Do decentralized community treatment plants provide better water? Evidence from Andhra Pradesh

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Abstract

Highly advanced, community-level drinking water treatment facilities are increasingly seen as water supply solutions in locations where piped in-house water systems are nonexistent or unreliable. These systems utilize combined technologies, such as advanced filtration plus ultraviolet disinfection or reverse osmosis, which are known to be highly effective for the removal of pathogens and other water contaminants. Yet there is a paucity of rigorous evidence on whether the community-level treatment model delivers water quality and health benefits to households that source water from them. This paper utilizes a quasi-experimental approach that combines construction of counterfactual groups of households with a difference-in-differences methodology to examine such impacts. We find that only a little over 10% of households in treatment villages source water from the community water systems (CWS), and there is no evidence of health and water quality benefits among households in treated villages, relative to controls. Furthermore, among users of the CWS (but not non-users), we observe lower water quality and higher diarrheal disease rates relative to control households. These negative impacts can perhaps be explained by a combination of non-exclusive use of clean CWS water and reduced self-protection against water quality risks: we find evidence that households accessing the CWS increase the number of water sources on which they rely even as they reduce self-protection using in-house water treatment methods. In the longer term, as the CWS model spreads throughout the region, we observe that most of the differences between households in treated and control communities fade away. These findings suggest that caution and additional scrutiny is warranted before concluding that such systems provide safer water to households in communities facing drinking water quality problems.

Key words: Water quality, diarrheal disease, impact evaluation, community water kiosks, rural India

1. Introduction

In many less-developed countries, the majority of households obtain water for household consumption from sources located outside the home (WHO and UNICEF 2012). This is especially true in rural areas, where reliable piped water systems that reach inside households' living quarters are rarely affordable for households or local governments. Meanwhile, accessing water for domestic purposes from outside sources costs households time, given the need to travel to collect and bring water home, as well as money, if they must pay to use water from community sources and invest in storage or in-house water treatment technology (Whittington et al. 2012). There are also significant health concerns related to the use of water sources outside the home, given that such water is subject to contamination from a variety of natural and man-made contaminants, and is difficult to manage hygienically following collection (Shaheed et al. 2014).

The literature on interventions designed to improve either the convenience or quality of water sources located outside the home is fairly ambivalent about whether they deliver health or other economic benefits to households. In fact, a general consensus has emerged within the water, sanitation and hygiene (WSH) community working in low-income countries that household-level treatment is typically more effective than community-level treatment. This consensus, expressed in individual studies as well as meta-analyses (Fewtrell et al. 2005, Waddington et al. 2009), reflects concerns that high quality community sources are often inconvenient for many potential beneficiaries, and that there is great potential for recontamination between the point-of-source (POS) and point-of-use (POU) (Clasen and Bastable 2003, Wright et al. 2004). For example, the World Bank's Independent Evaluation Group published a summary of the research on effectiveness of WSH interventions in 2008 stating that "there is overwhelming evidence that hand washing, sanitation, and household and point-of-use water treatment improve health outcomes. . . However, there do not appear to be health gains for water treatment at the source" (Independent Evaluation Group (IEG) 2008). Such statements notwithstanding, there have been relatively few rigorous evaluations of water source improvements. Notable exceptions include a few relatively high profile experimental studies that show modest positive changes in in-house water quality from community-level improvements (Kremer et al. 2011). To date, there have been no rigorous evaluations of interventions that allow households to purchase highly treated water (using advanced treatment processes) from water shops or kiosks.

This negative view of source water improvements has not prevented a variety of community-level efforts and investments in less-developed countries – from both public and private actors – to expand access to decentralized and higher quality water sources. Examples of such efforts include water kiosks that sell highly treated drinking water, investments in spring protection, or the digging of boreholes to tap (presumably safer) water from deep aquifers (Arlosoroff et al. 1987, Kariuki and Schwartz 2005). One such program is the Safe Water Program (SWP), initiated in 2006 in rural Andhra Pradesh by non-profit institutions. The SWP is one of several kiosk-based programs that focuses on provision of drinking water to rural households from small-scale treatment plants – known in this program as Community Water Systems (CWS) – equipped with advanced water purification technologies (e.g., ultraviolet disinfection or reverse osmosis). Users of such water generally purchase the water directly from the kiosks, or access it through a home delivery service.

This paper examines the effects of the SWP on water sourcing, water and hygiene behaviors, and health outcomes, by comparing changes over time in 25 communities originally chosen to receive the SWP with changes observed in a matched sample of 25 control communities that were not originally chosen to receive the program. In this design, control communities represent "business as usual", rather than "doing nothing" (Ravallion 2008). In fact, as we will discuss in this paper, several of the communities originally assigned to receive the SWP ended up not receiving it, and eventually, some of the control communities did. Furthermore, households living in treatment and control communities were affected by a variety of other circumstances and programs during the evaluation period that affected the same household water, sanitation and hygiene behaviors and outcomes (e.g., health, safe water practices, access to water sources, sanitation) that we tracked in the evaluation.

Our evaluation strategy is to first measure the effect of the program over and above other activities that may have affected this broader study population, using a difference-in-differences (DiD) approach in combination with an intent-to-treat (ITT) estimator, whereby sample households are considered exposed to treatment if they reside in one of the 25 communities originally assigned to receive the SWP intervention. We also discuss how results change when we instead implement the DiD methodology on a) households residing in communities that actually had received a CWS by 2008; and b) only households who sourced water from the CWS, using both simple OLS and propensity-score matching (PSM) to identify households in control villages who are observationally similar to these users of CWS water. Finally, we analyze use and outcomes in the treatment and control communities over the longer term, using follow-up data collected more than 4 years after the baseline. We first examine several key outcomes, namely access and use of different water sources, water quality measures, and self-reported diarrheal disease. Then, we use the same methods to study a range of other variables – adjustments in other water-related behaviors, convenience of drinking water sources and expenses on drinking water, and other coping costs – across treatment and control households that help to shed light on the mechanisms that underlie the observed changes in these outcomes.

We find that treatment households were generally aware of the SWP intervention, but that only a minority (just over 10%) were sourcing water from the CWS at the time of the short-term follow-up conducted two years after the initiation of intervention planning. This rate of use then declined further to about 6% by 2011. Counter to initial expectations, we observe little evidence of water quality and health benefits among households living in villages initially assigned to receive one of these treatment plants, relative to those living in control villages. Even more surprisingly, we observe lower water quality and increases in reported rates of diarrheal diseases in households sourcing drinking water from the CWS, relative to non-users and households in control villages. These changes can perhaps be explained by two other trends among CWS users. First, the change in the number of water sources used for drinking purposes among such households is higher by 0.7-1.2 sources among such households, suggesting that these households did not discontinue use of their original sources even as they started buying water from the CWS. Second, CWS users reduced self-protection at home, which likely created a risk of re-contamination of drinking water at the household level. Specifically, these users became 13-25 percentage points less likely to use in-house drinking water treatment methods (down from about 50% overall at baseline).

Over the longer term, we observe few differences (on average or comparing CWS users to non-users) across households between the originally defined treatment and control communities. Overall, our findings suggest that the CWS plants serve a small fraction of households and do little to lessen the drinking water quality challenges faced by households. This is noteworthy given that the basic intervention model for these plants has been successfully extended in Andhra Pradesh, and that similar alternatives are increasingly found across a range of locations in less-developed countries. The remainder of the paper is organized as follows. The next section briefly reviews the literature on community-level water interventions and water kiosks in particular. Section 3 presents a theoretical model of averting behavior that motivates the need for empirical testing of interventions such as the SWP. The evaluation design and DiD methodology used to assess the impacts of the SWP follow in Section 4, and Section 5 describes the intervention, household sampling, and data. Section 6 discusses the results, and Section 7 concludes.

2. Background and literature

Over the past two decades, there has been steady growth in the number of rigorous impact evaluations of water, sanitation and hygiene (WSH) interventions in low-income settings, including ones geared toward improving the quality of drinking water. This body of evidence has contributed to arguments that household-level point-of-use interventions are generally more effective than community-level investments in drinking water treatment, and that the latter do not provide significant disease reductions. A closer look at the evidence on community water source improvements, however, reveals that there is a remarkable dearth of rigorous evidence about their effects on drinking water quality and health.

In fact, many water source improvements that have been subject to evaluation do not actually focus on water quality, but rather aim to make water supplies more convenient and accessible to beneficiaries. The most prominent meta-analyses of water quality improvements include a handful of studies about community source interventions, almost all of which are observational (Fewtrell et al. 2005, Waddington and Snilstveit 2009, Waddington et al. 2009). Evaluations of such community interventions are generally more difficult to conduct than household-level randomized controlled trials. The challenge stems partly from costs: community-level infrastructure is much more expensive than point-of-use treatment (which inherently limits the scale of experimental programs) (Whittington et al. 2012), and attaining sufficient statistical power to detect differences between treated and control units requires inclusion of a large number of communities (Sanson-Fisher et al. 2007). In addition, statistical inference is hindered by the fact that outcomes of interest (e.g., self-reported diarrheal disease prevalence) occur with relatively low probability, may be short-lived, and are often correlated across households within the enrolled communities (Blum and Feachem 1983, Schmidt et al. 2007).

Among the more rigorous studies of community interventions to improve water quality, Kremer et al. (2011) used a randomized controlled trial to examine the effectiveness of community spring protection. The authors found that this intervention reduced fecal contamination in water by two-thirds at the source, but by only 25% for water stored at home, with a corresponding 25% reduction in childhood diarrheal disease prevalence. A related study assessed the effectiveness of providing chlorine dispensers at the point of water collection, and found these to be highly cost effective for reducing diarrheal disease (Ahuja et al. 2010). To date, however, there has not been a rigorous evaluation of water treatment kiosks or refill stations, which are an increasingly common model for delivering high quality drinking water at the community-level (Sima and Elimelech 2013). Water treatment facilities of this type, which typically utilize a combination of technologies (e.g., filtration coupled with disinfection or even reverse osmosis), today exist in a large number of countries in urban as well as rural settings, in locations as diverse as Jordan, Indonesia and Ghana (Al-Jayyousi 2001, Sima et al. 2012, Opryszko et al. 2013). An important feature of these kiosk-based programs is that users pay for the water they collect.

The business model for these types of treatment systems can generally be categorized into two types: small entrepreneurial businesses and public-private partnerships with growth dependent on donor organizations, government support or community ownership (Sima and Elimelech 2013). The SWP considered in this paper is based on the latter model. For the first eight years, the kiosk is jointly owned by the community and a specialized water sector NGO. At the end of this period, full ownership is transferred to the community. One major benefit of this model is that the management and ownership structures of the stations can be adapted to local conditions. Additionally, it is thought that the competitive nature of these for-profit enterprises and the availability of other water alternatives in target communities provide incentives to system operators to maintain the quality of their service. A potential downside of such systems is their reliance on the demand for improved water quality; Sima and Elimelech (2013), for example, argue that water kiosks are most viable in urban areas where demand and awareness of water quality problems is highest. The sustainability of ongoing operation and maintenance, as well as access to replacement parts and technical labor, also presents more significant challenges in rural areas.

This paper is the first quasi-experimental evaluation of the water kiosk model. In an observational study, Sima et al. (2012) compared purified water from kiosks to tap and bottled water in Jakarta, Indonesia. The researchers monitored daily diarrhea and consumption of drinking water from different sources in a sample of 1000 children 1-4 years of age over a 5 month period, and found that diarrhea rates were lower for bottled and kiosk water users than for tap water users in an urban slum. In a peri-urban area, overall diarrhea rates were lower for all children, but diarrhea rates of kiosk users were not significantly different from those of people consuming water from other sources. Because of the high prices of bottled water, the authors argue that kiosks present a more cost effective way to reduce rates of childhood diarrhea, as water from kiosks is nearly four times cheaper than bottled water. A second study examined the effectiveness of for-profit water vending kiosks in Ghana (Opryszko et al. 2013). The study used before and after surveys of 49 households living in 5 different villages over a 3-year interval. The researchers found that the four intervention villages had somewhat lower rates of *E. coli* (though 60% still had such contamination) in household water storage containers than households that used surface water, but that purchases of treated kiosk water declined significantly (to 38% of households) over the three-year period. The authors interpreted this as evidence that drinking water from kiosks is somewhat susceptible to recontamination prior to consumption. They argued that the deterioration of water quality at the point of use and declining usage rates over time are issues that need to be addressed for kiosks to be fully successful.

These observational studies provide important background for understanding the challenges of kiosk-based water provision. However they stop short of providing convincing evidence that the observed changes were caused by the improvements in water quality delivered by kiosks, given that consumers of such water may be systematically different from non-users in ways that are correlated with in-house water quality and diarrheal disease outcomes. Another issue for safe water interventions is households' use of water from multiple different sources. In one study by Evans et al. (2011), 64% of households across three different regions reported using a secondary water source, and 46% of those households had on-site water supply. The use of different sources implies that researchers should do more to understand why households may rely on multiple sources to meet their needs, and how the use of multiple sources affects the quality of the water these households consume.

3. Theoretical model

Our starting point for considering household responses to a new investment in drinking water quality adapts ideas from a general theory of household production of health (Grossman 1972, Pattanayak and Pfaff 2009) with ideas from economic epidemiology (Philipson 2000). For the purposes of illustration, we assume that a household's utility is a decreasing function of time spent sick s and an increasing function of consumption of a numeraire good X and leisure time l.[1] Illness s is increasing in the dose d of health-damaging contaminants that are ingested $\left(\frac{\partial s}{\partial d} > 0\right)$:

$$u = u[s(d), X, l]. \tag{1}$$

We further assume that $d = d[C, a, q]$ is increasing in the contaminant load in the environment C, which is exogenous to the household, and decreasing in both in-house averting behaviors a and water

[1] We thus abstract from the case where averting behavior, introduced further below, directly affects utility. The complications that arise from a more complete model that allows for such effects are discussed in some detail in Freeman (2003). For an environmental health application that is somewhat related to the one described in this paper, refer to Jeuland et al. (2015).

acquired from higher quality sources q $\left(\frac{\partial d}{\partial C} > 0;\ \frac{\partial d}{\partial a},\ \frac{\partial d}{\partial q} < 0\right)$. This in turn implies that sickness is also increasing in $C$and decreasing in a and q.

We assume that the household maximizes utility subject to the budget constraint:

$$I + w \cdot (T - l - s) - X - p_a a - p_q q \geq 0, \tag{2}$$

where I is income non-wage income; the wage is w; and p_a and p_q are the relative prices of averting behavior and higher water quality, respectively, relative to that of the numeraire good.[2]

The household then chooses a, q, X, and l so as to maximize utility, given the level of environmental risk posed by the environmental contaminants c. The full Lagrangian can thus be written as follows:

$$Max\ \mathcal{L} = u[s(C, a, q), X, l] - \lambda[X + p_a a + p_q q - I - w \cdot (T - l - s)]. \tag{3}$$

The solutions to the first order conditions are summarized below:

$$\partial u/_{\partial x} = \lambda; \quad \text{(4a)} \qquad \partial u/_{\partial l} = \lambda w; \quad \text{(4b)} \qquad \partial u/_{\partial s} - \lambda w = \lambda\left(\frac{p_a}{\partial s/_{\partial a}}\right) = \lambda\left(\frac{p_q}{\partial s/_{\partial q}}\right). \quad \text{(4c, 4d)}$$

Equation 4a says that individuals will purchase the numeraire good according to the marginal utility of money (the Lagrange multiplier λ). Equation 4b indicates that the marginal utility of an additional unit of leisure time is set equal to the marginal cost in terms of labor that is displaced by that re-allocation of time (valued at the wage rate). Finally, conditions 4c and 4d show that the individual will choose averting activities and/or higher quality sources in a way that equates their marginal benefits, in terms of utility gains and additional wages from reduced illness, with their marginal costs, which are a function of their price and of the effectiveness with which they reduce illness.

The solution to the utility maximization problem in equation 3 yields the optimal demand for averting behavior $a^*(I, p_a, p_q, w, C)$ and higher quality source water $q^*(I, p_a, p_q, w, C)$.

We are particularly interested in what might happen to illness with a reduction in the price of high quality source water p_q, as might occur with the introduction of new CWS facilities in treatment communities. If we take the total derivative of the health production function $s(C, a, q)$ with respect to this price, we obtain:

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[2] We note here that in many low-income settings p_q is not a monetary price, but rather represents a shadow price that takes into account the non-pecuniary (mainly time) costs of collecting water from higher quality sources. This is not partly relevant in our empirical application since households must not only pay for water from the CWS plants, but must typically travel outside the home to collect water from the CWS or from other sources.

$$ {}^{ds}/_{dp_q} = \frac{\partial s}{\partial C}\frac{\partial C}{\partial p_q} + \frac{\partial s}{\partial a}\frac{\partial a^*}{\partial p_q} + \frac{\partial s}{\partial q}\frac{\partial q^*}{\partial p_q}, \tag{5} $$

(+) (?) (-) (?) (-) (-)

where the sign of each term is indicated below the equation. Whether illness decreases, increases, or stays the same in this case will depend on the relative size and signs of these three terms, and on the optimal levels of avoidance and use of high quality sources.

An increase (reduction) in p_q clearly implies that the product in the third term will be positive (negative), except for the corner solution where the household consumes no water from high quality sources at the prices in question. This will tend to increase (reduce) illness. The sign of the second term will however depend on the sign of the cross-price elasticity ${}^{da^*}/_{dp_q}$. If the household considers averting behaviors and the higher quality source to be substitutes, then ${}^{da^*}/_{dp_q} > 0$, and an increase (decrease) in p_q will cause the second term to be negative (positive), counteracting the effect on illness implied by the third term. If in contrast averting behaviors and higher quality sources are complements, then an increase (decrease) in p_q will put additional upward pressure on household illness, as households devote fewer resources to both a and q, at the expense of X and l. Whether *a* and *q* are complements or substitutes will hinge on whether the effects of reductions in illness on utility are diminishing or increasing in a and q (in other words on the sign of the second derivatives $\frac{\partial^2 u}{\partial a^2}$ and $\frac{\partial^2 u}{\partial q^2}$).

The first term is also interesting, and relates to the concept of prevalence elasticity (Philipson 2000). C is exogenous from the household perspective, but can be considered to depend on external inputs from government or other community institutions (for example, better water treatment infrastructure or protection of water supplies), as well as community-level averting behaviors $A = \sum_{i \in j} a_i$, where i indexes the households in the community j. Thus, we can write $C = C(G, A)$, where C is decreasing in both G and A.

If we assume that G does not change, then the first term in equation 5 can be expanded as follows (again with signs for each term as shown below the equation):

$$ \frac{\partial s}{\partial C}\frac{\partial C}{\partial p_q} = \frac{\partial s}{\partial C}\frac{\partial C}{\partial A^*}\frac{\partial A^*}{\partial p_q} \tag{6} $$

(+) (-) (?)

As with its effect on private averting behavior, the effect of an increase in p_q on community-level averting behavior A^* will depend on whether this behavior is a complement or substitute to household purchases q. If community averting behavior increases on net in response to higher prices for clean water (corresponding to the case where *A* is a substitute for *q*), then a household may find itself facing somewhat lower disease risk via the effect of term 1 despite the rise in the cost of better water. This in turn will decrease individual demand for a and q. On the other hand, if an increase in p_q leads to lower community averting behavior and clean water purchase (the case of complements), a household may find itself facing increased disease risk via this term, which will in turn increase its demand for both a and q.

The various possible combinations are summarized in Table 1. As shown, unless all three of these inputs – community averting behavior, private averting behavior, and water quality – are complements, the overall sign of the change in illness will be ambiguous. The empirical application described in this paper allows us to consider all three of these responses, and to estimate their cumulative effects on health. In our analyses, we first consider whether households responded to an intervention that made a new and clean source of drinking water available to them by purchasing that water (in other words, did households shift their amounts of q). Second, we explore the implications of this intervention for a costly private averting behavior a, in-house treatment of drinking water. Finally, we investigate the implications of these adjustments for in-house water quality (a measure of d) and illness s, among two groups of households: those who purchased the higher quality water, and those who did not. We also consider and discuss results that provide additional clues on some of the costs and benefits to households of these behavioral adjustments.

4. Empirical strategy

Consistent with the model presented above, we consider the effects of the SWP on five main outcomes measured at the household level: a) Access to CWS water, b) purchase of CWS water (and number of water sources used), c) investment in other averting behavior (namely in-house water treatment), d) in-house drinking water quality, and e) self-reported prevalence of diarrheal disease.[3] We employ a range of strategies to analyze these outcomes, as described in this section.

[3] Analyses of a more complete set of intermediate outcomes and indicators (i.e., a more complete range of water and sanitation related behaviors, time and money spent on collection of drinking water, cost of illness, and other

3.1. Design of the quasi-experimental evaluation

To explore the impacts of the SWP on household behavior, water quality and health, we implemented a quasi-experimental design based on a dual strategy of community-level matching and DiD for estimation of impacts. The SWP was not randomly assigned and was partly demand driven, so it is reasonable to expect that communities selected into the program would differ from communities that opted out, never showed any interest, or were not targeted by the program. To reduce the risk of systematic observable differences between SWP villages and comparison communities, we implemented PSM at the time of study design (Rosenbaum and Rubin 1983, Pattanayak et al. 2010). We created the matched sample of 25 intervention ("treatment") and 25 non-intervention ("control") communities using nearest neighbor matching (without replacement, retaining only the 25 best matches) implemented with pre-baseline characteristics that were obtained from several data sources.[4] The specific variables included in the estimation of the propensity scores for this procedure included the availability of perennial surface water sources, population, and several indicators of socioeconomic status (occupation, education) of community members. The variables explaining participation had the expected signs – that is, they were consistent with the criteria that the CWS/SWP program purported to use to select project villages (Poulos et al. 2006).[5] In the results section, we demonstrate that the PSM procedure was successful in creating samples of households that were observationally similar across the treatment and control arms.

DiD then allows us to compare changes in household outcomes in treatment and control communities measured prior to intervention (at baseline) with those measured during the post-intervention follow-

coping costs) that relate to these outcomes and provide additional insights on the results are provided in the Appendix.

[4] For additional details and evidence of covariate balance following the matching procedure, see Poulos (2006). The data sources used for matching included the Government of India's 2001 Census, the 2003 National Habitation Survey, the 2002-2004 Reproductive and Child Health (RCH) study, and the 1998-1999 National Family Health Survey. Prior to matching, 30 treatment communities were deemed eligible for the study based on two conditions. First, they had not had significant interactions with the implementing organizations beyond their selection into the program at the time of the planning of the baseline survey (and therefore did not yet have a CWS under construction). Second, they were expected to receive CWS units that would be completely operational for at least six months prior to the short-term follow-up survey. In addition, to ensure that control communities were sufficiently similar to treatment communities, the sample of controls retained for matching was restricted to include only villages: a) located in the 3 SWP districts of coastal Andhra Pradesh (Guntur, Krishna, and West Godavari); b) with population exceeding the thresholds for SWP eligibility; c) with no known chemical contamination of drinking water sources (as reported in the 2003 National Habitation Survey); d) that were not included in lists for planned future marketing, construction, or operation of CWS facilities; and e) for which Census data indicated that no households were using untreated surface water for drinking purposes.

[5] These selection criteria are discussed in more detail below but comprised 5 factors: a) access to surface water; b) no known chemical contamination; c) sufficient population; d) evidence of demand for a CWS among leaders and the community; and e) the ability to resources for construction of the plant, and to grant land and water use rights.

up. The difference in differences estimator approximates the "treatment effect" according to equation 1 (Heckman et al., 1998):

$$DID = \{E[Y_{1t}|p(X)] - E[Y_{1c}|p(X)]\} - \{E[Y_{0t}|p(X)] - E[Y_{0c}|p(X)]\}; \qquad (7)$$

where Y is the outcome of interest, the subscripts 0 and 1 refer to pre- and post-treatment, and the subscripts t and c indicate intervention and control unit outcomes, respectively. E is the expectations operator; that is, the DiD measure of impact is the expected treatment effect across treatment units (note that individual subscripts have been suppressed). The estimate is conditional on the propensity score for community participation in the program, $p(X)$, which depends on the covariates X included in the propensity score estimation.

Using this approach, any time-invariant unobservable differences between treatment and control units (not controlled for using PSM) that are related to outcomes are differenced out. This helps to ensure that the measured changes in outcomes are the result of the intervention, and not to these time-invariant unobservable differences, or to other external factors affecting all units over time. The bias due to time-variant unobservables is likely to be negligible for many of the outcomes of interest in this study because we conduct pre- and post-treatment surveys over a relatively short time period and because control group members are drawn from communities that are very similar to treatment communities, at least in terms of the intervention probabilities calculated using PSM.

3.2. Analytical strategy 1: Intent-to-treat (ITT) DiD analysis

In our first set of analyses, we implement the DID approach using a regression framework that includes an interaction variable for the study condition d and for the treatment period T:

$$Y_{ijt} = \alpha + \beta Z_{ijt} + \gamma T_{jt} + \delta d_{jt} + \kappa T_{jt} \cdot d_{jt} + \varepsilon_{ijt}; \qquad (8)$$

where d is equal to 1 if household i is in a treated community, and 0 otherwise, and T is equal to 1 once the intervention has occurred in community j. This regression is a multi-level model: treatment is assigned at the community-level, but we generally measure outcomes at the household level (e.g., diarrheal disease prevalence among children under the age of 5). Z_{ijt} represents a set of household specific controls that are related to the outcome of interest and that vary over time and is not included in our base case specifications (except for age in the regressions for diarrheal disease prevalence), and ε_{ijt} is a household-specific error term. The primary coefficient of interest is κ; this coefficient measures the change in the outcome Y for affected households relative to that for control households, while γ indicates the change in Y over time among controls. Because not all households in a given community choose to purchase drinking water from the CWS (and because not all communities in the treatment group end up having a CWS by the follow-up survey in 2008), the coefficient κ represents an ITT estimate. This ITT estimate indicates the average effect of the community-level intervention across all households living in that community, whether or not they adopt the intervention improvements (Galasso et al. 2004).[6]

3.3. Analytical strategy 2: Estimating impacts on CWS users versus nonusers using DiD

We also estimate the average effect of treatment on the treated (or ATT) by considering impacts on those households who actually purchase water from a CWS in the communities originally assigned to receive the intervention:

$$Y_{ijt} = \alpha + \beta Z_{ijt} + \alpha^{u} U_{ijt} + \alpha^{nu} N_{ijt} + \gamma T_{jt} + \beta^{u} U_{ijt} \cdot d_{jt} + \beta^{nu} N_{ijt} \cdot d_{jt} + \nu_{ijt}; \qquad (9)$$

where U is a dummy variable that is equal to 1 if household *i* is a purchaser of water from the CWS following the intervention, and 0 otherwise. β^{u} is the parameter measuring the effect of the SWP on users of the CWS, or the average effect of the treatment on the treated, while β^{nu} measures the impact of being in a SWP community among those who do not purchase water. The time trend for the change in the outcome of interest among households in (originally-assigned) control communities is again indicated by γ. Relative to the ITT estimates, interpretation of these ATT coefficients is complicated by the fact that purchasers of CWS water may not be directly comparable with non-purchasers, even after controlling for time-varying observable characteristics Z_{ijt} that affect outcomes Y_{ijt}.

3.4. Analytical strategy 3: Estimating impacts on CWS users using ex-post PSM

As an additional way to study the effect of the treatment among users (ATT), we conducted propensity score matching (PSM) to compare users in treatment villages to observationally similar households in the control villages. In implementing PSM, we specified the first stage for selection into use of the CWS using the following logit model:

$$U_{ij,post} = \alpha + \beta Z_{ij,baseline} + \nu_{ijt}; \qquad (10)$$

[6] In sensitivity analyses, we also estimate equation 8 with the community treatment assignment specified according to whether the community actually had obtained a CWS by 2008. Due to concerns over the endogeneity of final treatment status, these are not our preferred estimates of the program's impact.

where $Z_{ij,baseline}$ is a vector of baseline characteristics that are related to the decision to use the CWS. Based on theoretical expectations about the likely drivers of use and on data availability with regards to those drivers, we developed both a parsimonious and more complete list of such characteristics for inclusion in the model. The full list of such criteria included household income, household size, the number of children under 5 and prevalence of diarrhea among those children, literacy of the household head, age of household head, the time spent collecting water, and indicators for whether the household reported being very satisfied with its main drinking water source, for treating water in-house, for believing that unsafe water causes diarrhea, for thinking that the government should pay for improvements to water supply, and for participation of household members in village cleaning activities. We tested the sensitivity of our results to inclusion of this full list and a shorter list of these variables.

5. Description of the intervention and data

5.1. The Safe Water Program (SWP)

The SWP implemented in Andhra Pradesh combines a CWS that uses advanced drinking water treatment with a health promotion program designed to encourage the consumption of safe drinking water. The CWS collects and conveys water from a community surface water source to a storage and treatment unit, using an electric pump. The water is then filtered, passed through UV radiation units (or in some cases, reverse osmosis), treated with ozone, and stored until it is distributed to customers via taps located at the facility. A non-profit foundation helps to identify eligible communities and facilitate the financing requirements of the SWP interventions, while a specialized water NGO is responsible for technical aspects, including construction of the system and operations and maintenance of the system during the first eight years. The intervention is designed such that most communities recover sufficient costs to gain ownership of the CWS at the end of this period.

At the time of the evaluation, community eligibility for an SWP was determined based on five factors: a) access to a perennial source of surface water; b) no chemical contamination in communities using systems other than reverse osmosis (as indicated by district engineers, with verification for arsenic and fluoride); c) a population of 4000 or more (or 2000 for a smaller, modified CWS); d) interest from both local leaders and the community as a whole; and e) the ability to mobilize a 20-40% down payment for construction of the CWS, in addition to the willingness to grant land and water use rights where it would be constructed.[7] Determining community interest and ability to mobilize a down payment involved a series of meetings and marketing efforts spread over weeks to months and targeted at local leaders. The first three of these eligibility criteria are directly observable, whereas the second two are not, which provides the motivation for using PSM to create a matched sample based on a wider set of community characteristics that are correlated with selection into the program.

Salaries for water operators and operations and maintenance expenses at the CWS are paid using revenues from the sales of water. The water and hygiene promotion staff were hired and trained by the institutions supporting the project. These promoters visited households to describe the system and provide water quality information, collect baseline data on water sources and perceptions, and build interest by communicating the benefits of water treatment. Once construction was completed, residents could register, pay the deposit for an approved 12 or 20 liter water container (80-120 Rs.), and begin purchasing water for a single-use cost of 1-2 Rs. depending on the facility and the size of the container.[8] The SWP continued to employ the water promoter to visit households and promote use of the facility and adoption of safe water handling practices during the initial period following the establishment of the CWS.

5.2. Sampling

A target sample size of 2,500 households in 50 villages was developed to allow for detection of anticipated effects on diarrheal prevalence among children under the age of five (Poulos et al. 2006). In each survey village, households were randomly selected from village lists of all those residing in the community, and only those having at least one child under 3 years of age in 2006 were included. Fifty-five households were enrolled from each community; it was hoped that the extra 10% would protect against loss of power due to attrition of households between baseline and follow-up. Unfortunately, we found in the follow-up survey that an unexpectedly high number of study households could not be recontacted due to high rates of out-migration in these communities. As a result, we replaced households that could not be relocated with new households having at least one child under 5 years of age. So long as migration is not related to the SWP (which in the short term seems plausible and which

[7] The balance of the cost of the CWS was financed with commercial loans backed by the Acumen Fund's loan guarantee, that were repaid using revenues from sales of water produced by the CWS. The financial model for the program assumes that the average system would be paid off and ownership transferred to the community after 8 years.

[8] Users could purchase single-use coupons entitling them to fill their containers, booklets of coupons, or punch cards that were valid for one month. If they opted to discontinue use of the CWS, they could return the project water can and obtain a refund of their deposit

we verify using balance tests), these replacements should not affect our ability to accurately identify program impacts.

5.3. Data

The data for our analysis come primarily from two waves of surveys conducted in the sample villages. Due to the threat of unobservable time-varying confounders, the bulk of our analyses use the data from the baseline (prior to any CWS project activities) and follow-up surveys conducted in 2006 and 2008 (the timing of this first follow-up survey was determined based on qualitative assessments of field progress with CWS installations). Since diarrheal disease is a key outcome variable in this analysis, both of these waves were conducted in October, shortly after the monsoon, in order to avoid inconsistencies arising from the seasonality of diarrhea prevalence, and to coincide with peak levels of diarrhea. Also, for a reduced set of outcomes, we present long-term impacts using data collected in a later wave, conducted in January 2011. After 2008, CWS promoters broadened their marketing strategy, which led to implementation of new systems throughout the region (including in many control areas). Analysis of the data from 2011 therefore allows us to see whether there were any long-term effects on the original treatment communities relative to these broader trends.

To analyze the CWS' impacts, we used carefully pre-tested household and community surveys and water quality sampling to measure variables related to our final outcomes (as well as a variety of intermediate variables). The household questionnaires thus included questions on: demographics (e.g., age and sex of household members); caste and poverty levels; education; diarrhea prevalence (2-week and 1-month recall) and cost of illness; water sourcing and consumption; water handling, storage and treatment practices; sanitation and housing conditions; and a variety of socio-economic characteristics. The community questionnaire was used to collect information on a range of community-level variables, including roads, electricity, sanitation conditions, water sources, health and educational facilities; general availability of employment opportunities, credit, and markets; and important governmental and nongovernmental programs providing services in the community. This questionnaire was administered to key informants such as the village leader, governing council members, or a member of the local water and sanitation committee. In addition to these questionnaires, water samples were tested from both community sources, and from a sub-sample of 1,396 household storage containers (and 1,161 in round 2). The samples were tested for total coliform and *E. coli*.

6. Results

6.1. Descriptive statistics and sample balance

We begin our discussion of results by describing the sample of households and communities, and presenting balance tests on the treatment and control samples using the baseline data obtained in 2006. Table 2 presents summary statistics for the original (2752 households) and follow-up (2361 households) samples; baseline balance for a variety of relevant variables across treatment and control arms is then shown in Table 3. Average household size in 2006 was 4.5 members, with 1.4 of those members being children under 5 years of age. Almost all survey respondents were female and their average age was 23 years old. The average household income was roughly 2760 rupees (Rs.) per month.[9] By 2008, following strong economic growth in Andhra Pradesh, households in both treatment and control villages were significantly better off, with average monthly household income rising to about 4290 Rs., though 47% of households still reported being below the poverty line (a very large reduction from the baseline level of 91%). Respondents reported that 54% of household heads were literate at baseline, with an average number of years of schooling of only 4.3 years. At baseline, community participation rates were relatively low, with only 13% of households stating that at least one member participates in neighborhood cleaning activities and 15% of households having at least one member who attended a community meeting (Gram Sabha) in the six months prior to the survey.

There was substantial variation in household sanitation and hygiene habits at baseline, with just under half of the sample (48%) practicing open defecation, and the rest having access to a private toilet. Respondents were asked when and how they washed their hands in the past 24 hours. On average respondents reported washing their own, and their young (under five years old) children's hands with soap 1.8 out of 5 and 0.6 out of 2 critical times, respectively – these critical times were (1) before preparing food or cooking (adults only), (2) before eating, (3) before feeding children (adults only), (4) after changing baby/handling child's feces (adults only), and (5) after defecation. Handwashing with water alone, though, was more common: respondents used water alone on their own and their young children's hands at 4.3 and 1.7 of those times, respectively.

Safe water storage behaviors also varied considerably within the sample. In 2006, while 97% of households fully covered their water storage container and 84% washed their storage container daily, only 11% used a narrow mouth water vessel and only 8% elevated their main drinking water container

[9] At the time of the baseline survey, US$1 = 45 Rs.

more than 3 feet off the ground. Thirteen percent of households claimed to remove drinking water from containers using a method that minimizes the possibility of contamination. Additionally, enumerators observed flies near 32% of households' drinking water containers. Nearly half (48%) of households treated or filtered their drinking water by boiling, filtering or using chemicals. Households used an average of 1.6 water sources and reported consuming an average of 56 liters per capita per day.

At baseline, 9% of children under 5 and 10% of children under 3 had had diarrhea in the two weeks prior to the survey, while the rate of diarrhea prevalence for adults was only 2%. Ten percent of households whose water was analyzed tested positive for *E. coli* contamination. In 2006, prior to the implementation of the SWP, only 3% of households said they had access to some type of treated commercial (non-bottled) water supply, and none were regular users of such sources. By 2008, over 45% of households had access to such commercial water, though only 8% of households in the sample reported buying water from a CWS.

As indicated previously, we used PSM to draw a sample of matched treatment and control villages prior to undertaking the baseline survey, using secondary data obtained from a variety of data sources. Balance tests of 28 key variables – including our primary outcomes plus a range of other demographic, water sourcing, and water-related behaviors – collected at baseline confirms that the treatment and control arms were generally balanced, and that there was no differential attrition across treatment and control groups (Table 3). We found only 3 statistically meaningful imbalances in treatment and control communities. First, treatment households reported significantly less satisfaction with their main drinking water source at baseline (p=0.04), although more than half (53%) of treatment households still reported being very satisfied (compared to 69% in control communities). Perhaps for similar reasons, treatment households were also more likely to think that water supply was the most important environmental problem in their village (p=0.02), and less likely to think that sanitation and hygiene was (p=0.01).[10] Given that treatment households were sensitized to the fact that CWS construction was planned for their community at the time of the baseline survey (i.e., treatment communities had already been selected for the program), these differences are not surprising.

6.2. Short-term impacts of the Safe Water Program

[10] A large number of other characteristics were also assessed for balance (results not shown). This set of tests revealed differences in the number of community surface water bodies and agricultural loans (higher in the treatment group), and use of neighbors' toilets, educational loans, and sewing machine ownership (lower in the treatment group). The number of such imbalances is not inconsistent with the expected probability of Type 1 errors.

The ITT estimates from our DID analysis of the impacts of the SWP on the outcomes of interest are mostly unremarkable (Table 4). These estimates are derived from the regression model shown in equation 8; as indicated in the notes below Table 4, our base specification does not include controls (and the results are not sensitive to their inclusion).[11] We observe that access to a CWS increases by 43 percentage points among treatment households relative to controls. At baseline, only 3% of households reported access to commercialized, treated water. The DiD estimate of 43 percentage points shows, however, that reported access in 2008 is not universal (it rises to 67% overall, since control households report access of 22% to such water in 2008). The lack of universal access in the treatment group is partly due to the fact that not all communities originally scheduled to receive a CWS actually had one by 2008 (of the 25 treatment communities, 20 received the planned CWS). Similarly, 2 control communities ended up receiving a CWS by 2008, such that some control households gained access to a CWS in their villages. Others in the control group became aware of, and reported access to CWS in neighboring treated villages. Due to the endogenous selection of such communities into treatment, our preferred estimates of overall impacts of the SWP are these ITT estimates; if we use actual treatment status in 2008 the effect on access in treated communities is a net increase of 83 percentage points over and above the reported access of 12.5% among households in the control group, representing nearly 100% reported access (results not shown).

Looking beyond access alone, we find that the ITT estimates of impacts on use of CWS water are only 10 percentage points (13% of treatment households report being users vs. 3% of control households). In those communities actually receiving a CWS by 2008, use reaches almost 18% (compared to 1% in communities without a CWS). These levels of uptake of CWS water are modest, however, and may partly explain why so few of the other outcomes tracked by the evaluation change significantly among treatment households when using the ITT estimator (Table 4). We do find that households in treatment communities report using 0.14 more drinking water sources on average, and become less likely to treat their water at home (by 7.3 percentage points). These changes suggest that treatment households may maintain use of alternative sources but that many of them substitute more expensive source water with reduced investments in other averting behavior. There is a somewhat greater percentage of samples with *e. coli* contamination among households in treatment communities (by about 8 percentage points), although these results are not statistically distinguishable from zero. There do not appear to be any impacts on average diarrheal disease prevalence among young children in treatment communities.

[11] These controls include income, age of the respondent, and the number of nearby water sources.

To look more specifically at CWS users, we first estimate the model shown in equation 9 that ignores the possibility of confounding by time-varying unobservable factors that are related to selection into purchases from the CWS. As expected, users from villages originally assigned to the treatment group (N = 163) report greater access to the CWS; reported access in this group is 77 percentage points higher than that among households in control communities. Non-users (N =1,011) in treatment communities report 60% access (this corresponds to 22% access among controls + the 38% increase relative to these), but experience no changes in the other outcomes of interest. The changes in several other impact variables among CWS users however run counter to expectations. By 2008, CWS users have 14% higher rates of *e. coli* contamination in their household drinking water containers (though this estimate is imprecise and not statistically different from that among non-users or controls). These households also experience increases in two-week diarrheal disease prevalence (by 4% and 7% among under 5 and under 3 year olds, respectively). These higher levels of risk may be related to reduced in-house averting behavior, and specifically treatment of drinking water; users are 25 percentage points less likely to treat their water than control households at follow-up (and there is no significant change among non-users relative to control households). At the same time, CWS users increase the number of drinking water sources from which they collect water by 0.7 sources on average, suggesting that most households continue to use their prior sources to some extent, which may compromise water quality.

In the Appendix (Table A1), we present estimates of impact on a range of other indicators of water use that are consistent with these findings. In particular, we show that users increase expenses on drinking water relative to non-users and households in control communities. Based on the prices charged in intervention communities, the estimated increases correspond to about 20-30 containers of water from the CWS each month. Users also spend an additional 18 minutes per trip to their main drinking water source, and have increased ownership of narrow mouth water containers by 24 percentage points relative to controls, which is consistent with the CWS requirement that households own a narrow mouth container. They also use somewhat safer means of removing water from containers, by 14 percentage points more than controls. None of these variables are different for non-users relative to control households, and few of the ITT estimates (the only exceptions are for water purchases, water consumption, and time spent per trip to the main source) reveal overall differences between households in treatment and control communities.[12]

6.3. Short-term impacts among CWS users accounting for selection

As an additional way to study the effect of the treatment among users of the CWS, we conducted propensity score matching to compare outcomes for these households to observationally similar households in the control villages who did not have the same opportunities to access a CWS. For this analysis, 130 treated (user) households were matched to an eligible sample of 929 control households from untreated communities; the results of parsimonious and more complete selection models are shown in Table 5.[13] The results of the first stage support the idea that there is positive selection into use of CWS: users tend to be more educated and somewhat better off, and also tend to have more young children and are more likely to engage in averting behaviors at baseline. They are also less likely to state that the government is responsible for paying for improvements to the water supply.

We analyzed the same set of outcomes and downstream impacts for the matched samples of users and controls as in the OLS analyses discussed above. The results of the PSM and ATT analyses are generally consistent, but the former mostly appear stronger, consistent with the pattern of positive selection into use. User households have significantly greater access to commercial treatment plants and use a greater number of drinking water sources (Table 6). They have more positive E.coli tests (estimates of this increase range from 8 to 16 percentage points), and become significantly less likely to treat their water at home (by 12 to 13 percentage points). As with the OLS estimates, children in households using the CWS also appear to suffer increases in diarrheal disease prevalence (by 3 to 6 percentage points). Results for other indicators of change are presented in the Appendix (Table A2) and are not substantively different from the OLS results shown in Table A1.

As an added check on the robustness of these PSM estimates, we also assessed differences in outcomes between users and their matched controls for outcomes observed at baseline, prior to the installation of the CWS plants in the treatment communities. We note very few meaningful differences; users only have slightly higher treatment of water at home (the opposite of what is observed at follow-up).

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[12] If we compare communities that were actually treated by 2008 with those that were not, the ITT differences increase but most remain insignificant at conventional statistical levels, with the exception of 1-month diarrhea prevalence rates, which are somewhat higher in actually treated communities for children < 3 years old ($p<0.1$).
[13] Six user households were excluded as being off support, and the remainder were excluded due to missing covariates required for the first stage selection model. These users missing covariates were mostly replacement households who were only enrolled in 2008 and therefore did not have the required data for the first stage.

Reported diarrheal disease rates at baseline are also somewhat higher among eventual users, but these differences are not statistically distinguishable from zero.

6.5. Long-term impacts among households in treatment communities and CWS users

We conclude the analysis of CWS impacts by examining longer term changes in treatment versus control communities. For this analysis, we utilize data collected in 2011 in an additional wave of surveys. Given the changes detected among users in particular in the preceding section, we would ideally focus solely on users of CWS water for this assessment, but this is complicated by two issues. First, there is nearly total contamination of the treatment and control samples of communities by 2011. Specifically, 78% of households report access to the CWS in communities originally assigned to the treatment group in 2011, while access reaches 77% in those originally assigned to the control group (Figure 1). On the one hand, this can be taken as evidence that the matching algorithm used to create a sample of control communities for the study that were similar to treatment villages was successful; unfortunately it also means that we cannot easily compare users in treated communities to a set of control households that no longer have access to a CWS. Second, the set of users is dynamic and we only observe these households at very specific points in time. These dynamics make interpretation of the effects on users difficult, since use may be driven by unobserved factors that are endogenous. Thus, for assessment of impacts over the longer term, we first present the results of ITT analysis to address the question of whether the original assignment to participate in the SWP had any long term impacts on households living in those communities. We then consider users in more detail solely using DiD OLS regression (since PSM is no longer possible given the sample contamination).

Not surprisingly given the previous results, we find no impact of the program on households in the original treatment communities over the longer term (Table 7 Columns A1 and A2). Even the impacts on use of the CWS over the short term disappear once control communities gain access to treatment facilities, as shown by the significant negative DiD coefficient on use in treatment communities during the later period. On the one hand, this could be seen as evidence of success of the business model for the CWS, which managed to spread across the region during this time. Nonetheless, the lack of positive impacts on users noted in the preceding section raises questions about the value of those changes. In addition, in both treatment and control communities, use of the CWS is very low by the end of the survey period (ranging from 3-6% across control and treatment communities in 2011) despite the widespread awareness of such supplies (Figure 1). In fact, the only persistent average impact on households in treatment communities appears to be in lower household treatment of drinking water, which decreases by 11% relative to in-house treatment in control communities.

Turning to the DiD analysis of impacts among users over the period 2006-2011, we explore impacts using two definitions of users. The first (reported in Columns B1 and B2) compares only users in communities originally assigned to the treatment group with all households living in control communities. Interpretation of results over the period 2008-2011 and 2006-2011 is complicated because many control households did gain access to CWS water over the later period, and because there is very little overlap between users in the two samples.[14] We observe no differences between users in these original treatment communities relative to households from control communities in terms of averting behaviors or diarrheal disease prevalence over the long term (Table 7). Analyzing a variety of other outcomes (in the Appendix), we observe that users in originally treated communities do become less likely to be using narrow-mouthed containers in 2011, and partake in less frequent hand-washing.

The second set of comparisons (reported in Columns C1 and C2) offers similar evidence, this time for users in both treated or control communities compared to non-users.[15] We again see few significant differences, although CWS users in this case do appear slightly more likely to also practice in-house water treatment over the later period; this result is driven by the subgroup of users in control communities. As with the ITT results, the addition of control variables for income, age of the respondent, and number of nearby water sources does not alter the coefficients in a substantial way. Using the same specifications for predicting use in 2011 as in 2008 (shown in Table 5), we determine that user households in 2011 in both treated and control communities remain more likely to have been treating drinking water at baseline than non-users (results not shown), but that few other factors predict use in 2011. Overall, we conclude that these users are somewhat more aware of the CWS than nonusers even in 2011, but that the only changes in behavior and outcomes among users over the long term that are discernible using DiD analysis are in slight adjustments to hygiene and other risk-averting water behaviors. Perhaps more importantly, very few (only 6 households) of the users from 2008 were still purchasing CWS water in 2011.

[14] In particular, there are 163 CWS users in treated communities in 2008, and 55 in 2011, but only 6 of these households are users in both periods.
[15] In this case, there are 200 users in 2008, and 86 in 2011, but only the same 6 households are users in both periods.

7. Discussion

This paper examined the impact of the SWP program, implemented in Andhra Pradesh, India, on a representative sample of households living in communities originally targeted by the intervention. The SWP combined advanced community water systems (CWS) at the village-level with hygiene and behavioral change messaging aimed at marketing CWS water and improving safe water practices at the household level. Using a quasi-experimental approach that combined pre-intervention matching on village-level Census characteristics of treated and control communities with difference-in-differences analysis, we observe low purchase rates for CWS water (ranging from 5-10% over the time horizon for the study) and little evidence of impacts on households in treated communities, at least on average, in either the short (2 years post-baseline, in 2008) or long term (5 years after baseline, in 2011). In parallel with the modest increase in CWS water use, we observe a concurrent decline in in-house water treatment (by about 7 percentage points).

Additional analysis using both regression and post-survey propensity-score matching provides evidence that CWS users in treated communities regularly collected water from more sources, were especially likely to stop using in-house treatment, and had worse water quality as well as marginally higher child diarrheal disease rates in 2008, suggesting that the substitution to CWS water was neither complete nor sufficient to improve water quality at the household level. Because such households were wealthier, had more education, and were more likely to treat their water at baseline, the results obtained using PSM (to find similar households in control communities) are somewhat stronger than those obtained using simple DiD regression. By 2011, the majority of households in control villages had also gained access to CWS water plants, and we observed that most differences between treatment and control households, or between user and non-user households, had disappeared, with the exception of somewhat persistent declines in in-house water treatment among CWS users in the originally treated communities.

Overall, our findings suggest that the CWS plants succeeded in serving only a small fraction of households in their communities and did little to lessen the drinking water quality challenges faced by these households. The results are also largely consistent with the theory of constrained utility maximization for production of household environmental health (Pattanayak and Pfaff 2009). In particular, this theory motivates a hypothesis that additional expenditures on water from the CWS might lead to substitution away from other time and resource-intensive activities such as household water treatment, if these inputs are considered substitutes. Without clear evidence of complementarities between specific health inputs, households doing their own cost-benefit analysis would perhaps instead seek to maintain higher levels of utility-enhancing consumption and leisure rather than investing in high levels of multiple inputs, thereby negating the potential positive impacts on health. Indeed, we observed limited purchase of high quality water even at a low price, as users spent time and money on accessing this source, and offsetting reductions in water treatment, which somewhat decreased other water-related coping costs. Meanwhile, the behavior change features of the SWP did not appear to have many positive effects on other safe water practices: the only averting input that increased in the short term was the use of narrow-mouthed containers (a required complement for purchasing CWS water). Thus, overall community-level risks (as indicated by water sample contamination and diarrheal disease prevalence) may have been unchanged or may even have increased with the decline of in-house treatment. More intensive social marketing or use of salient messaging regarding water quality may be required to promote the maintaining of in-house averting behaviors in this context (Pattanayak et al. 2009, Hamoudi et al. 2012).

These results are noteworthy given that the basic intervention model of advanced water treatment plants has been successfully extended across many communities in rural Andhra Pradesh, and that similar kiosk-based alternatives are increasingly found across a range of locations in less-developed countries (Kariuki and Schwartz 2005, Sima et al. 2012, Opryszko et al. 2013). While this spread of the decentralized community water treatment model suggests that it is often financially viable, there is no rigorous evidence that it provides water quality and health improvements in settings where in-house water storage is required. In effect, the relatively modest rates of household consumption of water from such plants may stem from the cost of such water, the inconvenience of accessing a community-level kiosk (relative to other water sources), or the knowledge that the plant does not effectively provide improved water quality or protection from diarrheal diseases.

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Tables and Figures

Table 1. Potential changes in illness resulting from a water source improvement

Water quality & community averting behavior / Water quality & private averting behavior	Substitutes	Complements
Substitutes	$\frac{\partial s}{\partial C}\frac{\partial C}{\partial A^*}\frac{\partial A^*}{\partial p_q}+\frac{\partial s}{\partial a}\frac{\partial a^*}{\partial p_q}+\frac{\partial s}{\partial q}\frac{\partial q^*}{\partial p_q}={}^{ds}/_{dp_q}$ (+) (-) (+) (-) (+) (-) (-) = ?	$\frac{\partial s}{\partial C}\frac{\partial C}{\partial A^*}\frac{\partial A^*}{\partial p_q}+\frac{\partial s}{\partial a}\frac{\partial a^*}{\partial p_q}+\frac{\partial s}{\partial q}\frac{\partial q^*}{\partial p_q}={}^{ds}/_{dp_q}$ (+) (-) (-) (-) (+) (-) (-) = ?
Complements	$\frac{\partial s}{\partial C}\frac{\partial C}{\partial A^*}\frac{\partial A^*}{\partial p_q}+\frac{\partial s}{\partial a}\frac{\partial a^*}{\partial p_q}+\frac{\partial s}{\partial q}\frac{\partial q^*}{\partial p_q}={}^{ds}/_{dp_q}$ (+) (-) (+) (-) (-) (-) (-) = ?	$\frac{\partial s}{\partial C}\frac{\partial C}{\partial A^*}\frac{\partial A^*}{\partial p_q}+\frac{\partial s}{\partial a}\frac{\partial a^*}{\partial p_q}+\frac{\partial s}{\partial q}\frac{\partial q^*}{\partial p_q}={}^{ds}/_{dp_q}$ (+) (-) (-) (-) (-) (-) (-) = **+**

Table 2. Sample descriptive statistics

	2006		2008	
Variable	**N**	**Mean**	**N**	**Mean**
Demographics				
Female Respondent	2752	1.00	2361	0.99
Respondent's Age	2752	23.0	2361	25.1
Average total monthly HH income (Rs.)	2751	2756	2349	4292
HH faced serious crisis in the past year	2749	0.16	2292	0.06
HH is below poverty line (bpl)	2725	0.91	2310	0.47
Average years of schooling of HH head	2749	4.31	2353	3.69
Average HH size	2752	4.48	2344	4.57
Number of children under 5	2752	1.36	2361	1.19
Community participation				
HH participates in neighborhood cleaning	2751	0.13	2357	0.10
HH attended Gram Sabha, prior 6 months	2742	0.15	2311	0.22
Water supply				
HH uses a private connection for drinking	2752	0.29	2361	0.25
HH uses a public tap for drinking	2752	0.51	2361	0.43
HH uses a public well for drinking	2752	0.07	2361	0.11
HH uses a private well for drinking	2752	0.11	2361	0.08
HH uses surface water for drinking	2752	0.04	2361	0.02
Access to commercial treatment plants	2752	0.03	2361	0.45
HH uses water from CWS	2752	0.00	2361	0.08
Water consumption (lpcd)	2752	56.1	2361	27.7
Number of water sources used	2752	1.56	2361	1.67
Number of drinking water sources used	2752	1.08	2361	1.14
HH very satisfied with main drinking water source	2752	0.61	2361	0.70
Water treatment, handling, sanitation, and hygiene				
HH practices open defecation	2751	0.48	2357	0.40
Flies observed near main drinking water vessel	2645	0.32	2352	0.13
Main drinking water vessel is fully covered	2751	0.97	2352	0.99
Main drinking water vessel has narrow mouth	2749	0.11	2352	0.12
Main drinking water vessel elevated > 3 feet	2684	0.08	2352	0.13
Wash drinking water storage containers daily	2752	0.84	2361	0.81
Water is removed from container with safe method	2750	0.13	2352	0.07
Treats or filters water before drinking	2752	0.48	2361	0.30
# of times adults wash hands with soap at critical times	2752	1.83	2358	1.33
# of times children wash hands with soap at critical times	2752	0.61	2358	0.59
Water quality and diarrheal disease				
HH has ecoli	1396	0.10	1161	0.20
2 week diarrhea, all children under 3 years old	2524	0.10	1196	0.05
2 week diarrhea, all children under 5 years old	3745	0.09	2818	0.03
2 week diarrhea, all adults	8573	0.02	8044	0.01
Cost of diarrheal illness (Rs./month)	2752	535	2361	142
Coping costs				
Time spent collecting water (minutes/month)	2752	664	2361	1027
Costs of treating water (Rs./month)	2752	296	2361	181
Costs of storing water (Rs./month)	2622	8	1807	11
Water purchase cost – all sources (Rs./month)	2752	14.9	2361	17.6
Total coping costs (Rs./month)	2752	364	2361	287

Notes: Due to laboratory constraints, *E coli* was only tested in a randomly selected half of the sample. Observation of drinking water containers was attempted, but was not possible in 102 households in 2006 and 534 households in 2008; outcomes for these households are self-reported. Prevalence of diarrhea, measured based on having 3 or more loose stools within any 24 hour period, is for all sample children within the specified age groups. Coping costs are calculated as described in the text.

Table 3. Balance tests for treatment and control communities

Household Characteristic	Treatment	Control	p-value
Sample size	1377	1375	n.a.
Demographics			
Respondent is female	99.9%	100%	0.15
Respondent's age	22.9	23.1	0.27
Average household income (Rs./month)	2,786	2,726	0.67
Household faced a serious crisis in the prior year	18.1%	13.0%	0.18
Household is below the poverty line (bpl)	92.1%	90.9%	0.65
Average schooling of respondent (years)	4.3	4.4	0.82
Respondent is literate	53.4%	53.8%	0.91
Average size of household	4.5	4.5	0.98
Household was lost to follow up	16.2%	14.9%	0.55
Water sourcing			
Household uses drinking water from a private water connection	33.8%	33.6%	0.97
Household uses public taps for drinking water	87.5%	89.7%	0.65
Household uses public wells for drinking water	70.1%	71.4%	0.91
Household uses surface water for drinking water	15.3%	13.3%	0.75
Household is very satisfied with main drinking water source	53.0%	68.8%	0.04**
Distance from house to nearest surface water source (in minutes)	8.5	8.2	0.78
Water treatment, handling, sanitation, and hygiene			
Household practices open defecation	50.6%	45.0%	0.27
Household has a private toilet	50.1%	52.9%	0.55
Flies observed near main drinking water storage vessel	32.8%	30.8%	0.69
Main drinking water storage vessel is fully covered	96.7%	96.8%	0.96
Main drinking water storage vessel has a narrow mouth	10.1%	12.1%	0.72
Respondent washes drinking water storage containers daily	84.5%	83.3%	0.79
Household treats or filters water before drinking it	51.5%	44.2%	0.17
# of times adults wash hands with soap at critical times	1.9	1.8	0.64
# of times children wash hands with soap at critical times	0.6	0.6	0.76
Community environmental problems			
Respondent thinks sanitation / hygiene is the most important problem	14.9%	25.4%	0.01***
Respondent thinks water supply is the most important problem	14.2%	7.2%	0.02**
Household members participate in activities for cleaning neighborhood	14.1%	12.9%	0.77
Diarrheal disease			
Child (≤3 years old) had diarrhea in the prior two weeks	11.5%	11.5%	1.00
Child (≤5 years old) had diarrhea in the prior two weeks	12.8%	13.3%	0.82
Any member of household had diarrhea in last two weeks	21.3%	21.2%	0.98
% lost to attrition in 2008	22.1%	19.3%	0.34

Notes: Balance tests were conducted by regressing the variable value in 2006 on treatment assignment using OLS. Standard errors are clustered at the community level, and statistical significance is denoted by the asterisks (1% level ***; 5% level **; 10% level *). Observation of drinking water containers was attempted, but was not possible in 102 households in 2006; outcomes for these households are self-reported. Prevalence of diarrhea, measured based on having 3 or more loose stools within any 24 hour period, is for all sample children within the specified age groups.

Table 4. Comparison of key outcomes for treatment and control households: OLS regression

Outcomes	Intent to Treat (ITT)[1]			Average Treatment Effect[2]			
	Assigned to treatment	R^2	N	ATT Users	ATT Non-users	R^2	N
(1a) Access to commercial water treatment plants	0.43*** (0.11)	0.40	5108	0.77*** (0.082)	0.38*** (0.12)	0.42	5108
(1b) Use of commercial water treatment plants	0.10*** (0.033)	0.076	5108				
(2) Number of drinking water sources used	0.14*** (0.051)	0.026	5108	0.68*** (0.12)	-0.04 (0.11)	0.066	5108
(3) % household samples with E. coli [3]	0.079 (0.051)	0.022	2556	0.14 (0.094)	0.07 (0.04)	0.022	2556
(4) % of households treating water at home	-0.073* (0.041)	0.036	5108	-0.25*** (0.060)	-0.048 (0.043)	0.038	5108
(5) 2-week diarrhea prevalence in children under 5 years of age [4]	0.017 (0.013)	0.022	6559	0.041* (0.021)	0.013 (0.013)	0.022	6559
(6) 2-week diarrhea prevalence in children under 3 years of age [4]	0.016 (0.018)	0.013	3719	0.073* (0.043)	0.006 (0.019)	0.015	3719
Household fixed effects	Yes			Yes			

Notes:

[1] We report the coefficient κ on T*d shown in equation 2, where treatment is assigned at the community level based on planned CWS installation in 2006. These coefficients were estimated using an OLS regression model that does not include any covariates *Z*, except for the diarrhea prevalence regressions, which also control for age. Inclusion of additional controls for income, age of the respondent, and number of water sources within 5 minutes of the home did not alter the results (not shown). Standard errors, shown in parentheses, are clustered at the community level, and statistical significance is denoted by the asterisks (1% level ***; 5% level **; 10% level *).

[2] We report the coefficient β^u from equation 3 for users, and β^{nu} for non-users. For all but the diarrheal disease outcomes, there are 163 users and 1,011 non-users, with the balance being control households. As with the ITT, these are estimated using an OLS regression model for the simple specification that does not include any covariates Z, except for the diarrhea prevalence regressions, which control for age. Additional controls for income, age of the respondent, and number of water sources within 5 minutes of the home did not alter the results (not shown). Standard errors, shown in parentheses, are clustered at the community level, and statistical significance is denoted by the asterisks (1% level ***; 5% level **; 10% level *).

[3] Due to laboratory constraints, *E coli* was only tested in a randomly selected half of the sample.

[4] Prevalence of diarrhea, measured based on having 3 or more loose stools within any 24 hour period, is for all sample children within the specified age groups.

Table 5. Logit Model for first stage of PSM: Selection into CWS use in 2008

Variable	Full model	Parsimonious model
Household income ('000 Rs/month)	0.019 (0.022)	0.038* (0.023)
Household size	-0.048 (0.084)	
Number of children under 5 in household	0.34*** (0.13)	0.30*** (0.12)
Household head is literate	0.48** (0.22)	0.33* (0.20)
Age of head of household	0.020** (0.008)	
Household diarrhea prevalence among children under 5	0.41 (0.31)	
Household head is very satisfied with main drinking water source	0.21 (0.30)	0.21 (0.30)
Time spent collecting water ('00 minutes/month)	-0.01 (0.013)	-0.012 (0.014)
Household treats drinking water	0.21 (0.15)	0.27* (0.16)
Household head thinks unsafe drinking water can cause diarrhea	0.25 (0.27)	
Household thinks government should pay for improvements to water supply	-0.49*** (0.18)	-0.49*** (0.17)
Household members participate in village cleaning activities	0.035 (0.39)	
Constant	-3.3*** (0.83)	-2.5*** (0.48)
N	1146	1156
Pseudo-R^2	0.039	0.029

Notes: Dependent variable is use of the CWS at the time of the survey in 2008, and regressors are survey measures at baseline, in 2006. Standard errors, shown in parentheses, are clustered at the village level, and statistical significance is denoted by the asterisks (1% level ***; 5% level **; 10% level *). These models are used to generate the propensity scores used for obtaining the matched samples that are considered in Table 5.

Table 6. Comparison of key outcomes for treatment and control households: Propensity Score Matching

	Outcomes in 2008		Outcomes in 2006		
Outcomes	**ATT: Full model**	**ATT: Parsimonious model**	**ATT: Full model**	**ATT: Parsimonious model**	**N**
(1a) Access to commercial water treatment plants	0.82***	0.81***	0.008	-0.008	124
	(0.045)	(0.049)	(0.013)	(0.018)	
(2) Number of drinking water sources used	1.2***	1.2***	0.064	0.081	124
	(0.063)	(0.072)	(0.047)	(0.054)	
(3) % household samples with E. coli	0.079	0.16**	0.00	-0.045	66
	(0.094)	(0.079)	(0.046)	(0.058)	
(4) % of households treating water at home	-0.13*	-012*	0.072	0.14**	124
	(0.066)	(0.070)	(0.075)	(0.063)	
(5) 2-week diarrhea prevalence in children under 5 years of age[1]	0.036*	0.032	0.028	0.012	124
	(0.020)	(0.023)	(0.044)	(0.039)	
(6) 2-week diarrhea prevalence in children under 3 years of age[1]	0.056**	0.051*	0.056	0.019	107
	(0.022)	(0.028)	(0.054)	(0.052)	

Notes:
The first stage propensity scores were obtained using the logit model specifications shown in Table 4. To maintain the same samples for comparison across all 4 sets of columns, only households present during the baseline survey are included. Total eligible user households for the comparison is thus 130, except for e.coli (only 66 users tested) and diarrhea among children under 3 (112 users). A small number of these users (3-6) were found to be off support and are therefore excluded; the final sample of users for each comparison is shown in the rightmost column. Similarly, there are 929 households from control communities eligible for matching (and 463 for e.coli); all of these were on support. We use 1-1 nearest neighbor matching, trimming the worst 5% of matches. All standard errors are bootstrapped and shown in parentheses, and statistical significance is denoted by the asterisks (1% level ***; 5% level **; 10% level *). Differences in outcomes for 2006 (prior to treatment) are included as a falsification test.

[1] Prevalence of diarrhea, measured based on having 3 or more loose stools within any 24 hour period, is for all sample children within the specified age groups.

Table 7. Outcomes for treatment households over the longer term: OLS Regression

	A. Intent-to-treat[1]		B. Users in treated villages[2]		C. Users in all villages[2]	
Outcomes	**2008-2011**	**2006-2011**	**2008-2011**	**2006-2011**	**2008-2011**	**2006-2011**
(1a) Access to commercial water treatment plants	-0.46*** (0.12)	-0.030 (0.062)	-0.095 (0.18)	0.20*** (0.047)	0.28*** (0.094)	0.23*** (0.032)
(1b) Use of commercial water treatment plants	-0.080** (0.038)	0.025 (0.022)	n.a.	n.a.	n.a.	n.a.
(2) Number of drinking water sources used[3]	No data	No data	No data	No data	No data	No data
(3) % household samples with E. coli[3]	No data	No data	No data	No data	No data	No data
(4) % of households treating water at home	-0.040 (0.066)	-0.11 (0.068)	-0.10 (0.10)	-0.12 (0.089)	0.15** (0.067)	0.073 (0.083)
(5) 2-week diarrhea prevalence in children under 5 years of age[4]	-0.012 (0.015)	0.004 (0.018)	-0.040 (0.028)	-0.048 (0.033)	-0.33 (0.033)	-0.037 (0.038)
(6) 2-week diarrhea prevalence in children under 3 years of age[4]	-0.028 (0.029)	-0.013 (0.027)	-0.083 (0.070)	-0.084 (0.066)	-0.058 (0.071)	-0.024 (0.070)
Household fixed effects	Yes	Yes	Yes	Yes	Yes	Yes

Notes:

[1] We report the coefficient κ on T*d shown in equation 2, where treatment is assigned at the community level based on planned CWS installation in 2006.

[2] We report the coefficient β^u from equation 3 for users in columns B1 and B2; and columns C1 and C2 show the same coefficient but for a model in which non-users (rather than households in control communities) are the reference group. The reported coefficients were estimated using an OLS regression model for the simple specification that does not include any covariates *Z*, except for the diarrhea prevalence regressions, which control for age. Additional controls for income, age of the respondent, and number of water sources within 5 minutes of the home did not alter the results (not shown). Standard errors, shown in parentheses, are clustered at the community level, and statistical significance is denoted by the asterisks (1% level ***; 5% level **; 10% level *).

[3] These outcomes were not measured during the long-term follow-up survey.

[4] Prevalence of diarrhea, measured based on having 3 or more loose stools within any 24 hour period, is for all sample children within the specified age groups.

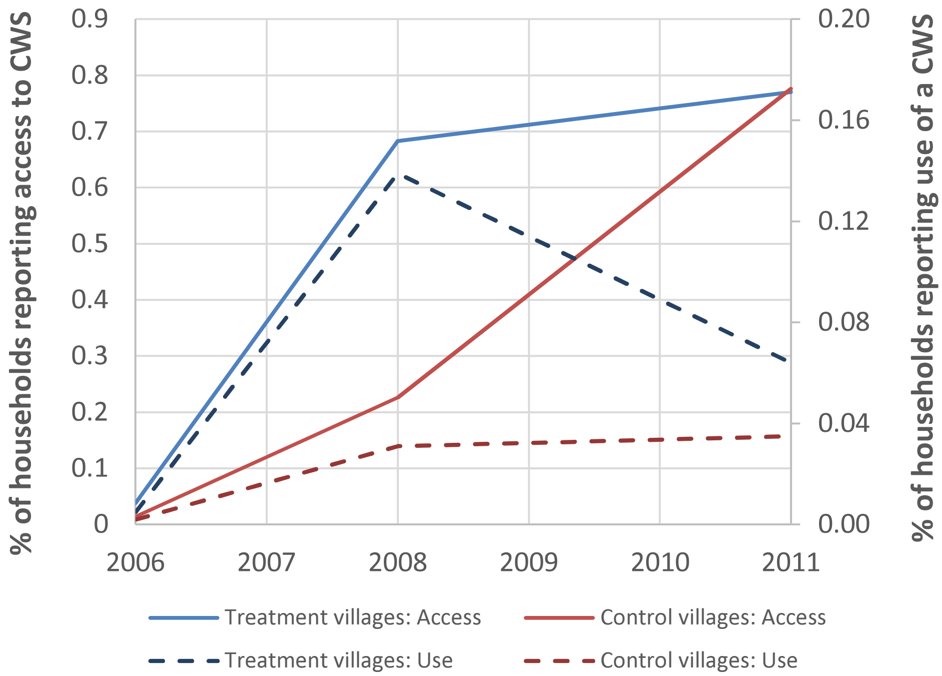

Figure 1. Access to community water systems in treatment and control communities over time

Appendix

Table A1. Comparison of additional outcomes for treatment and control households: OLS Regression Analysis

	Intent to Treat (ITT)[1]			Average Treatment Effect[2]			
Outcomes	**Assigned to treatment**	**R^2**	**N**	**ATT Users**	**ATT Nonusers**	**R^2**	**N**
Time spent collecting water from main source (minutes/trip)	3.6** (1.5)	0.03	5108	18.4*** (2.4)	1.4 (1.6)	0.055	5108
Water consumption for all uses (lpcd)	-6.8* (3.5)	0.19	5108	-0.8 (6.3)	-7.6* (3.5)	0.20	5108
% of households using drinking water storage vessels with a narrow mouth	0.020 (0.057)	0.001	5108	0.24*** (0.088)	-0.014 (0.058)	0.016	5108
% of households covering drinking water storage vessel	-0.00 (0.016)	0.009	5108	0.013 (0.034)	-0.001 (0.015)	0.010	5108
% of households elevating drinking water storage vessel	0.022 (0.028)	0.008	5108	0.032 (0.040)	0.020 (0.028)	0.008	5108
% of households that use safe method to remove water from vessel (ladle or spigot)	-0.024 (0.039)	0.014	5108	0.14* (0.076)	-0.050 (0.038)	0.026	5108
# of critical occasions at which adult respondent washes hands with soap	0.027 (0.11)	0.035	5108	0.048 (0.19)	0.016 (0.15)	0.035	5108
1-month diarrhea prevalence in children under 5 years of age[3]	0.021 (0.016)	0.036	6556	0.021 (0.035)	0.019 (0.016)	0.037	6556
1-month diarrhea prevalence in children under 3 years of age[3]	0.026 (0.023)	0.025	3717	0.038 (0.048)	0.021 (0.023)	0.027	3717
Water purchase cost – all sources (Rs./month)	13.0* (7.5)	0.01	5108	37*** (9.3)	8.9 (8.6)	0.023	5108
Monthly costs of coping with inadequate and unsafe water (Rs./month)[4]	-24.1 (43.8)	0.005	5108	-131 (85)	-50 (54)	0.012	5108
Total time spent collecting water (minutes/month)	183.1 (134.7)	0.023	5108	213 (148)	187 (142)	0.023	5108
Cost of treating water in-house (Rs./month)	-42.6 (43.4)	0.011	5108	-4.1 (75)	-45 (44)	0.011	5108
Household cost of illness due to diarrhea in previous month (Rs./month)[5]	64.4 (96.9)	0.019	5108	-133 (158)	80 (103)	0.02	5108
Household fixed effects	Yes			Yes			

Notes:

[1] We report the coefficient κ on T*d shown in equation 2, where treatment is assigned at the community level based on planned CWS installation in 2006. These coefficients were estimated using an OLS regression model for the simple specification that does not include any covariates *Z*, except for the diarrhea prevalence regressions, which control for age. Inclusion of additional controls for income, age of the respondent, and number of water sources within 5 minutes of the home did not alter the results (not shown). Standard errors, shown in parentheses, are clustered at the community level, and statistical significance is denoted by the asterisks (1% level ***; 5% level **; 10% level *).

[2] We report the coefficient β^{u} from equation 3 for users, and β^{nu} for non-users. For all but the diarrheal disease outcomes, there are 163 users and 1,011 non-users, with the balance being control households. As with the ITT, these are estimated using an OLS regression model for the simple specification that does not include any covariates Z, except for the diarrhea prevalence regressions, which control for age. Additional controls for income, age of the respondent, and number of water sources within 5 minutes of the home did not alter the results (not shown). Standard errors, shown in parentheses, are clustered at the community level, and statistical significance is denoted by the asterisks (1% level ***; 5% level **; 10% level *).

[3] Prevalence of diarrhea, measured based on having 3 or more loose stools within any 24 hour period, is for all sample children within the specified age groups.

[4] Monthly coping costs were calculated as the sum of (1) the monetized value of time spent collecting water, (2) expenditures on water treatment (boiling, filtering, and using chemicals), and (3) expenditures on water storage. The value of the time spent collecting water was calculated as the time spent walking to the household's water source plus the time spent waiting at the main water source times the number of trips per day to the main water source times the average hourly wage of the person collecting water (as calculated as the village hourly wage over the rainy and dry seasons for men, women, and children, respectively)

[5] Cost of illness is measured as the sum of out-of-pocket expenditures and lost income.

Table A2. Propensity Score Matching- ATT Estimates

Outcomes	Outcomes in 2008: ATT: Full model	Outcomes in 2008: ATT: Parsimonious model	Outcomes in 2006: ATT: Full model	Outcomes in 2006: ATT: Parsimonious model	N
Time spent collecting water from main source (minutes/trip)	13.6***	13.8***	0.42	0.76	124
	(2.2)	(2.2)	(1.6)	(1.5)	
Water consumption for all uses (lpcd)	-0.24	-1.2	2.6	-2.2	124
	(2.67)	(2.5)	(4.6)	(5.1)	
% of households using drinking water storage vessels with a narrow mouth	0.12**	0.21***	0.024	-0.008	124
	(0.061)	(0.055)	(0.042)	(0.047)	
% of households covering drinking water storage vessel	0.00	0.008	-0.040*	-0.024	124
	(0.006)	(0.009)	(0.023)	(0.024)	
% of households elevating drinking water storage vessel	0.032	-0.032	-0.024	-0.032	124
	(0.056)	(0.058)	(0.041)	(0.045)	
% of households that use safe method to remove water from vessel	0.14***	0.12**	-0.008	-0.032	124
	(0.044)	(0.050)	(0.051)	(0.054)	
# of occasions at which adult respondent washes hands w/ soap	0.18	0.23	0.14	-0.056	124
	(0.20)	(0.17)	(0.18)	(0.19)	
1-month diarrhea prevalence in children under 5 years of age[1]	0.080***	0.077**	0.045	0.054	124
	(0.029)	(0.031)	(0.050)	(0.050)	
1-month diarrhea prevalence in children under 3 years of age[1]	0.075***	0.070**	0.075	0.075	107
	(0.027)	(0.033)	(0.064)	(0.062)	
Water purchase cost – all sources (Rs./month)	45***	38***	8.9	0.5	124
	(7.3)	(9.4)	(5.8)	(6.6)	
Monthly costs of coping with inadequate and unsafe water[2]	-20	-37	-94	-17	124
	(84)	(79)	(90)	(79)	
Time spent collecting water	62	16	52	104	124
	(162)	(153)	(111)	(83)	
Cost of treating water in-house	-40	-53	-97	-25	124
	(74)	(72)	(87)	(80)	
Household cost of illness due to diarrhea in previous month[3]	125	115	272	220	124
	(80)	(100)	(265)	(245)	

Notes: The first stage propensity scores were obtained using the logit model specifications shown in Table 4. To maintain the same samples for comparison across all 4 sets of columns, only households present during the baseline survey are included. Total eligible user households for the comparison is thus 130, except for e.coli (only 66 users tested) and diarrhea among children under 3 (112 users). A small number of these users (3-6) were found to be off support and are therefore excluded; the final sample of users for each comparison is shown in the rightmost column. Similarly, there are 929 households from control communities eligible for matching (and 463 for e.coli); all of these were on support. We use 1-1 nearest neighbor matching, trimming the worst 5% of matches. All standard errors are bootstrapped and shown in parentheses, and statistical significance is denoted by the asterisks (1% level ***; 5% level **; 10% level *). Differences in outcomes for 2006 (prior to treatment) are included as a falsification test.

[1] Prevalence of diarrhea, measured based on having 3 or more loose stools within any 24 hour period, is for all sample children within the specified age groups.

[2] Monthly coping costs were calculated as the sum of (1) the monetized value of time spent collecting water, (2) expenditures on water treatment (boiling, filtering, and using chemicals), and (3) expenditures on water storage. The value of the time spent collecting water was calculated as the time spent walking to the household's water source plus the time spent waiting at the main water source times the number of trips per day to the main water source times the average hourly wage of the person collecting water (as calculated as the village hourly wage over the rainy and dry seasons for men, women, and children, respectively)

[3] Cost of illness is measured as the sum of out-of-pocket expenditures and lost income.

Table A3. Outcomes for treatment households over the longer term: OLS Regression

	A. Intent-to-treat[1]		B. Users in treated villages[2]		C. Users in all villages[2]	
Outcomes	**2008-2011**	**2006-2011**	**2008-2011**	**2006-2011**	**2008-2011**	**2006-2011**
Average time spent collecting water (minutes per trip)	-5.1***	-1.6	-3.9	-3.1	-2.5	-2.2
	(1.5)	(1.6)	(3.5)	(3.2)	(2.2)	(2.1)
% of households using drinking water storage vessels with a narrow mouth	-0.002	0.019	-0.21***	-0.18**	-0.19***	-0.18***
	(0.028)	(0.063)	(0.072)	(0.057)	(0.058)	(0.061)
% of households covering drinking water storage vessel	-0.008	-0.008	-0.006	0.004	0.005	0.016
	(0.010)	(0.014)	(0.019)	(0.035)	(0.012)	(0.024)
# of occasions at which adult respondent washes hands w/ soap	-0.015	0.007	-0.78**	-0.74	-0.67***	-0.60*
	(0.16)	(0.15)	(0.24)	(0.45)	(0.17)	(0.30)

Notes:
[1] We report the coefficient κ on T*d shown in equation 2, where treatment is assigned at the community level based on planned CWS installation in 2006.
[2] We report the coefficient β^u from equation 3 for users in columns B1 and B2; and columns C1 and C2 show the same coefficient but for a model in which non-users (rather than households in control communities) are the reference group. The reported coefficients were estimated using an OLS regression model for the simple specification that does not include any covariates *Z*, except for the diarrhea prevalence regressions, which control for age. Additional controls for income, age of the respondent, and number of water sources within 5 minutes of the home did not alter the results (not shown). Standard errors, shown in parentheses, are clustered at the community level, and statistical significance is denoted by the asterisks (1% level ***; 5% level **; 10% level *).