 140 million inhabitants preferring well water. Approximately one-third of the country is highly impacted by arsenic, possessing wells with concentrations greater than the country limit of 50 micrograms/liter (ug/l) (BGS and DPHE, 2001). As a result, health experts estimate that 35 million of Bangladesh's population is at increased risk for cancer, cardiovascular, neurologic, and other diseases due to their chronic exposure to arsenic (UN Foundation, 1999).

Arsenic mitigation strategies in Bangladesh have run the gamut over the last decade – from home filtration methods to water treatment facilities (WHO, 2000). Yet the quickest and most cost effective solutions over the short-term need to provide households with clean water (or specific information on where to find clean water) within the existing system of tubewells. The purpose of this project is to examine household behavioral responses to a countrywide tubewell testing and labeling program by the World Bank sponsored Bangladesh Arsenic Mitigation Water Supply Project.

Tubewell Testing and Labeling

Arsenic is colorless and odorless and therefore impossible to detect without a chemical test. As a result, communities have been greatly dependent on government and international agencies for expensive testing services to determine the status of their water. Since the first discovery of groundwater arsenic in 1993, government and international agencies have worked to test wells and inform households about their water status with hope that safe wells could be shared by many. The first effort involved the field-testing of 51,000 tube wells by UNICEF and the Bangladesh Department of Public Health and Engineering (BGS and DPHE, 2001). The largest testing and labeling project to date, however, is the World Bank sponsored Bangladesh Arsenic Mitigation Water Supply Project or BAMWSP (Rahman, 2002).

As of 2004, BAMWSP had field-tested about half the country's 10 million wells in many of the country's 86,000 villages. Following an onsite arsenic test, BAMWSP workers painted the spout of each tube well red if over the 50-ug/l-country standard, or green if under this concentration (UN Foundation, 1999; BAMWSP, 2005). Because of the large number of wells sampled for this project, BAMWSP could not provide follow-up to villages after testing. Also, BAMWSP was not tasked to determine the impact of the project on household knowledge of well status and the act of well switching.

However, as the largest project of its kind in Bangladesh, it is critical to evaluate this countrywide program to determine the willingness and ability of households to switch to a safe water source when presented with well-specific arsenic information.

Household well switching behavior has actually been documented following testing and labeling by BAMWSP and Columbia University within a 25 square kilometer area of Araihazar upazila. In addition to well testing, Columbia health, earth, and social scientists have worked in this area since January 2000, monitoring the extent of groundwater arsenic, testing the development impacts of arsenic on mothers and children, presenting an arsenic information campaign, and surveying households to determine responses to mitigation (van Geen et al, 2003a).

Surveys from the Columbia study area show that nearly two-thirds of unsafe well owners switched their water source in response to well testing and labeling (Opar et al, 2004; Madajewicz et al, 2003). Although this proportion of well switching indicates a positive response to BAMWSP and Columbia well labeling, it is not clear to what extent this relatively high proportion reflects the reinforcement provided by the continuous presence of Columbia field workers.

Araihazar upazila therefore provides a unique location for studying the impact of a low presence testing and labeling program like BAMWSP. The upazila possesses several villages where BAMWSP was the only provider of specific well information. Well switching behavior in these villages can then be compared to the Columbia University study area (with both BAMWSP and university information and presence) (**Figure 1a**).

It is essential to determine the singular impact of BAMWSP testing because this project may likely serve as a model for future mitigation, which is certainly necessary in the country's remaining unsurveyed villages. In contrast, it would not be cost-effective to repeat the entire Columbia program countrywide. It is also important to examine switching on a village and household level without academic presence to further understand variables that limit or promote switching behavior throughout the country.

2. Methods

Village Selection – BAMWSP Only

A total of 75 villages were selected within Araihazar, primarily east and north of Columbia University's original study area, and up to the banks of the Meghna River (**Figure 1a**). These villages only received well testing and labeling from BAMWSP and are referred to as 'BAMWSP Only' villages.

Not all villages within the 100-km^2 area were surveyed. The selection process for the 75 chosen villages was as follows:

Sixteen villages were originally selected for the response survey from a database of 30,000 well tests provided by BAMWSP. Eight of the villages were picked with a mixed distribution of 50% safe and unsafe wells; the remaining eight were characterized by a particularly high (80-100%) proportion of unsafe wells at the time of BAMWSP testing.

As additional funding became available, another 46 villages with medium to high proportions of unsafe wells were randomly selected from the BAMWSP dataset. The combined 62 villages are referred to as 'Outside CU' throughout the paper.

Thirteen villages were also selected outside of the Columbia University study area for a future children's health study within the School of Public Health. Household surveys for this research project were also utilized for the current study. These villages were chosen based on their roadway proximity to a clinic that is operated by the university. These 13 are referred to as 'Close to Clinic' villages (**Figure 1b**).

The subcategories for the 75 BAMWSP Only villages – Outside CU and Close to Clinic – were used when comparisons were made to villages within the Columbia University study area (for the sake of examining the influence of clinic and study area proximity on switching behavior).

Village Selection – Columbia Study Area

Thirty-four villages encompassing 6,000 wells were previously examined in a 2003 survey within the Columbia University study area or the 'CU Study Area' (**Figure 1a**). The 2003 survey covered all villages within this 25-km^2 area.

Sixteen village sections (**Figure 1b**) were selected from the 34 whole villages based on the following criteria to make them more comparable to the 75 BAMWSP Only villages:

- Whole villages that appeared in BAMWSP's Araihazar dataset were selected to ensure these villages had been tested by BAMWSP
- Of these 16 whole villages, wells greater than 200 meters from the nearest community well were selected to control for the positive effect community wells have on switching behavior (a 10% increase as noted in Opar, 2004).

It should be noted that whole villages and village sections do not include observed unknown wells at the time of the 2003 survey. These wells were present, but not included in the survey as it was performed based on wells that had been previously tested in 2000-2001. Wells missed in this prior survey or installed afterward were not included in the 2003 survey. In contrast the BAMWSP Only surveys included all wells.

Household Survey Methods

Surveys were conducted with Hewlett-Packard iPAQ Pocket PCs (Model h5500) fitted with NAVMAN Global Positioning Systems sleeves (Model 3450) that were previously deployed within Columbia's study area to create a Geographic Information System (GIS) (van Geen et al, 2003a; Opar et al, 2004). Global Positioning System (GPS) coordinates and survey responses were taken at every well using ESRI ArcPad 6.02.

The wife of the owner of each well, or a close female relative, was asked a standard set of questions by pairs of trained students from the Geology Department at the University of Dhaka (**Appendix A**). Women were preferentially surveyed, as they are the primary well users in Bangladesh. The survey included observations of the well's physical state, as well as questions on education, community involvement, knowledge of well status, and well usage. If a household had switched to a new well, the location of the well presently used by the household was also recorded. As in past surveys, the nature and purpose of the survey was explained to each respondent to obtain informed consent before questions were asked.

Data collected by the 3 pairs of students was transferred to a laptop computer each evening and compiled each week in Microsoft Excel. Spreadsheets were emailed to Columbia each week and corrections made prior to compiling all data. ESRI ArcView GIS 3.3 was used to calculate the distance between unsafe wells and the nearest safe or chosen well.

Well Testing and Arsenic Analysis

A small water sample was collected from each new or previously untested well, to achieve more complete knowledge of well status in a village and to provide for households. These samples were periodically shipped to Columbia where high-resolution inductively coupled plasma mass spectrometry (HR ICP-MS) was utilized for arsenic analysis (Cheng et al, 2004).

The resulting arsenic concentrations, which in approximately 90% of cases is expected to be consistent with the BAMWSP field test, will ultimately be communicated to individual households within 6 months of sampling. The households will be located with the help of the GIS stored on the PocketPC/GPS units; as in the past, individual wells will be unambiguously identified by numbered stainless steel tags attached to the base of each well during the initial interviews. Households still using unsafe wells when lab results are communicated will be encouraged to switch to neighboring safe wells.

3. Results

3.1 The Effect of Information -- A Snapshot of BAMWSP Only Villages

Condition of Painted Labels

Of 4372 surveyed wells in the 75 villages tested only by BAMWSP, surveyor observations showed that 76% had paint and 24% did not (**Figure 2a**).

A question on well status (**Appendix A**, #11) revealed that roughly 15% of the 1056 unknown well owners stated they knew their well status based on BAMWSP paint, 77% did not identify paint as the source of knowing well status, and 8% gave no response (comprising 4%, 19%, and 2% of all wells, respectively).

A question on well installation dates (**Appendix A**, #7) showed that 15% of all unpainted unknown wells were installed before BAMWSP (older than 24 months) and 85% were installed after BAMWSP (less than 24 months), comprising 3% and 16% of all wells, respectively.

Knowledge of Well Status

Of 4372 wells surveyed in villages only tested by BAMWSP, 77% of all owners claimed they knew the status of their well based on paint, whether currently visible or previously present (**Figure 2b**). Of the 3213 individuals that gave this response and had observable painted wells, 98% claimed a status that matched the surveyor's observation.

The remaining 23% of all owners included 19% that didn't know how they knew the status, less than 1% that said others had tested their well or told them the status, and 3% that gave no response.

Switching Response

In response to a question about well switching (**Appendix A**, #13), 29% of unsafe (or red-painted) well owners stated that they had switched to an alternate well prior to the household survey. Approximately 3% of owners with safe (or green-painted) wells and 15% with unknown wells (displaying no paint) stated that they had switched (**Figure 3a**).

Based on a question regarding the well installation date (**Appendix A**, #7), the frequency of switching from unsafe, safe, or unknown wells was determined over time. Most of the stated switching took place in the 2 years prior to the household surveys, as BAMWSP completed its testing and labeling in these areas (**Figure 3b**).

A question about motivations for switching (**Appendix A**, #13) revealed that among switchers from unsafe wells, 92% claimed to have switched because of arsenic and 7% switched for other reasons (1% gave no response). 53% of switchers from safe wells and 58% of switchers from unknowns stated that they acted because of arsenic (**Figure 3c**).

3.2 Response to BAMWSP by Area

BAMWSP Only villages were divided into Outside CU and Close to Clinic (**Figure 1b**). These areas were then compared to village sections in the original Columbia University study area with wells greater than 200 meters to a community well. Whole villages from the 'CU Study Area' were also included in the comparison.

The proportion of observed unsafe, safe, and unknown wells vary among the four areas, with the Outside CU possessing a larger percentage of unsafe. The average distance to the nearest safe well was greatest for the Outside CU villages (75m), however standard deviations overlapped for all (**Table 1**).

The Outside CU villages showed 27% switching by observed unsafe well owners. In contrast, the Close to Clinic villages had 46% switching by unsafe well owners. The CU Study Area village sections had 52% switching by unsafe well owners compared to the 62% found among the whole villages (with community wells).

Switching from observed safe wells increased in the same order, from Outside CU villages to whole CU Study Area villages, ranging from 2% to 15%. Switching from observed unknown wells was a bit higher than switching from safe wells for the Outside CU and Close to Clinic villages.

The above percentages were based on observed well status and were comparable to percentages based on owner-defined status. However, the percentages of switchers from stated unknown wells within the CU Study Area village sections and whole villages (76% and 81%) are higher than those from Outside CU and Close to Clinic (13% and 22%).

3.3 Response to BAMWSP by Village

Village Variation

The Outside CU, Close to Clinic, and CU Study Area sections comprised 91 villages. Switching by unsafe well owners varied greatly among them, from 0 to 100%, with some of the lowest percentages occurring within the floodplain of the Meghna River (**Figure 4**). The proportion of unsafe wells among all surveyed wells (all observable red wells among all labeled and unlabeled wells) ranged from 0.09 to 0.85. The distance to the nearest safe well varied from 3 to 241 meters (**Tables 2a-c**).

When percent switching was divided into ranges, half of the Outside CU villages showed switching behavior in the 0-20% range, and a third fell within the 20-40% range. Less than one-fifth showed switching in the 40-60 and 60-80% ranges and none fell within the 80-100%. In contrast, Close to Clinic villages fell within all ranges. The CU Study Area sections showed no switching in the 0-20% range, but were represented in all others, with the greatest percentage of villages in the 60-80% range (**Figure 5**).

Influence of Distance and Proportion of Wells on Switching

The relationship between the proportion of unsafe wells and the distance to the nearest safe well was examined (**Figure 6**) to help understand the influence of these variables on switching behavior (**Figure 7 and 8**). As the proportion of unsafe wells increased in a village the average distance to the nearest safe well generally increased. The distance stayed within 0-100 meters until a proportion of 0.45. Above this proportion, distances varied widely, from 29 to 241 meters.

For any village proportion of unsafe wells there was a wide range of switching (**Figure 7**). In most cases the switching within a CU Study Area village section fell above the switching within the Outside CU and Close to Clinic villages.

When the village average distance to nearest safe well was within 100 meters (**Figure 8**), village percent switching by unsafe well owners varied widely between 0 and 100% for all three proportion categories (low, medium, and high). For villages with an average distance greater than 100 meters, switching only ranged between 0-40%.

3.4 Response to BAMWSP by Household

The distance to a chosen well from an unsafe owner's original well was examined for all owners in Outside CU and Close to Clinic villages (that had accurate chosen well information). CU Study Area sections and villages are not included in this section, as data on distance to chosen wells had not been collected in these locations.

Two-thirds of unsafe well owners that switch (n=531) chose alternate wells within 50 meters of their original. Approximately 23% chose wells between 51 and 100 meters, 9% between 101 and 150, and less than 2% chose greater than 150 meters away (**Figure 9**).

When studied individually (n=531), 41% of switching unsafe owners chose a well that was also the nearest safe well. Approximately 38% chose a well further than the nearest safe and 21% chose closer (**Figure 10**, those that fall along the 1 to 1 line chose the nearest safe, while those above chose further and those below chose closer).

Distances to the nearest safe well were also examined for owners of unsafe wells that did not switch (**Figure 11**). More than 50% of non-switchers were within 50 meters from a safe well and less than 30% fell with 50-100 meters. The remaining non-switchers were more than 100 meters from a safe well.

Based on a question regarding interaction with health workers from BRAC, the largest NGO in the country, only 3% of all surveyed owners stated that they met with these workers through the year (**Appendix A**, #6). There was no difference in responses from switchers and non-switchers from unsafe wells (4 and 2%, respectively). These women live and work within villages, selling medicine and providing advice on health issues.

4. Interpretation

4.1 The Effect of Information -- A Snapshot of BAMWSP Only Villages

Condition of Painted Labels

Two years after BAMWSP tested and labeled wells within these villages, three-quarters of all surveyed wells still had observable paint (**Figure 2a**). Of wells without labels, most were new, and only small numbers had been missed by BAMWSP or had lost their paint.

These results indicate that:

- BAMWSP testing and labeling reached most wells within this surveyed area
- Paint is an effective, lasting label

- New wells installations are common (at least 16% of all surveyed wells)

Knowledge of Well Status

Most well owners acknowledged BAMWSP labels and used this information to determine their well's arsenic status (**Figure 2b**). Even owners that had lost paint claimed to remember their status. (We do not know if their assessments were accurate, as only completely unknown wells were sampled. However, some owners with lost paint presented surveyors with the arsenic concentration cards that BAMWSP had provided).

It is also important to note that nearly 20% of the population in these villages was not aware of their well's status, as many wells had been newly installed (and some missed).

In addition, BAMWSP was likely the only organization to test in these villages, as less than 1% of owners said they received testing or recommendations by others.

Switching Response

Some owners of unsafe, safe, and unknown wells had switched from their original well to an alternate well at the time of our surveys. The greatest percentage of switching occurred among the unsafe well owners (**Figure 3a**).

Based on survey responses, households were switching wells prior to BAMWSP testing and labeling (and prior to knowing well status). However, the majority of switching from all well types took place in the two years since BAMWSP (**Figure 3b**), indicating that testing and labeling had an impact and encouraged all well owners to seek safe wells.

Nearly all switchers from unsafe wells stated they were driven by arsenic reasons (**Figure 3c**). Therefore, BAMWSP encouraged existing awareness that may have come from government media campaigns or community gossip and influenced household behavior.

4.2 Response to BAMWSP by Area – The Effect of Presence

The lowest switching from unsafe wells in Araihazar (29%) occurred within BAMWSP Only villages that are far from the Columbia study area and clinic (based on road access). Villages tested only by BAMWSP that are near the clinic and major roadways connecting to the study area, showed greater switching (46%). Village sections that are far from safe community wells in the study area showed even more switching by unsafe well owners (52%). Whole villages in the study area have the highest switching at 62% (**Table 1**).

These results indicate that substantial switching requires reinforcement above and beyond specific information about well status. In the case of the original Columbia study area, reinforcement involved an information campaign, household social and medical surveys, regular well testing, and community well installation – amounting to a very strong presence over the course of four years.

Switching from unknown wells was also influenced by academic presence. The percent switching from stated unknown wells within the CU Study Area village sections and whole villages (76% and 81%) was much higher than in the Outside CU and Close to Clinic villages (13% and 22%). Regular reminders on the importance of testing and knowledge of well status by Columbia researchers and staff may be behind this increase.

It is important to note that the four comparison areas (**Table 1**) displayed differences in the proportion of unsafe and safe wells. The following section examines the extent to which availability of safe wells influences switching behavior.

4.3 Response to BAMWSP by Village – The Effect of Spatial Heterogeneity

Village switching by unsafe well owners varied significantly within all surveyed areas in Araihazar. However, unsafe well proportion does not appear to solely control switching, as there is not a strong correlation between these two variables (**Figure 7**). For any village proportion of unsafe wells, switching varies widely, although the lowest proportion villages do not show less than 20% switching and the highest proportion do not have greater than 80% switching. These results also indicate that various switching percentages from the four comparison areas (presented in Section 4.2) are not likely due to differences in the proportion of unsafe wells.

It is important to note that within a single proportion, percent switching is generally higher in the CU Study Area villages than the Outside CU or Close to Clinic villages. This strengthens the argument that intense presence or reinforcement in these villages increases switching, beyond any differences in unsafe well proportion.

There is also little correlation between the average distance to the nearest safe well and switching for a village, particularly within 100 meters from the original well (**Figure 8**). Above this distance, however, village switching is limited to 40% or below.

Physical factors such as the village proportion of unsafe wells and the average distance to the nearest safe have a slight correlation. As the proportion increases, the average distance generally increases. Below 0.45, the distance remains within 100 meters; above this proportion, distances vary widely (**Figure 6**).

Although these physical factors do not specifically define switching behavior, they do act as boundary conditions that limit or encourage the behavior. Knowledge of these factors can help target communities that have much lower switching rates, especially those with an average distance to nearest safe above 100 meters, and village proportions of unsafe wells above 0.45.

Beyond the physical factors measured in this survey, geographical factors, such as location in a floodplain, should also be examined. A crude examination of this factor, based on proximity to the Meghna River (**Figure 4**), shows that proneness to flooding could potentially limit well switching within a village.

4.4 Response to BAMWSP by Household – The Effect of Social Constraints

Unlike previous surveys, recent work in BAMWSP Only villages provides data on the actual distances traveled by switching owners of unsafe wells. The majority of these owners chose wells within 50 meters from the original, indicating that distance is important (**Figure 9**).

However, only 41% of switchers from unsafe chose the nearest safe well. Approximately 38% traveled further than the closest safe well, primarily to safe wells. This implies that finding a safe well is worth the extra time and energy and indicates that social or political barriers may prevent use at the closest well. A fifth of switchers from unsafe actually chose a well that was closer than the nearest safe, most often to an unknown or unsafe well. Although favorable well features such as low iron concentration or cooler water can cause households to switch to nearby unsafe wells, social constraints may also completely limit switching to safe in these cases.

The household level data for non-switching unsafe well owners showed that the majority was within 50 meters to an unsafe well (**Figure 11**). These data indicate that a small distance to a safe well does not ensure switching and reemphasizes that social limitations can prevent switching.

To provide insight on these complex limitations, the surveyors collected anecdotes about social constraints. For example, one group of women would not switch to a nearby safe well because they felt uncomfortable collecting water in front of an adjacent mosque. Many others traveled long distances to safe wells or switched to unknown wells because of arguments with the owner of the nearest safe well.

Efforts should be made when possible to relieve such constraints, such as constructing a barrier around a well near a mosque, so that women could feel comfortable collecting water. On the other hand, disagreements are much more difficult to counteract.

In contrast to these examples, social conditions may also positively influence switching behavior and lift constraints. For example, a 50-year-old primary school teacher in Elmdi-Kamaldi village functioned as an arsenic activist within this community. This well-educated man possessed a deep tube well of approximately 700 feet that was known to have safe levels of arsenic. This man encouraged all villagers to use this well, despite the travel time. He also influenced the installation of other deep safe wells within the community. As a result such efforts, more than 74% of unsafe well owners in this community had switched to alternate wells, many of them safe.

The Elmdi-Kamaldi activist was rare, while social constraints were quite common throughout the surveys. This activist gap could potentially be filled by BRAC health workers. Although surveys found that few households interact with these medicine women, BRAC could extend their duties to include arsenic education and even the sale of well tests.

Although constraints or mobilizers are not easily identified or quantified in a quick household survey, they are important to acknowledge when determining the extent of switching behavior, as they can work significantly towards or against this action, above and beyond the influence of distance.

5. Conclusions

Well specific information helps. BAMWSP testing and labeling increased switching from all well types within the surveyed areas and paint provided an effective label that households trusted and remembered. *Testing and labeling programs should be performed in unsurveyed villages throughout the country. In addition, new wells are installed frequently, so follow-up testing services must be provided for all surveyed areas*.

Presence or activism has an impact. Areas with a strong academic presence had much greater switching among unsafe well owners than those without – 62% compared to 27%. Arsenic activists or social leaders within a village can increase switching in areas without academic reinforcement. As these leaders are rare, *BRAC health workers could potentially fill this need in the villages where they already reside*.

Spatial patterns matter. The number and proximity of safe wells within a village can limit switching, but they are boundary conditions and do not strictly define this behavior. *It is therefore important to target villages limited by physical factors for additional testing, reinforcement, or new well installation*. Potential targets include villages with an average distance to the nearest safe well above 100 meters and village proportions of unsafe wells above 0.45. Villages within the floodplain may also be a concern.

Social constraints exist. Switching from unsafe wells can be limited because of arguments between households, angry well owners, and social norms for women. Some of these issues can be remedied, while others may never be fixed and will always limit switching. It is also hard to predict and quantify these constraints among villages. *It is important then to provide additional safe water sources to villages, such as the deep safe community wells* installed in the original Columbia University study area and by others throughout the country.

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APPENDIX A – HOUSEHOLD SURVEY

Observations

1. Well ID from BAMWSP white paint or new Columbia University numerical tag
   - Enter [12345]
   - If no tag and not functioning, enter [11111]

2. Well status (visible on well)
   - [0] None
   - [1] Red paint
   - [2] Green paint
   - [3] Other

3. Does the well function?
   - [0] No
   - [1] Yes

Questions

1. What is the village name?

2. What is the well owner's name? (Confidential data)

3. What is the father's name? (Confidential data)

4. What is your relation to the owner?
   - [1] Close family
   - [2] Same bari
   - [3] Neighbor

5. How many years of education have you completed?

6. How many times per year do you interact with your village's BRAC health worker?

7. When was the well installed (# months ago)?

8. What is the well depth (feet)?

9. Is there a safe depth in your village where water is arsenic free?
   - [0] Don't know
   - [###] Depth in feet

10. Do you use this well for drinking or cooking?
    - [0] No
    - [1] Sometimes
    - [2] Drink
    - [3] Cook
    - [23] Both

11. What is the status of this well?
    - [0] Unsafe
    - [1] Safe
    - [2] Don't know

12. How do you know the status of this well?
    - [1] Paint
    - [2] Other testing
    - [3] Told by someone
    - [4] Don't know

13. Have you changed the well you drink from or shifted (picked up and moved) your well? If yes, how many months ago?
    - [0] No
    - [11##] Yes, switched to a community well for arsenic reasons, ## months
    - [10##] Yes, switched to a community well for other reasons, ## months
    - [21##] Yes, switched to a private well for arsenic reasons, ## months
    - [20##] Yes, switched to a private well for other reasons, ## months
    - [31##] Yes, shifted/moved this well for arsenic reasons, ## months
    - [30##] Yes, shifted/moved this well for other reasons, ## months

14. If you have switched to another private or community well, where is the new well located?

15. If the well is labeled unsafe and you believe it to be unsafe, why have you not switched to a safe water source?

    - [0] Don't care
    - [1] Safe well too far
    - [2] Not allowed at safe well
    - [3] Safe well water high in iron
    - [4] Don't know of safe well
    - [5] Other (_____________)

Figure 1a. Villages Surveyed within Araihazar, Bangladesh

Yellow dots indicate all villages within the original 25-km2 study area, while blue symbols show the 75 selected villages included in the 2005 surveys. Well symbols indicate the arsenic labeling used in each area -- BAMWSP applied green or red paint and Columbia placed metal tags bearing drink and don't drink symbols for wells below and above the country standard of 50 ug/l. (One inch equals approximately 3 km).

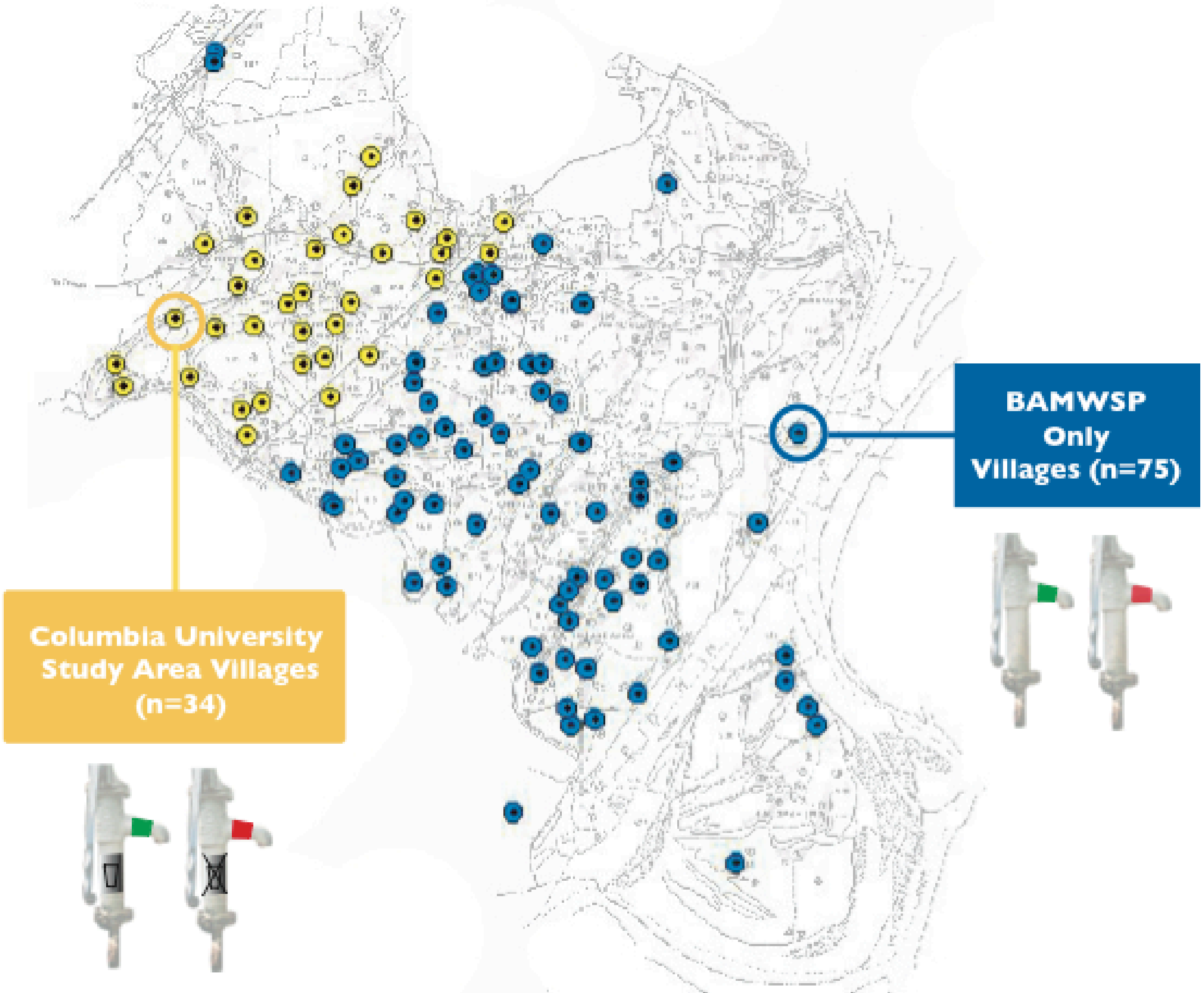


Figure 1b. Villages Selected for Comparison

To make the CU Study Area villages more comparable to BAMWSP Only villages, village sections where wells were far from community wells were utilized . BAMWSP Only villages were divided by their original selection categories -- Outside CU and Close to Clinic -- to determine if proximity to the study area or clinic had an influence on switching. The approximate clinic location is designated with a black cross below. Although two Outside CU villages fall among the Close to Clinic villages, these were kept separate, as Close to Clinic village data was collected for another research project at Columbia's School of Public Health. (One inch equals approximately 3 km).

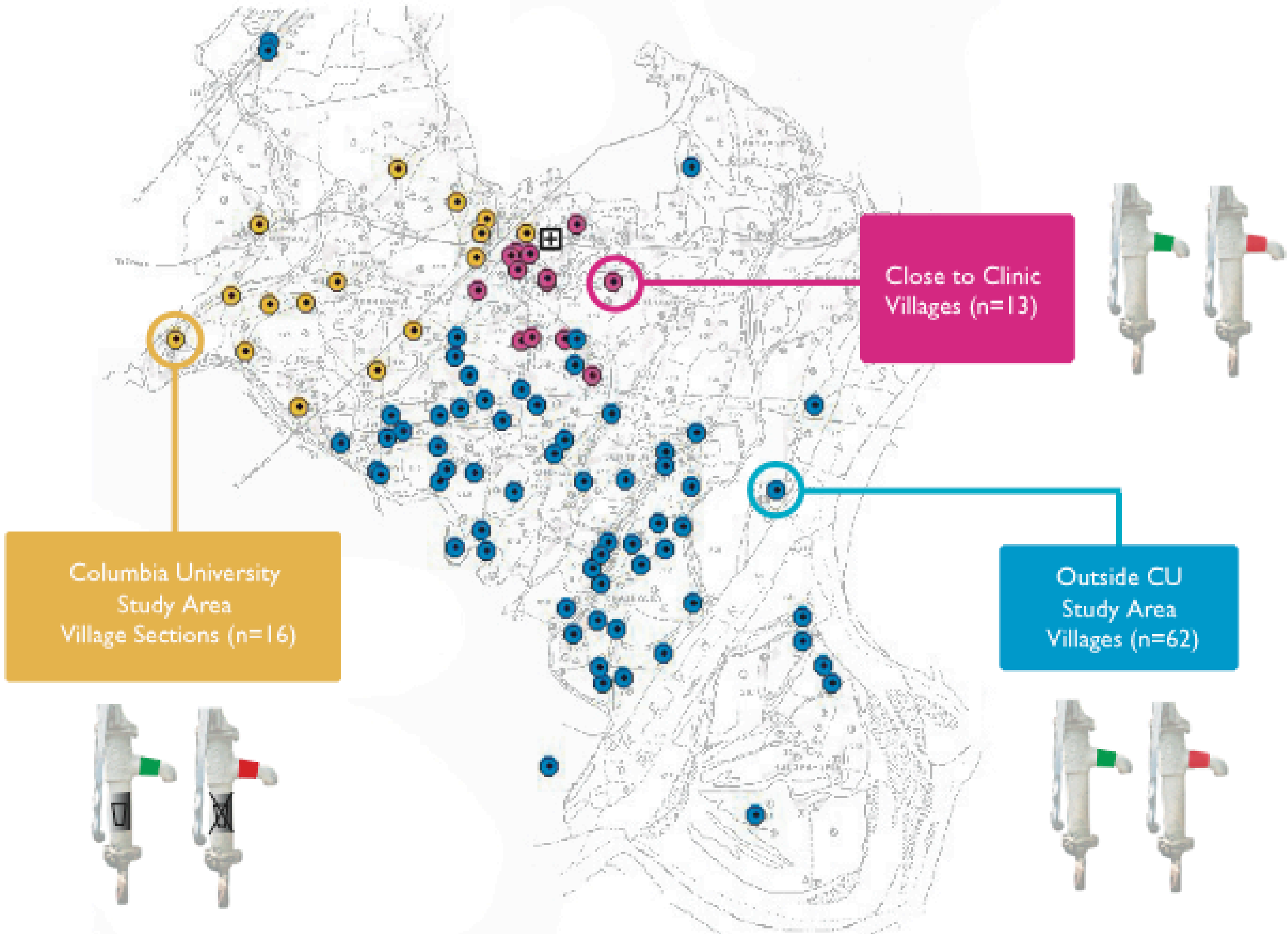


Figure 2a. Condition of Painted Labels

Of the 4372 wells surveyed in BAMWSP Only villages, three-quarters still had observable green or red paint. Based on surveys, only 3% of all wells were missed by BAMWSP, 4% originally had paint, 16% had been installed after BAMWSP, and 2% could not be determined as owners did not respond.

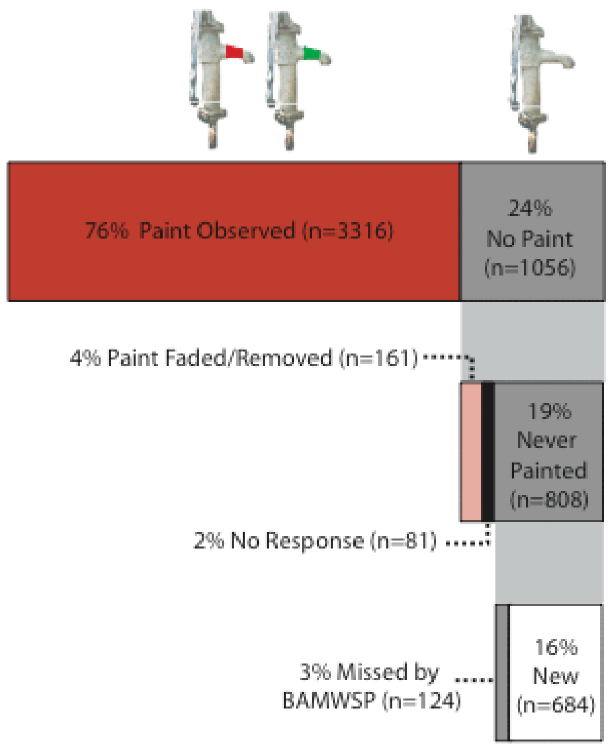
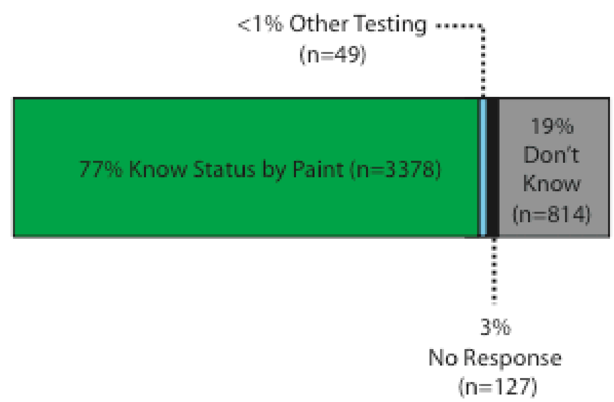


Figure 2b. Knowledge of Well Status

Of the 4372 wells surveyed in BAMWSP Only villages, the majority of owners stated they knew their well status based on paint. Some did not know the status, while a tiny percentage said they knew their status from other testing. The remaining owners gave no response.



* Figures do not include a <1% surveyor error

Figure 3a. Switching Response by Well Status

Some owners of observed unsafe, safe, and unknown wells within the BAMWSP Only villages stated that they switched to alternate wells prior to the surveys. The highest percentage of switching occured from unsafe wells, followed by unknown wells. Owners of safe wells had the lowest percentage of switching.

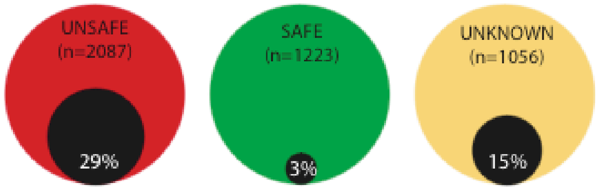


Figure 3b. Switching over Time by Well Status

The frequency of switching from unsafe, safe, and unknown wells has varied over time in the BAMWSP Only villages, with the majority of the behavior occurring after the BAMWSP testing program (approximately 24 months prior to our household response surveys).

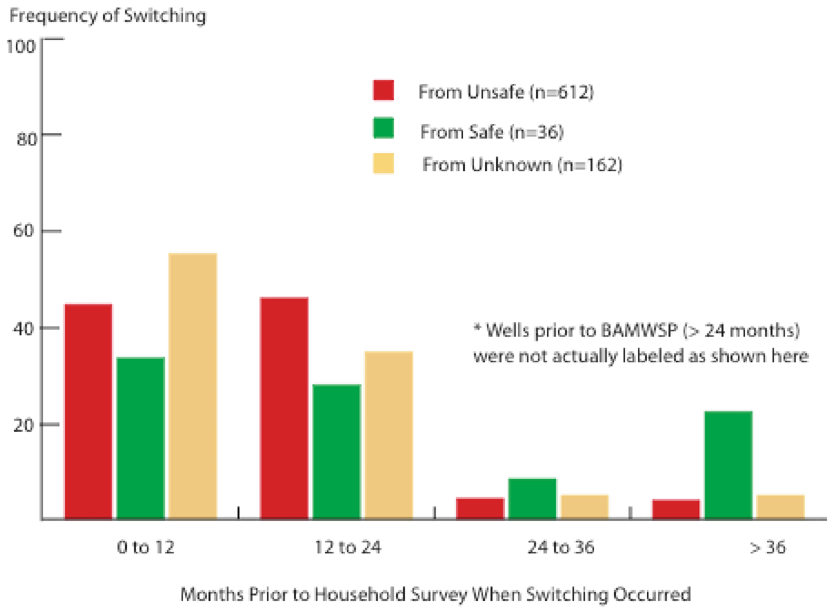


Figure 3c. Motivations for Switching

Among BAMWSP Only Villages, the majority of owners that switched from unsafe wells stated they were driven by arsenic. Only half of owners that switched from safe and unknown wells claimed to have switched wells because of arsenic.

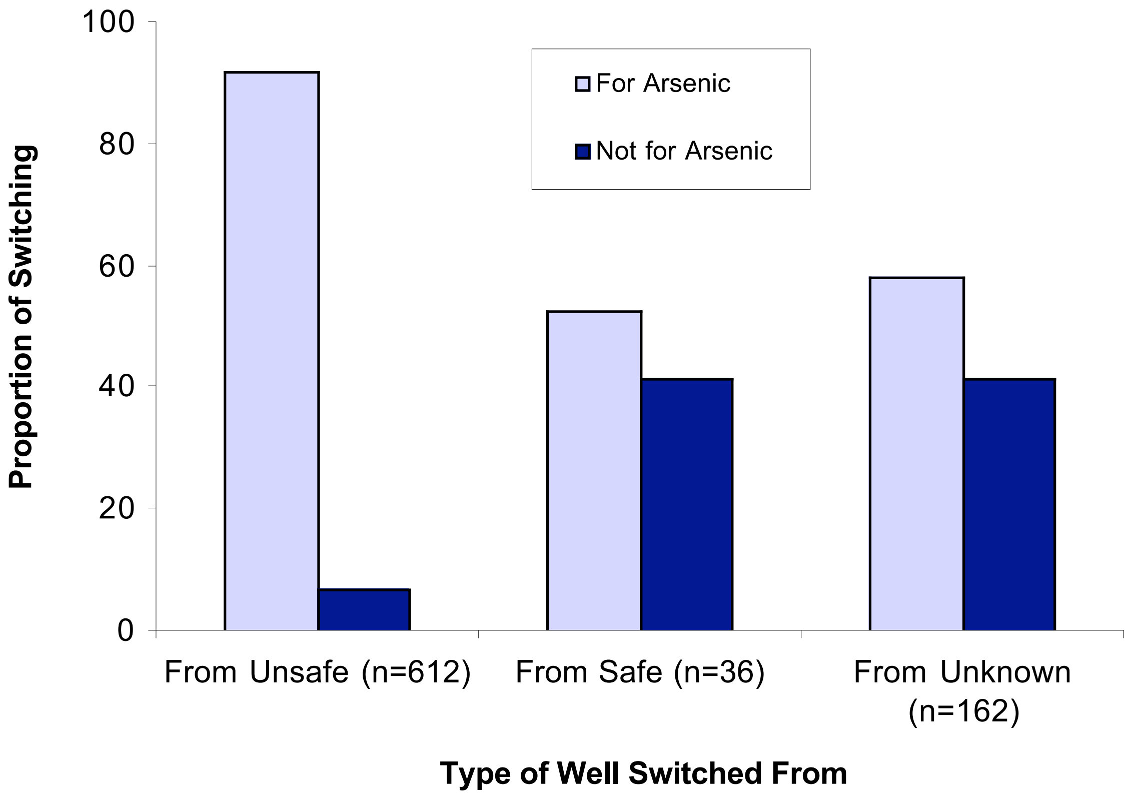


Table 1. A Comparison of Outside CU, Close to Clinic, CU Study Area Sections and CU Whole Villages

	Outside CU (n=62)	Close to Clinic (n=13)	CU Study Area Sections (n=16)	CU Study Area Villages (n=34)
# of Wells	3,597	775	1,729	6,459
Avg Distance to Nearest Safe Well (Std Dev)	75 (+/-90)	48 (+/-38)	48 (+/-60)	55 (+/-50)
Percentage of Unsafe, Safe, and Unknown	52 / 25 / 22	27 / 39 / 33	37 / 63 / 0	52 / 48 / 0
% Switchers of Unsafe, Safe, and Unknown Owners	27 / 2 / 13	46 / 7 / 22	52 / 15 / 0	62 / 15 / 0

Figure 4. Village Variation -- Well Locations and Village Switching Among Unsafe Owners

Village switching among unsafe well owners (as shown by bold percentages) varied widely based on 2003 and 2005 surveys. Each dot represents a single well within the CU Study Area sections, Outside CU, or Close to Clinic villages. The unsafe wells with switching owners (blue dots) lie on top of all others, so wells within a circle may not appear to match the attached percentage.

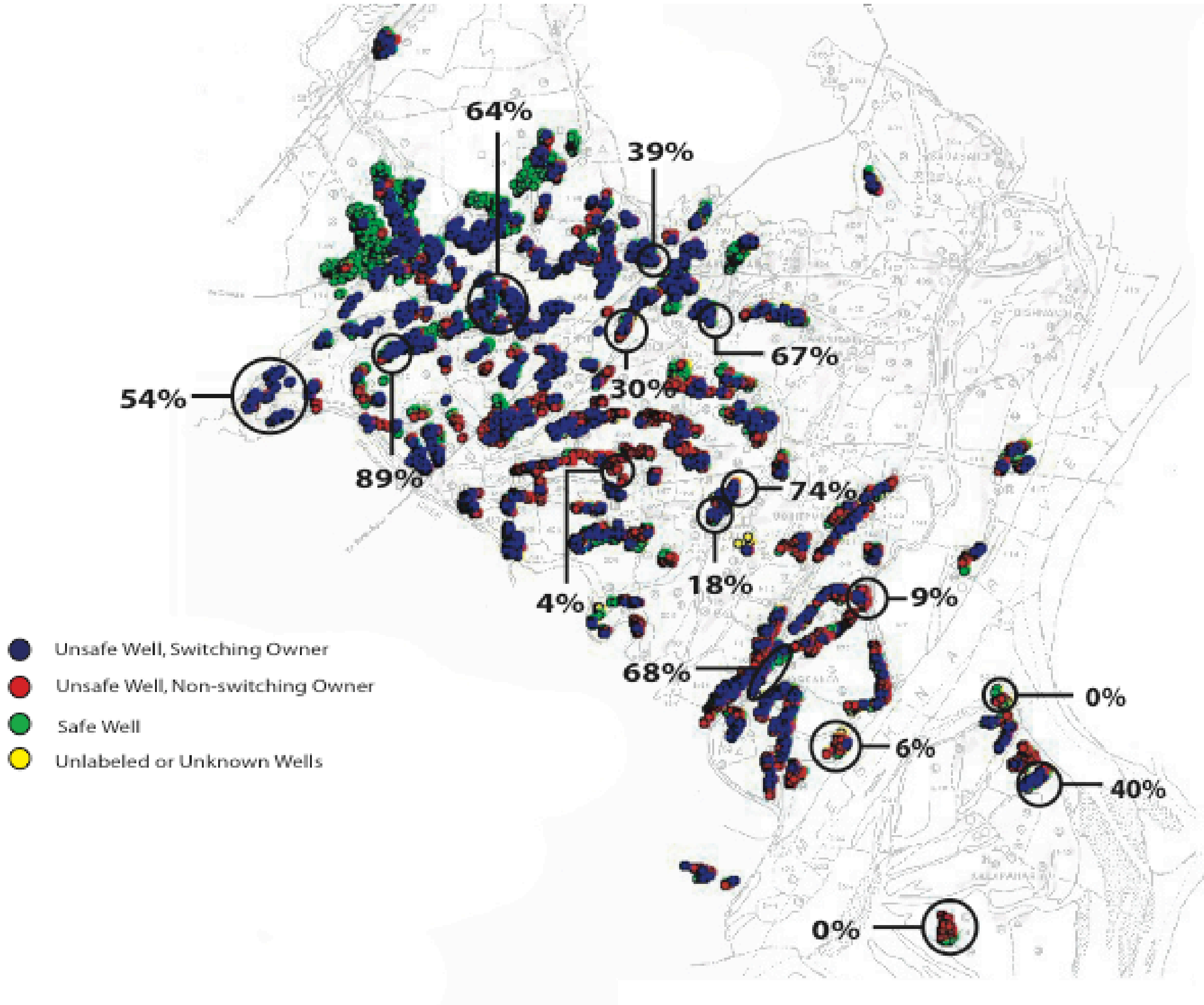


Table 2a. Proportion of Unsafe Wells, Safe Well Availability, and Response Behavior for 62 Outside CU Villages

Village	BAMWSP Proportion Unsafe	BAMWSP Village N	Village N	Unsafe N	Unknown N	Proportion Unsafe of Labeled Wells	Proportion Unsafe of All Surveyed	Distance to Near Safe (m)	Std Dev of Distance	% Switching
Alisadi	0.57	23	30	14	5	0.56	0.47	67.8	35.0	14.3
Asarampur	0.48	31	26	7	7	0.37	0.27	31.6	16.8	71.4
Atabdi	0.62	34	33	15	3	0.50	0.45	43.0	39.5	40.0
Badalpur	0.85	53	52	35	12	0.88	0.67	86.3	52.8	2.9
Ballabdhi Kanda	0.81	36	29	14	12	0.82	0.48	189.7	95.6	14.3
Ballabhdi	0.66	76	99	42	27	0.58	0.42	29.0	13.6	23.8
Bara Baral Para	0.78	183	178	113	27	0.75	0.63	44.4	27.3	35.4
Bhairabdi	0.56	118	54	20	16	0.53	0.37	34.2	11.8	35.0
Bhiti Kamaldi	0.80	59	65	41	13	0.79	0.63	52.8	33.6	46.3
Bibirkandi	0.71	17	24	7	12	0.58	0.29	94.5	26.3	0.0
Burumdi	0.55	31	46	17	11	0.49	0.37	20.0	7.0	17.6
Champaknagar	0.56	39	63	22	12	0.43	0.35	37.8	25.7	68.2
Chandibardi	0.64	28	27	18	2	0.72	0.67	70.1	41.2	22.2
Chengakandi	0.70	83	79	60	3	0.79	0.76	41.1	30.3	6.7
Dariabad	0.91	22	23	14	8	0.93	0.61	111.4	84.2	7.1
Dengurkandi	0.81	34	36	19	5	0.61	0.53	46.4	53.2	36.8
Dhandi	0.98	53	66	51	13	0.96	0.77	89.5	61.8	58.8
Dighirpar	0.59	22	48	19	12	0.53	0.40	33.0	14.9	36.8
Dumar Char	0.87	78	46	33	8	0.87	0.72	57.1	25.7	9.1
Elmdi-Kamaldi	0.81	36	53	35	11	0.83	0.66	61.2	53.7	74.3
Gadadhardi	0.56	16	25	6	13	0.50	0.24	49.5	19.6	66.7
Gang Para	0.34	32	39	4	10	0.14	0.10	20.8	7.6	25.0
Gurubdi	0.70	61	70	35	22	0.73	0.50	56.8	38.0	5.7
Ilamdi	0.89	56	29	11	5	0.46	0.38	31.0	19.2	18.2
Islampur	0.85	27	34	21	11	0.91	0.62	230.8	105.1	28.6
Kadamtali	0.53	30	35	12	10	0.48	0.34	41.2	21.0	50.0
Kadmir Char	0.76	50	50	25	13	0.68	0.50	43.8	24.1	40.0
Kakailmora	0.57	129	50	15	13	0.41	0.30	33.9	16.5	46.7
Kalagachhia	0.92	180	213	160	37	0.91	0.75	188.8	191.5	25.0
Kandakar Kalagachia	0.94	34	51	40	10	0.98	0.78	169.6	72.4	7.5
Khagkanda	0.57	113	123	52	33	0.58	0.42	57.6	33.0	21.2
Khagkanda Naya Para	0.91	33	34	17	15	0.89	0.50	92.6	47.7	5.9
Khan Para	0.78	32	35	26	1	0.76	0.74	43.1	18.3	26.9
Lalurkandi	0.56	72	81	27	25	0.48	0.33	31.6	19.1	7.4
Mohanpura	0.57	81	50	22	12	0.58	0.44	50.2	34.9	40.9
Nagarjoar (Fatehpur Union)	0.82	22	20	10	5	0.67	0.50	62.7	18.8	20.0
Nagarjoar (Haizadi Union)	0.93	15	9	7	1	0.88	0.78	97.9	93.3	0.0
Naya Para	0.91	22	23	5	6	0.29	0.22	23.2	7.8	20.0
Nayanabad	0.65	114	228	106	55	0.61	0.46	42.1	40.8	34.0
Noapara	0.62	47	46	20	7	0.51	0.43	29.3	12.5	0.0
Panchani	0.77	74	79	45	14	0.69	0.57	39.0	24.9	8.9
Para Manohardi	0.77	61	81	63	7	0.85	0.78	46.1	39.8	71.4
Purbakandi	0.54	65	50	22	7	0.51	0.44	33.0	19.9	54.5
Ramnagar	0.88	16	21	13	6	0.87	0.62	40.0	16.5	15.4
Rampur	0.73	52	45	27	6	0.69	0.60	45.3	27.7	7.4
Roynadi	0.60	43	66	41	9	0.72	0.62	59.9	51.8	14.6
Saizadi	0.88	16	24	13	9	0.87	0.54	110.3	69.7	7.7
Sambhupura	0.87	86	111	67	31	0.84	0.60	67.9	47.0	31.3
Sendi Hajibari	0.69	13	29	14	2	0.52	0.48	104.6	65.7	0.0
Shambhupura	0.87	23	28	13	12	0.81	0.46	98.7	34.1	23.1
Singapur	0.57	37	38	15	15	0.65	0.39	37.1	19.3	46.7
Singhadirkanda	0.79	19	138	50	24	0.44	0.36	29.4	20.3	24.0
Sonakanda	0.57	110	55	17	14	0.41	0.31	16.8	8.8	17.6

Table 2a (continued). Proportion of Unsafe Wells, Safe Well Availability, and Response Behavior for 62 Outside CU Villages

Village	BAMWSP Proportion Unsafe	BAMWSP Village N	Village N	Unsafe N	Unknown N	Proportion Unsafe of Labeled Wells	Proportion Unsafe of All Surveyed	Distance to Near Safe (m)	Std Dev of Distance	% Switching
Tataytala	0.53	55	41	14	12	0.48	0.34	29.4	13.0	64.3
Tatuakanda (Ka)	0.91	35	40	34	3	0.92	0.85	66.4	37.6	2.9
Tatuakanda (Kha)	0.41	75	85	20	20	0.31	0.24	18.1	13.0	5.0
Tetia	0.39	46	54	16	12	0.38	0.30	31.7	10.8	25.0
Tilchandi	0.85	66	87	55	20	0.82	0.63	56.4	31.4	50.9
Tuterbhag	0.88	34	43	28	12	0.90	0.65	237.0	97.5	3.6
Udoydi	0.97	60	47	37	8	0.95	0.79	241.1	60.1	8.1
Ulukandi	0.64	36	46	18	15	0.58	0.39	101.8	67.5	0.0
Utchipura	0.90	30	70	37	18	0.71	0.53	39.6	21.9	13.5

Table 2b. Proportion of Unsafe Wells, Safe Well Availability, and Response Behavior for 13 Close to Clinic Villages

Village	BAMWSP Proportion Unsafe	BAMWSP Village N	Village N	Unsafe N	Unknown N	Proportion Unsafe of Labeled Wells	Proportion Unsafe of All Surveyed	Distance to Near Safe (m)	Std Dev of Distance	% Switching
Abdullapur	0.74	35	40	10	23	0.59	0.25	93.7	54.3	30.0
Akhar Para	0.10	41	31	6	7	0.25	0.19	22.1	16.0	0.0
Araihazar	0.52	317	9	2	6	0.67	0.22	3.8	0.3	100.0
Chhota Daburpura	0.47	115	54	15	20	0.44	0.28	50.1	26.9	13.3
Dakshinpara	0.26	329	12	3	8	0.75	0.25	37.2	2.9	66.7
Debipura	0.25	28	28	7	12	0.44	0.25	36.7	34.5	100.0
Dighirpar	0.61	51	61	23	27	0.68	0.38	38.1	15.3	52.2
Goal Para	0.64	39	41	20	9	0.63	0.49	50.3	27.0	35.0
Kanda Para	0.20	115	123	21	26	0.22	0.17	26.5	15.3	38.1
Naikahan	0.53	79	132	32	43	0.36	0.24	53.8	40.8	59.4
Shibpur	0.16	120	58	5	26	0.16	0.09	46.6	12.4	100.0
Sultansadi	0.61	95	92	43	23	0.62	0.47	67.4	30.2	34.9
Uttarpara	0.43	136	135	41	23	0.37	0.30	29.5	14.8	43.9

Table 2c. Proportion of Unsafe Wells, Safe Well Availability, and Response Behavior for 16 Village Sections from CU Study Area

Village	BAMWSP Proportion Unsafe	BAMWSP Village N	Total Village N	Village Section N	Unsafe N	Unknown N	Proportion Unsafe of All Surveyed	Distance to Near Safe (m)	Std Dev of Distance	% Switching
Araihazar	0.52	317	92	51	26	0	0.51	96.8	124.6	73.1
Ballarpara	0.75	277	290	70	56	0	0.80	99.1	87.6	53.6
Bati Gobindi	0.23	65	123	37	12	0	0.32	41.4	46.1	75.0
Brahmandi	0.59	220	179	131	78	0	0.60	43.0	32.4	41.0
Chamer Kanda	0.36	152	154	116	24	0	0.21	27.0	13.3	33.3
Chhoto Manohordi	0.56	39	200	104	72	0	0.69	52.6	52.8	63.9
Darisatyabhandi	0.28	168	424	355	35	0	0.10	26.6	15.4	77.1
Edbardi	0.52	233	153	48	21	0	0.44	41.1	29.7	57.1
Kamrungirchar	0.21	204	129	95	46	0	0.48	46.0	36.5	43.5
Krishnapura	0.60	127	167	119	67	0	0.56	41.2	30.9	38.8
Lashkardi	0.26	443	187	136	31	0	0.23	26.0	65.1	29.0
Maouradi	0.52	232	297	239	94	0	0.39	38.7	41.6	40.4
Mukundi	0.57	118	114	60	25	0	0.42	30.9	17.2	76.0
Noapara	0.63	248	239	114	62	0	0.54	28.7	15.6	85.5
Rishir Char	0.51	123	74	40	18	0	0.45	21.6	11.0	88.9
Uttrapur	0.78	104	115	43	20	0	0.47	133.7	150.0	40.0

** The 16 Outside CU Village Sections did not have any observed unknown wells at the time of the survey, therefore, there is no 'Proportion Unsafe Wells of Labeled Wells' for these villages. Also note that the entire village N (or number of wells) is incl

Figure 5. Village Variation -- Breakdown of Percent Switching for 3 Areas

The majority of Outside CU villages had % switching below 40%. Close to Clinic villages had a wide range of switching from 0 to 100%, while the CU Study Area sections had percentages from 20% and up.

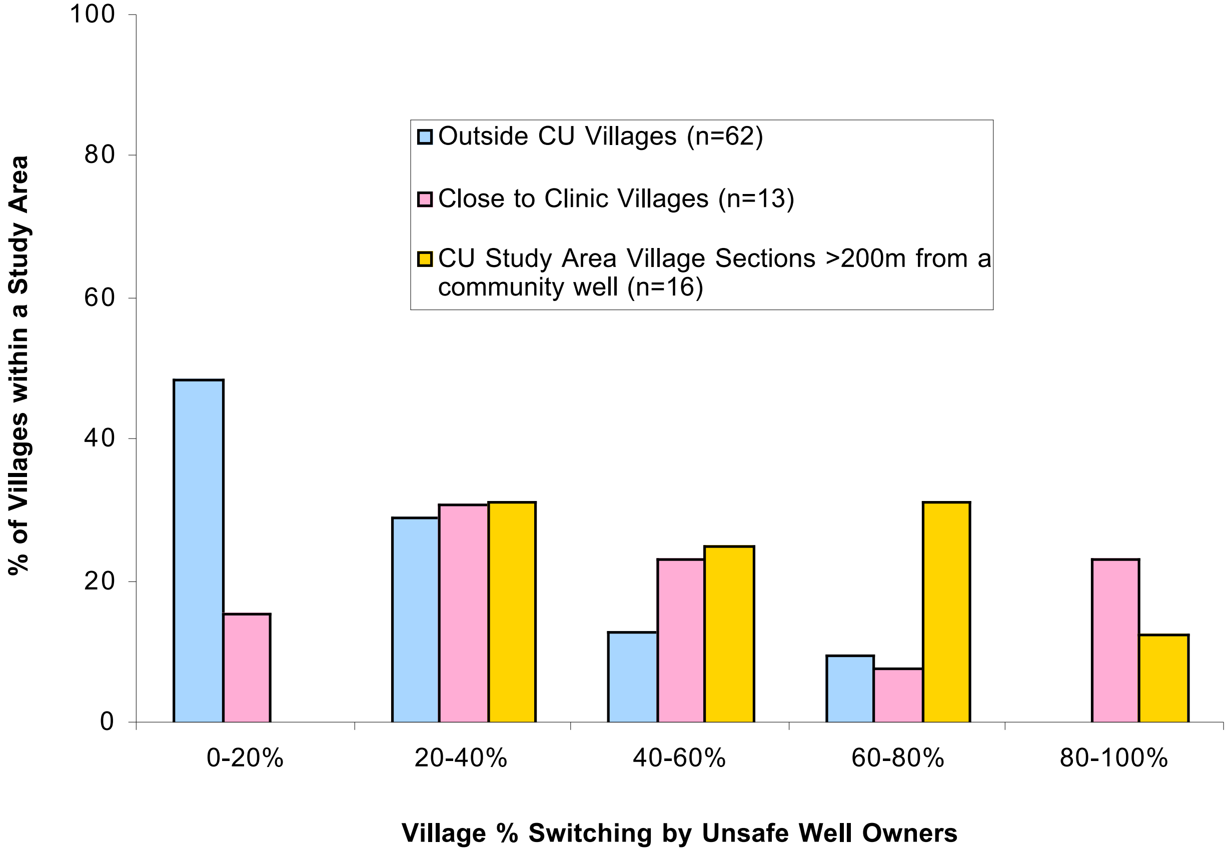


Figure 6. Average Distance to Nearest Safe Well Versus Proportion of Unsafe Wells

These physical factors have a slight correlation when examined for all 91 villages. As village proportion increases the average distance to the nearest safe well increases. Above a proportion of 0.45, distance varies widely.

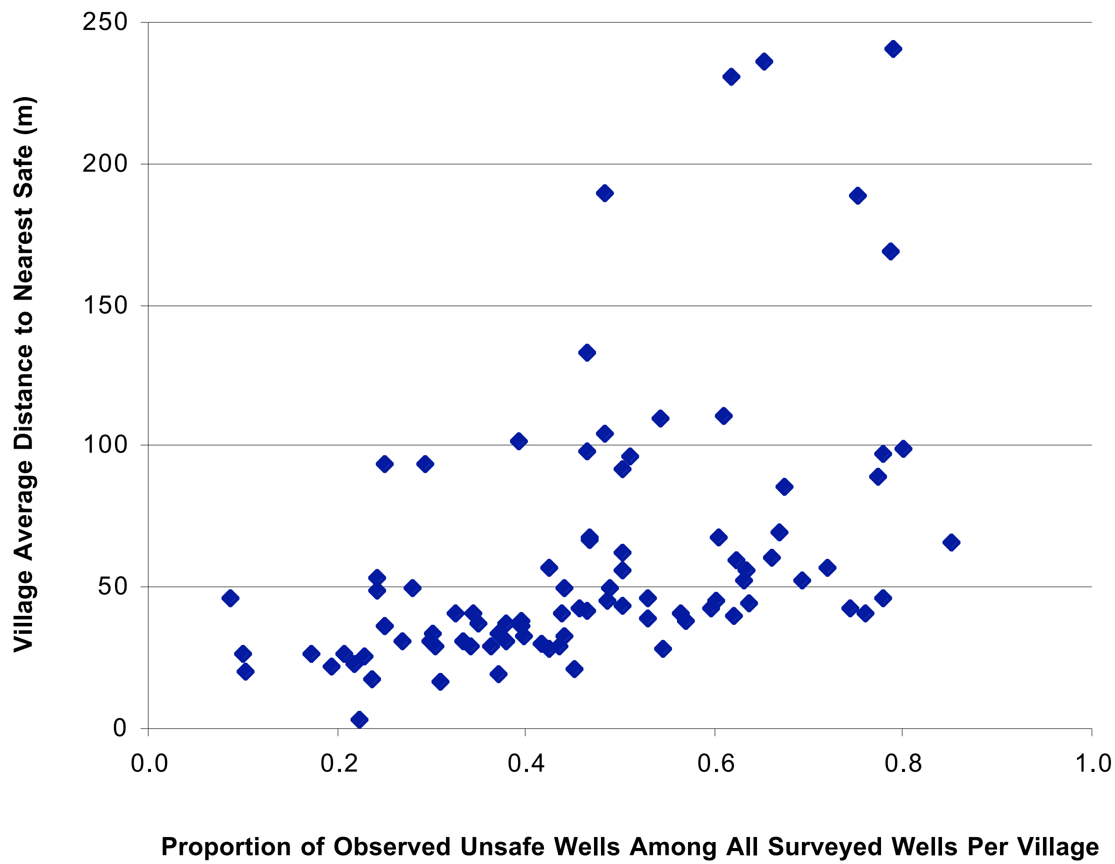


Figure 7. The Effect of Village Proportion on % Switching

For any village proportion of unsafe wells, there was a wide range of switching by unsafe well owners. In many cases the % switching of a CU Study Area village fell above switching from the Outside CU or Close to Clinic village within the same proportion class.

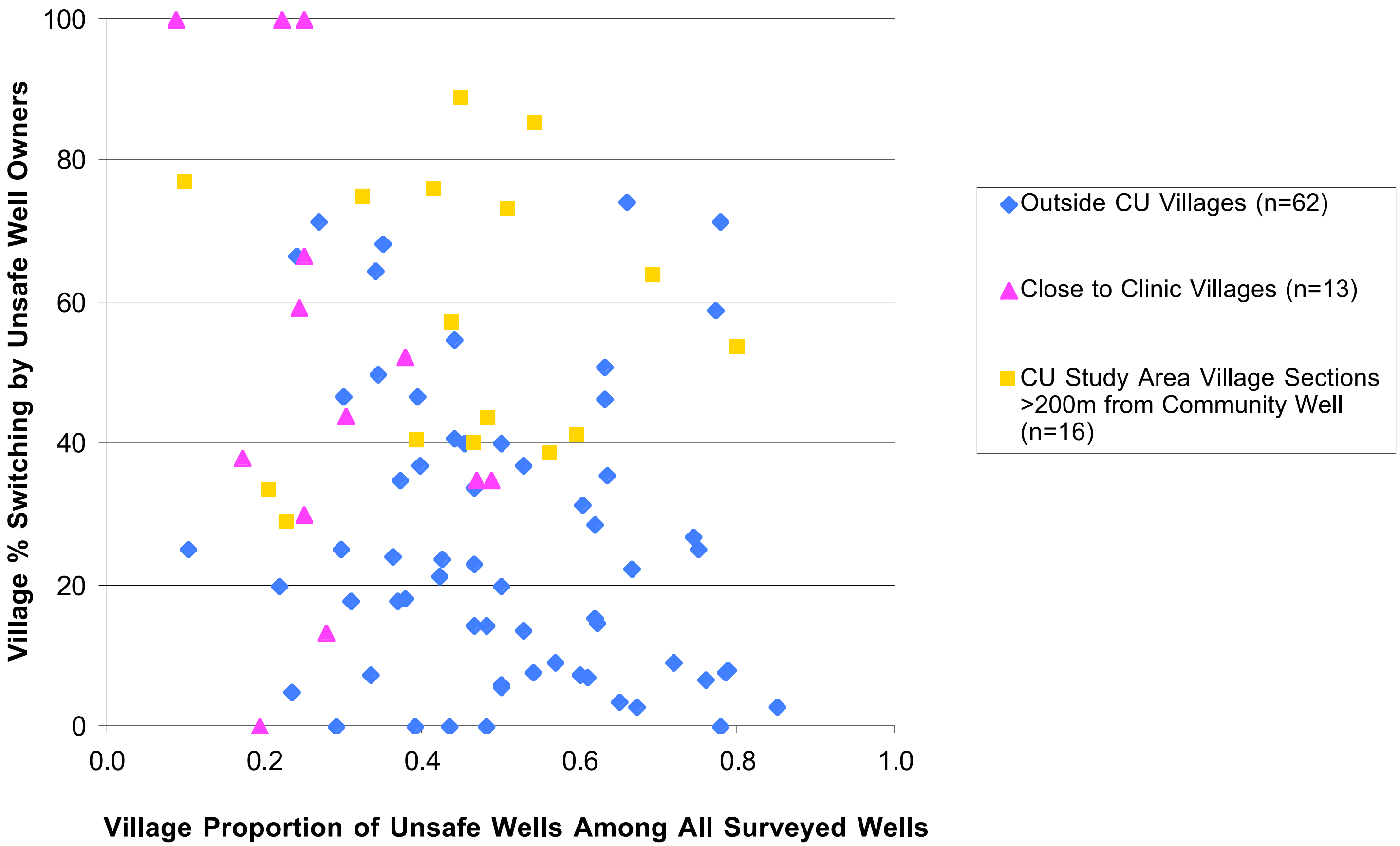


Figure 8. The Effect of Distance to Nearest Safe Well on Switching

When the village average distance to the nearest safe well was within 100 meters, village % switching by unsafe well owners ranged from 0 to 100 for all 3 proportion categories (low, medium, and high). Above 100 meters, switching only ranged from 0 to 40%.

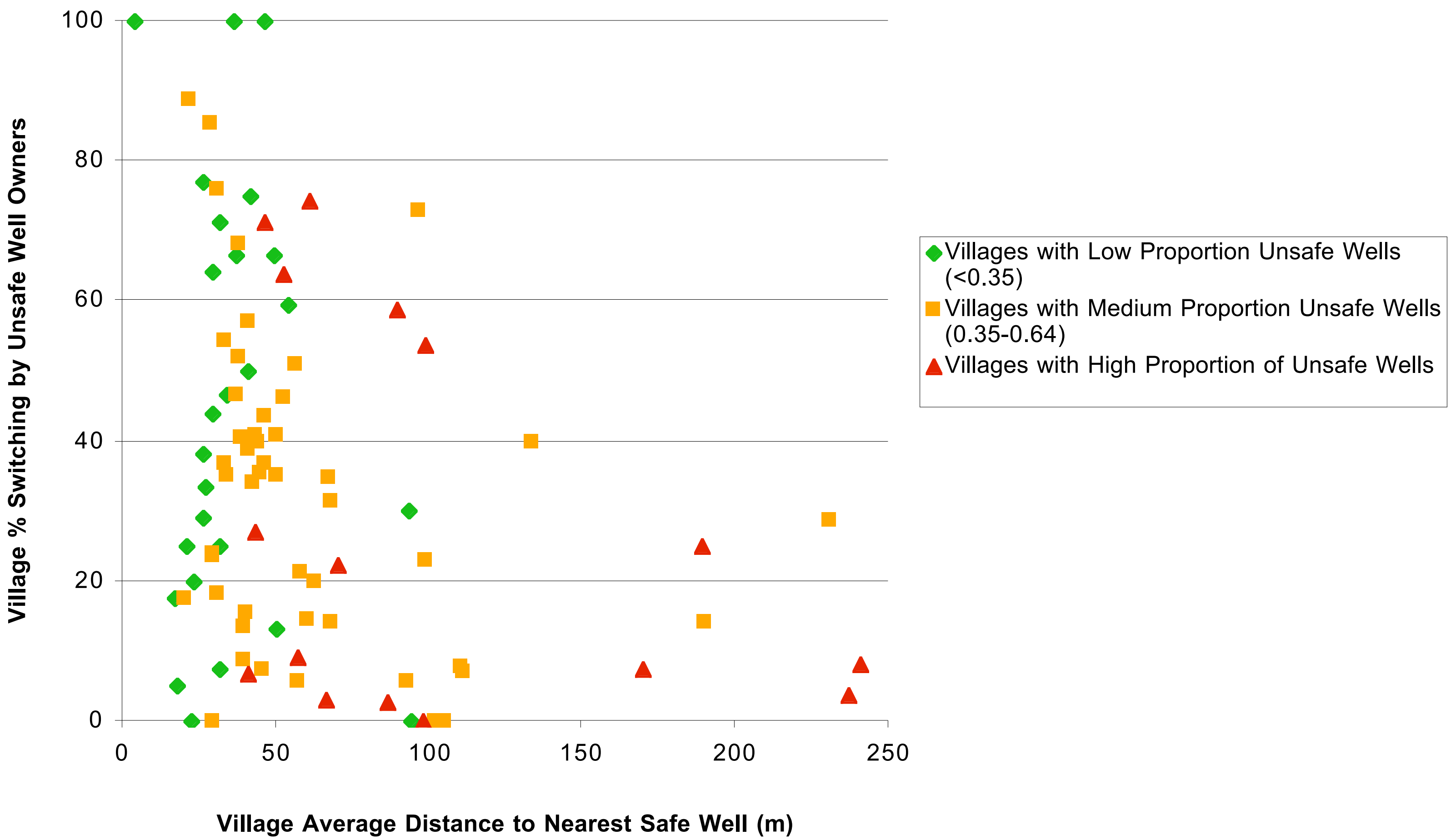


Figure 9. Breakdown of Actual Distance Traveled By Switching Unsafe Well Owners

Among switching unsafe well owners in BAMWSP Only villages (n=531 wells), the majority chose wells within 50 meters of the original, and almost all chose within 100 meters, indicating the importance of distance.

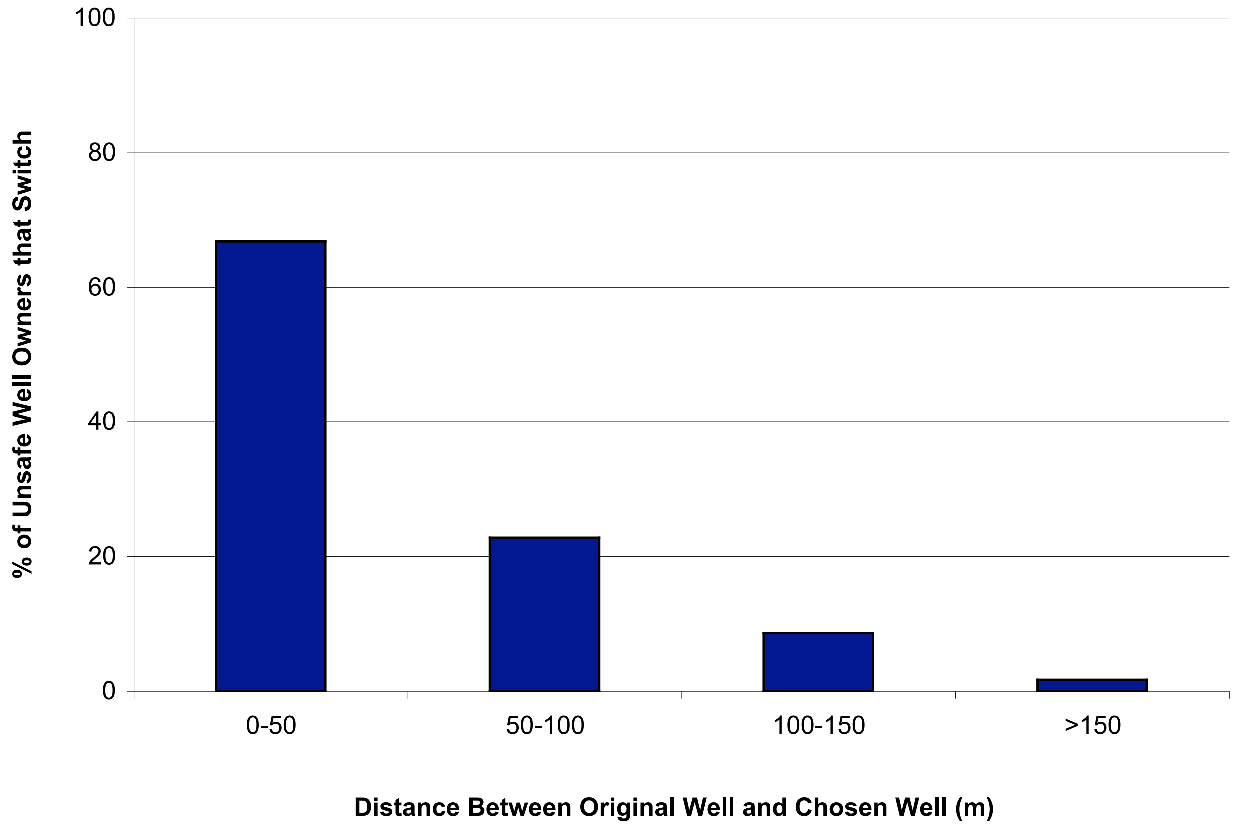


Figure 10. Comparison of Distance to Safe and Distance to Chosen Well

Among 531 unsafe well owners that switch, 41% chose a well that was also the nearests safe well (these fall on the 1 to 1 line), 38% chose a well further than the nearest safe (these fall above the line), and 21% chose closer (these fall below the line), often to unsafe or unknown wells.

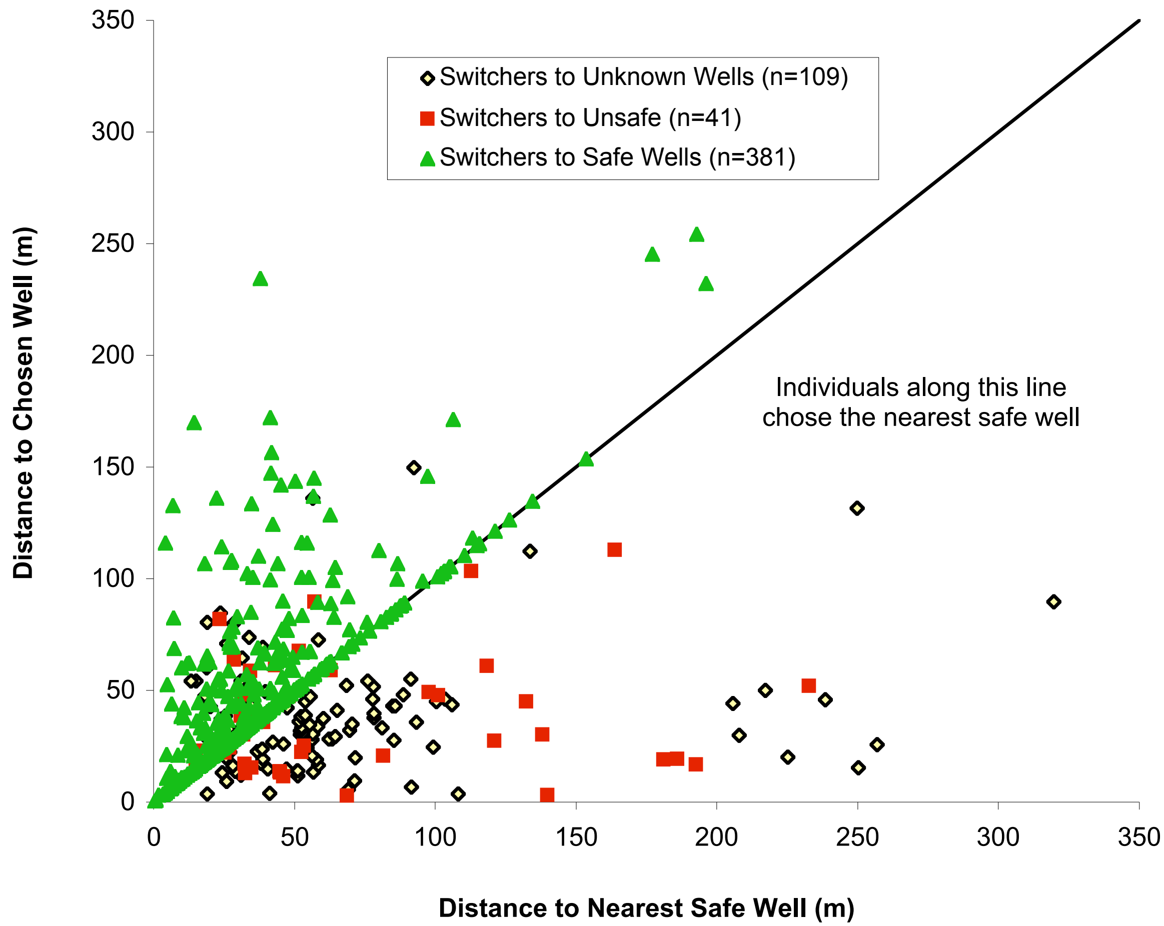


Figure 11. Proximity of Closest Safe Well for Non-Switching Well Owners

More than 50% of non-switching well owners were within 50 meters of a safe well, and just below 30% were within 100 meters. It is difficult to determine exactly why these owners do not switch, but social barriers are a likely contributor.