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Development Research
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ZEF-Discussion Papers on
Development Policy No. 222

Shyamal Chowdhury, Anabelle Krause, and Klaus F. Zimmermann

Arsenic Contamination of Drinking Water and Mental Health

Bonn, July 2016

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Shyamal Chowdhury, Anabelle Krause, and Klaus F. Zimmermann, Arsenic Contamination of Drinking Water and Mental Health, ZEF – Discussion Papers on Development Policy No. 222, Center for Development Research, Bonn, July 2016, pp. 37.

ISSN: 1436-9931

Published by:
Zentrum für Entwicklungsforschung (ZEF)
Center for Development Research
Walter-Flex-Straße 3
D – 53113 Bonn
Germany
Phone: +49-228-73-1861
Fax: +49-228-73-1869
E-Mail: zef@uni-bonn.de
www.zef.de

The author[s]:
Shyamal Chowdhury, School of Economics, University of Sydney; Institute for the Study of Labor (IZA).
Annabelle Krause, Institute for the Study of Labor (IZA).
Klaus F. Zimmermann, Harvard University; United Nations University – Maastricht Economic and Social Research Institute on Innovation and Technology (UNU-MERIT); Center for Development Research (ZEF), University of Bonn. Contact: zimmermann@fas.harvard.edu

Acknowledgements

We thank conference participants at the 12th IZA Annual Migration Meeting (AM^2) in Dakar, the 7th Annual Meeting on the Economics of Risky Behaviors in Izmir and the 3rd IZA Workshop: Labor Market Effects of Environmental Policies in Berlin as well as Xi Chen and Victoria Finn for valuable comments and suggestions on earlier versions of this paper.

Abstract

This paper investigates the effect of drinking arsenic contaminated water on mental health. Drinking water with an unsafe arsenic level for a prolonged period can lead to arsenicosis and associated illness. Based on rich and newly collected household survey data from Bangladesh, we construct several measures for arsenic contamination that include the actual arsenic level in the respondent's tubewell (TW), and past institutional arsenic test results as well as their physical and mental health. To account for potential endogeneity of water source, we take advantage of the quasi-randomness of arsenic distribution and employ the pre-1999 use of TW as an instrument and structural modelling as alternatives for robustness checks. We find that suffering from an arsenicosis symptom is strongly negatively related to mental health, even more so than from other illnesses. Calculations of the costs of arsenic contamination reveal that the average individual would need to be compensated for suffering from an arsenicosis symptom by an amount of money over 10 percent of annual household income.

Keywords: Arsenic; Water Pollution; Mental Health; Subjective Well-Being; Environment; Bangladesh

JEL Classification: Q53; I10; I31

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1 Introduction

The arsenic contamination of groundwater in Bangladesh is regarded as the largest poisoning of a population in human history (Smith et al., 2000). It was caused by the reaction to the observation that surface water contaminated with diarrhea-causing bacteria contributed to high infant mortality rates. Therefore, United Nations Children's Fund (UNICEF) initiated the construction of tubewells (TW) in the 1970s to provide safe drinking water. However, arsenic is a naturally occurring phenomenon in Bangladesh's groundwater,[1] and the groundwater used for drinking and pumped up via the TW was not tested for arsenic before installation. Estimations with data from 2009 reveal that about 20 million people in Bangladesh are at risk of drinking water that contains a level of arsenic higher than 50 µg/L, the maximum level permitted in Bangladesh; moreover, 45 million people are at risk of drinking water with a level higher than the WHO's maximum contaminant level of 10 µg/L (Flanagan et al., 2012).[2] Drinking water contaminated with an unsafe level of arsenic over a prolonged time period can lead to arsenicosis,[3] which includes symptoms such as black spots on the skin and subsequent illnesses such as different cancers.[4] Moreover, a recent Human Rights Watch study fears that one to five million children may die in Bangladesh in the coming years from diseases related to arsenic contamination.[5]

This paper aims to analyze whether drinking arsenic contaminated water affects individuals' mental health. Mental health continues to be a largely unrecognized and under-researched topic in developing countries, particularly in Bangladesh, despite a seemingly high prevalence of mental disorders (Hossain et al., 2014). Moreover, this relationship is not yet understood, as there are very few other studies thus far. There is neuroscientific evidence showing that perinatal arsenic exposure may have long-lasting biochemical and behavioral effects on adult mouse offspring and results in depressive-like behavior (Martinez et al., 2008). Epidemiological and toxicological studies show that arsenic is a developmental neurotoxicant that affects intellectual functions such as IQ and memory in both children and adults as well as neural functions in animals (see, e.g., Tolins et al., 2014; Tyler and Allan,

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[1] Contamination of drinking water is not limited to developing countries, as can be seen by, e.g., the lead contamination of water in Flint, Michigan. See, e.g., https://www.michigan.gov/flintwater for details (last accessed on April 11th, 2016).

[2] World Bank estimates of the 2009 population in Bangladesh amount to about 150,000,000; see http://data.worldbank.org/indicator/SP.POP.TOTL?page=1.

[3] Arsenicosis is the illness related to the effect of consuming arsenic contaminated water or food over a prolonged period.

[4] Other diseases commonly associated with drinking unsafe levels of arsenic contaminated water include internal (bladder, kidney, lung) cancers, neurological effects, hypertension, cardiovascular disease, increases in miscarriages and premature delivery, decreased birth weights, as well as an increase in mortality (Smith et al., 2000; Kapaj et al., 2006; Argos et al., 2010). Moreover, Carson et al. (2011) find household labor supply, Asadullah and Chaudhury (2011) find children's test scores, and Pitt et al (2012) find productivity to be negatively affected by arsenic exposure.

[5] Please see: http://www.thedailystar.net/backpage/arsenic-scourge-may-claim-several-million-lives-1205452 (last accessed on April 11th, 2016).

2014). The few studies examining arsenic contamination and self-reported mental health or depression find a negative relationship between the two, but usually entail few observations (only two studies use samples greater than 200 observations, from which one uses a sample with about 1,200 observations) and only limited information about arsenic poisoning (see Brinkel et al., 2009 for a review; Keya, 2004 and Syed et al., 2012, for Bangladesh; Fujino et al., 2004 for China; Zierold et al., 2004, for the U.S.).[6]

These studies either have information only on arsenicosis, i.e. the health status, sometimes additionally duration of arsenicosis, *or* information about the level of arsenic in the water they actually use for drinking *or* level of arsenic only for the whole village. No study has a complete overview of arsenicosis health status, arsenicosis health status of other household members, current arsenic levels in the water that is actually used for drinking, and distance to water source. These different variables can all contribute to the drinking behavior and it is important to be able to test these altogether when investigating mental health. All studies use cross-sectional data like we do, but in our data we are at least able to use retrospective information about TW usage as well as geographical information to be able to discuss the possibility of potential selection into arsenic-free water sources that these other papers were not able to do. Moreover, we have a lot more information about other variables such as physical diseases that may be correlated with arsenicosis symptoms and further variables related to the individual and the household. Often the former studies use only age, gender and in some cases education, income, BMI, and smoking and drinking behavior as control variables in their regressions. Our data gives a more thorough overview of the household's arsenic situation and of other individual and household characteristics.

In contrast to the existing literature, we therefore provide new evidence on this question by using newly collected very rich, large household and community data that include the history of water source and TW usage, objective measures of arsenic exposure, and symptoms and diseases linked to arsenic exposures. Thus, we are able to provide answers to more relevant questions such as the effect of own arsenicosis and other household members' arsenicosis controlling for the effect of duration of TW usage on mental health. In addition, we also discuss possible mechanisms by which unsafe levels of arsenic may have affected mental health.

Moreover, we are able to account for the potential endogeneity of developing arsenicosis related to possible selection of certain households into using safe or unsafe TWs using a structural approach through a recursive modelling. We additionally employ an instrumental variable specification using the exogenous pre-1999 – when the government started an information campaign and tested all then-existing TWs – distribution of arsenic as an

[6] One study using life satisfaction instead of mental health includes Asadullah and Chaudhury (2011), who find that arsenic exposure negatively affects children's life satisfaction. They use a primary data set collected from secondary school children in 321 schools located across 60 unions. The arsenic contamination data is self-reported by students. This is important, since Headey, Kelley and Wearing (1993) have demonstrated that life satisfaction is quite strongly correlated with depression, a typical measure of mental health.

instrument for developing an arsenicosis symptom. We show that the household's initial choice of water source did not depend on its observed characteristics and was only affected by distance to the TW, but unrelated to arsenic contamination and moreover, that subsequent TW choice is still mainly determined by distance.

Our study contributes to three strands of literature: a) environmental economics (see, e.g., Graff Zivin and Neidell, 2013, for a comprehensive overview), b) "envirodevonomics," which combines environmental and development economics (Greenstone and Jack, 2015), and c) environment and subjective well-being (Frey et al., 2010). This research is part of a substantial effort among economists to make subjective measures part of the economic discipline (Kahneman et al., 1997; Kahneman, and Sugden, 2005).

Our measure of mental health is the GHQ-12 (General Health Questionnaire) score, which is a widely used measure of psychological distress (Argyle, 2001). The GHQ-12's validity and stability to assess psychological well-being has been shown by numerous studies including, e.g., Goldberg et al. (1997), Hardy et al. (1999), Quek et al. (2001), Tait et al. (2003), Navarro et al. (2007) and Sánchez-López and Dresch (2008). The GHQ-12 has also worked well in developing countries (Goldberg et al., 1997), no age-related bias could be detected (O'Connor and Parslow, 2010) and the measure is highly correlated with lifetime satisfaction (Clark and Oswald, 1994). Besides wide usage in the psychology and medical literature, it has also been applied by economists (e.g., Clark, 2003; Gardner and Oswald, 2007; Akay et al., 2014).

We envisage three possible channels through which unsafe arsenic levels in drinking water may affect mental health: physiological, social, and psychological. The physiological channel can occur due to two reasons: first, drinking arsenic contaminated water may affect certain brain functions and in turn directly increase the probability of depression (Martinez et al., 2008). Second, individuals affected by arsenicosis may actually feel sick, which has been shown to be related to lower mental health (Dolan et al., 2008). Arsenic may affect individuals socially if arsenicosis patients suffer from discrimination and social exclusion. Arsenicosis is not contagious. However, there is some evidence showing that arsenicosis is sometimes perceived to be contagious and that victims are socially stigmatized (George et al., 2013; Hassan et al., 2005; Brinkel et al., 2009). Suffering from arsenicosis symptoms should therefore lead to a decrease in mental health. A third channel, which is somewhat connected to the other two but refers to a different mechanism, is the psychological channel. Individuals may start worrying about their health, future or family (Schwartz and Melech, 2000) when they or one of their family members have arsenicosis symptoms, or when they drink out of a red or unlabeled TW.[7]

[7] Between 1999 and 2002, the government and few NGOs (non-government organizations) had tested a number of TWs, which they then labeled green if the water was safe to drink and red if the arsenic level was too high thus making the water unsafe to drink.

This paper is organized as follows: Section 2 describes the data and sample. Section 3 provides the results of the empirical analysis, Section 4 presents the sensitivity analysis, and Section 5 concludes.

2 Data and Sample

The data we use for the empirical analysis comes from the *Dataset on Arsenic Contamination, Labor Supply, Health and Wellbeing – a primary data set* that we constructed from four Bangladeshi districts: Chandpur, Gopalgonj, Netrokona, and Sunamgonj. We selected four districts from four administration divisions of Bangladesh (until recently, the country was divided into four divisions) in order to represent the whole country. The logic behind selecting four different districts was to give our study an external validity. While contamination of TWs with unsafe level of arsenic is a common phenomenon in all of the selected districts, they vary in terms of alternate sources of drinking water, and possibly arsenic contamination in food due to the difference in their sources of irrigation water.

In selecting districts, we considered three sources. The first was a survey of 3,534 boreholes from 61 of the 64 Bangladeshi districts conducted by the British Geological Survey (BGS) that was the first data set to measure the level of arsenic in Bangladesh. However, it is a relatively small data set (3,534 boreholes compared to over 7 million tubewells counted in 1999-2002) only available at the district level and did not measure the level of arsenic at each tubewell. We used BGS data to classify districts into contaminated or not, i.e. we constructed the proportion of households in the district that had arsenic levels greater than 10 µg/L and 50 µg/L. The next two sources were from the Department of Public Health and Engineering (DPHE) TW census conducted between 1999 and 2002, and the 2009 Multiple Indicator Cluster Survey (MICS) conducted by the Bangladesh Bureau of Statistics (BBS) and UNICEF. We then followed a two-step simple random sampling procedure, where in the first step we randomly selected 150 villages/clusters from four districts.[8] Including a village for random selection was contingent on fulfilling two criteria: first, the DPHE conducted its TW census in that village in 1999–2002, and second, there was at least one microfinance institution (MFI)/NGO currently operating in that village/sub-district.[9] In the second step, 30 households were randomly selected from each village.

In total, 30 households in 150 villages were interviewed in 2014, resulting in 4,500 households in the entire dataset. The household survey comprises information on the following: the history of TW use, current and past drinking water sources, information about education, height and weight, chronic and temporary illness, demographic information, migration history, housing conditions, labor supply, and income. Moreover, a TW census was conducted in all 150 villages. For each TW, this census recorded its precise arsenic level, its exact geographical location (latitude and longitude), the establishment date, and whether or not the TW is labeled for arsenic contamination.

[8] NGOs were not involved in the data collection process nor in the village selection process. A professional survey firm independently contracted for data collection managed the whole process including recruitment and training of enumerators, survey logistics and data collection.

[9] It turned out that the DPHE census covered all villages in the selected districts, and all sub-districts in those districts had MFI/NGO presence.

We investigate the following measures of arsenic contamination: 1) suffering from an arsenicosis symptom (including darkening of skin on palms, dark spots on the body, keratosis, cardiovascular disorder, and respiratory disorder), 2) the current level of arsenic measured in μ/L in the TWs sourced for drinking water, 3) distance to TW used for drinking water in minutes walking, 4) duration of drinking out of the TW used for drinking water in years, and 5) the TW color. The TW coloring includes a) the result of arsenic tests of water in TWs that were conducted by the government (and NGOs in some instances) where contaminated TWs were painted red and safe ones painted green according to their level of arsenic (self-reported by respondents), b) if the individual is currently drinking from a red, green, or unlabeled TW (also self-reported), and c) the enumerator's observation about a red, green, or unlabeled TW. These three information sources about the color can differ due to fading colors over time, for example a once painted red TW may no longer hold the cautionary color today, or because of respondents' differing memories.

Our mental health measure is the GHQ-12 score (Goldberg and Williams, 1988). It consists of 12 questions related to the respondents' well-being in the past few weeks, such as their ability to concentrate and the occurrence of worry, stress, depression, and self-confidence.[10] The answer possibilities range between 1 and 4, where a higher value refers to a more negative feeling. One person per household, preferably the household head or his/her spouse, responded to the survey on this issue. We sum each respondent's answers to an index score ranging from 0 to 36, whereas the responses were used in the way so that higher values of the final score indicate better mental health.[11]

We also calculate two different versions of the GHQ-12 score for robustness checks. First, we calculate a score ranging from 0 to 12, which is the GHQ caseness score. To calculate this score, we sum the answers to the two low mental health categories. The scale is again reversed so that a higher value reflects better mental health. Second, the GHQ-12 caseness score is transformed into a dummy variable equal to 1 if the 12-scale GHQ score lies between 9 and 12. Individuals are regarded as a 'case' and should receive further attention for psychiatric treatment if the GHQ-12 caseness dummy is equal to 0 with the reversed scale (Jackson, 2007).

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[10] Six of the questions are negatively phrased and the other six are positively phrased. Hankins (2008) shows that the variances of the responses to the negatively phrased items were significantly higher, which may bias the results; a model with correlated error terms on the negatively phrased items could resolve this bias. In our case, only three out of six negatively phrased items have higher variances, so we assume that the potential bias is rather small and therefore use the regular GHQ-12 measure. We also find very similar and stable arsenic effects when we run separate regressions for each GHQ-12 question in a robustness check in Section 4.

[11] Reversing the GHQ scale in the empirical analysis is not uncommon; other studies doing so include Akay et al. (2014) and Clark (2003).

The final sample for our analysis decreases to 4,099 individuals due to missing information in some variables of interest.[12] Table 1 displays summary statistics of the variables used in the analysis. The mental health variable has an overall mean of 24 (on a scale from 0 to 36). The number is a bit lower than the one from Akay et al. (2014), who analyze a sample of rural-to-urban migrants in China. The average of the GHQ-12 score in their study is around 28. See Figure 1 for a display of the GHQ-12 score distribution. One can see that most respondents have a GHQ-12 score between 20 and 30. Moreover, the average 12-point scale of the GHQ-12 score amounts to 9 in our sample as can be seen in Table 1, which is also slightly lower than the average of 10 of the working age population in Britain (see Clark, 2003). 30 percent of our sample can be regarded as mentally unhealthy and would need medical treatment, given the reversed scale of the GHQ-12 score that we use, which is again higher than the corresponding number in Clark (2003), namely 19 percent. The prevalence of mental disorders in Bangladesh detected in the literature varies from 6.5 to 31.0 percent among adults (Hossain et al., 2014).

Almost 5 percent of the sample suffers from an arsenicosis symptom themselves and another 7 percent of all households have at least one member other than the respondent with an arsenicosis symptom. There are three different information channels about the color of the TW: 1) what the respondents say about the color of the TW they are using for drinking water, these are the three variables 'Drinking from…' that sum up to 1; 2) what the respondents remember about whether an official arsenic test by the government or NGOs of the TW they are using for drinking water took place and if yes its result, these are the variables 'TW tested: Green', 'TW tested: Red', and 'TW not tested' and they also sum up to 1; and 3) what TW colors the interviewer observes (only checking the tested TWs). 17 percent of respondents say they drink from a green TW, 11 percent from a red TW and the vast majority of 72 percent drinks from an unlabeled TW. However, about half of the TWs were tested in the past and found that 29 percent were labeled green and 19 percent were red. The latter variables are all self-reported information by the respondents about a government or NGO arsenic test in the past. The enumerators checked the color on all tested TWs – so only 47 percent of all TWs – and interestingly they observed even fewer colored labels than the respondents: only 5 percent green and 4 percent red. Although the survey question to the respondents about the color on their current TW asks for how the TW *is* labeled, not *was* labeled, the difference in answers could be due to respondents giving information not only about the current state of the TW color, but rather mixing it up with what they remember from when the TW still had a color.

[12] To check possible bias of our results due to the smaller sample, we performed two regression analyses – one leaving out the variables with rather many missing variables and one including a dummy variable indicating if the observation is missing. For the latter regression, we set all missing values of continuous variables to their mean, and dummies to 0 if their mean was below 0.5 and to 1 if their mean was above 0.5. Both estimations are robust to our main analysis and the dummy indicating missing variables is not statistically significant. Therefore, we conclude that our results do not suffer from a sample selection bias.

The arsenic level in the TWs was measured by the enumerators in a new test during our survey in 2014 and is not connected to the self-reported test results of the past government or NGO test. The average level of arsenic amounts to 99 μg/L where the highest level observed is 720 μg/L. This is clearly much higher than both the maximum 50 μg/L allowed by the Bangladeshi government and the 10 μg/L maximum that the WHO recommends. However, half of the sample is using TWs that exceed the national threshold of 50 μg/L. It takes about one minute on average to walk to the TW and people have been using theirs for around 10 years. Almost half of the respondents either own a TW or there is a TW on their compound. Basically the entire sample uses TW water for drinking (99.4 percent) and about two thirds also use it for cooking.

Two thirds of the sample are female and accordingly almost 60 percent are spouses of the household head. One third of the sample are household heads and another 8 percent are other household members, such as, e.g., the household head's brother. A large majority of 92 percent is married. On average the respondents are 39 years old and there are 2.3 children in a household. About 42 percent of the sample is illiterate, which aligns with a 2015 literacy estimate of 61.5 percent (CIA World Factbook, 2015). Eight percent of the sample has at least a secondary school certificate (SSC); this is in line with the Bangladesh Household Income and Expenditure Survey's finding of 8.9 percent for rural areas (Bangladesh Bureau of Statistics, 2011). The majority of the sample has worked in the last 7 days and the annual household income amounts to 141,740 Taka (about 1,620 Euro), which is slightly higher than the 2010 rural national average of 115,776 Taka (Bangladesh Bureau of Statistics, 2011).[13] Half of the respondents live in households where at least one member migrated in the past year and on average about 20 relatives live in the same village. The Body Mass Index (BMI) is around 21, which aligns with the results of the Bangladesh Demographic and Health Survey 2011 (National Institute of Population Research and Training (NIPORT) et al., 2013). 36 percent of the respondents were ill in the past month and on average a respondent had about 11 sick days over the past year.

[13] The average household income of our sampled households in 2010 price (using CPI from the World Development Indicator) is 104,993 Taka, which is slightly lower than the rural national average.

3 Empirical Analysis

3.1 Analyzing Mental Health: The Baseline Equation

As a first step in our empirical analysis we investigate the effect of arsenic contamination of drinking water on mental health by performing various linear regressions. We report the results of unconditional and conditional regressions incorporating covariates that are usually included in subjective well-being studies plus some variables that are specific to the rural setting in Bangladesh. Our estimated equation is as follows:

$$GHQ\text{-}12_{ij} = \alpha + A'_{ij}\beta + X'_{ij}\gamma + Village\ FE_j + \varepsilon_{ij}, \quad (1)$$

where $GHQ\text{-}12_{ij}$ is the level of mental health measured by the GHQ-12 score reported by individual *i* in village *j*. A_{ij} is a vector of variables on arsenic contamination. These variables include suffering from an arsenicosis symptom (the respondent or another household member), drinking from a red or unlabeled TW, drinking from a TW that was tested or was not tested, drinking from a TW where the interviewer observes a red or no color, the actual arsenic level in the TW (in µg/L) measured by our field research team while executing the survey, the walking distance to the TW in minutes and the duration of TW usage in years. The vector X_{ij} contains individual characteristics of the respondent as well as his/her household characteristics. These variables include the TW being on the household's compound, gender, relation to household head, marital status, age and age squared, number of children in the household, education, working status, log of annual household income (in Bangladeshi Taka), whether a household member migrated in the past year, the number of relatives in the village, BMI and BMI squared, and information about physical health. Moreover, we include village fixed effects in all regressions.[14] ε_{ij} denotes the error term. The standard errors in the regressions are clustered at the village level.

Table 2 contains the results of including all measures of arsenic contamination and TW usage in separate unconditional and conditional regressions. Columns (1) to (7) show the unconditional regressions, which suggest a clearly negative relation between having an arsenicosis symptom and mental health. These individuals may feel physically ill, leading to lower mental health, they may worry about their future due to the arsenic poisoning, or they are being discriminated against in their village due to their symptoms. Moreover, drinking out of an untested TW is also associated with lower mental health. This may be due to an

[14] Figure 2 shows the distribution of unsafe TW within a village, where a TW with an arsenic level of 50 µg/L is counted as one and zero otherwise. A value of 0.2 means 20 percent of TWs in the village have an arsenic level above 50 µg/L, so are contaminated. The villages on the left-hand side of the graph have therefore more safe TWs, whereas the villages on the right-hand side of the graph have more contaminated TWs. The figure shows that there are ten percent of villages in the sample that have no contaminated TW in the village (the bar on the far left in the graph below) and about 8 percent of villages have no safe TWs. In other words, 90 percent of villages have at least one unsafe TW in the village, and 92 percent of villages have at least one safe TW in the village. The graph therefore confirms that there is enough within village variation of the arsenic level.

uncomfortable feeling of uncertainty about the TW's true arsenic level.[15] Having to walk a longer distance to the TW lowers mental health. All results stay robust when introducing control variables (see Columns (8) to (14); for the full list of control variables, please refer to Table A1).[16] We decided to keep the statistically significant variables in further regressions.

In Table 3, we add the information about other household members' arsenicosis symptoms and other illnesses as regressors. The results show first that there is a larger effect of suffering from an arsenicosis symptom than from a different illness. Second, it significantly lowers mental health if household members suffer from an arsenicosis symptom or from other illnesses, but these effects are smaller than the respective ones when the individual him- or herself suffers from the respective illness.[17] Third, it is more detrimental for mental health if a household member has an arsenicosis symptom than another illness. These results show that suffering from an arsenicosis symptom appears to have a more negative relation to mental health than being sick in general.

Table 4 shows the regression results by gender. It shows that men are slightly more affected by having an arsenicosis symptom and by living with an individual who suffers from that kind of symptom. However, men are less affected if another household member suffers from a different illness. Moreover, the negative effect of drinking from an untested TW is only significant for women, which might be due to the fact that it is mainly women who collect the water and therefore might be more aware of the TW color marks. The same interpretation holds for the negative effect of distance to TW that appears to be driven by the female respondents.

The respondents in the sample probably do not only ingest arsenic via drinking water, but also via the food they eat, especially rice (see, e.g., Williams et al., 2006). While we do not have detailed information on food intake, we are able to include information about whether they use TW water for drinking or cooking (boiling water does not reduce arsenic), which

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[15] We also estimated a regression containing an interaction term between arsenicosis symptom and drinking out of an untested TW. Since the untested TW dummy is still significantly negative, we can support the hypothesis that those drinking out of an untested TW without any arsenicosis symptoms fear future symptoms. But it also seems as if those drinking out of an untested TW while having symptoms suffer more, since the interaction term is negative and significant.

[16] Arsenic-exposure might have affected some of the right-hand side variables. In order to address this concern, at least partially, we estimated regressions dropping subsequently the control variables income, marital status, physical health and BMI. Not including income or marital status virtually does not change the coefficient of having an arsenicosis symptom, so there does not seem to be at least a direct correlation between these variables. Dropping additionally the physical condition variables leads to a slight increase of the arsenicosis symptom coefficient, which shows that there seems to be some correlation. This is not surprising as there is some evidence linking certain nutritional factors to modify cancer risks associated with arsenic (Smith et al., 2000), so the general physical condition may be related to developing arsenicosis symptoms.

[17] It would certainly be interesting to investigate whether respondents are even more affected when a child in the household has an arsenicosis symptom rather than another adult member. However, the number of observations in the sample does not allow for a separate analysis.

gives an approximation of the non-drinking water related intake of arsenic.[18] Table 5 shows the results. First, the dummy variables on the TW water used for drinking and cooking do not change the effects of the arsenic variables already included in the former regressions. Second, using TW water for cooking is positively related to mental health, however, the coefficient is not statistically significant. The large coefficient can be due to the easier access to TW water than to other water sources, e.g. surface water, for which individuals have to put in extra effort to collect.

3.2 Potential Endogeneity of Arsenic Water Use

So far, we have not taken into account the endogeneity issue that may threaten identifying the effect of arsenic symptoms properly. Up until 1998 households did not know if their TWs were contaminated by an unsafe level of arsenic and were therefore most likely obtaining water from the closest TW. Thus, the intake of arsenic was quasi randomly distributed among the population. In 1999 the arsenic issue was publicized and institutional tests of arsenic levels in the then-existent TWs began. When this public campaign ended in 2002, lots of TWs installed thereafter were not tested. Therefore, 1998 is the last time when TW choice was clearly exogenous, or in other words, not dependent on arsenic. Since then drinking from a contaminated TW has not to be random but could also be a choice in the sense that individuals were able to switch to existent or newly installed TWs to avoid high arsenic concentrations. Importantly, arsenic contamination may vary within short distances: a high-contaminated TW may be close to a low-contaminated TW (van Geen et al., 2002).

Therefore, people who suffer from an arsenicosis symptom might be very different from people who do not suffer from one if the latter switched TWs due to arsenic contamination. There might be one or several variables affecting the choice to use a contaminated TW (if it is known to be contaminated) and mental health at the same time, in which case our baseline results would display a spurious relationship. By taking the history of TW use into account, one would be able to reduce this endogeneity issue related to potentially switching TWs and the probability of developing symptoms. Moreover, if we can show that switching the TW is related to the distance to the TW rather than to its arsenic level, the probability of developing an arsenicosis symptom would not be related to households' specific switching behavior so that our baseline results would not suffer from any selection bias.

We approach this issue by first checking whether the household characteristics are in any way related to the level of arsenic in the nearest TW in 1998, when the arsenic contamination issue was still unrevealed. We use geographical information on TW location (latitude and longitude) and calculate the distance between the house and the closest TW in 1998. Moreover, since we only know the current level of arsenic in the TWs, we approximate

[18] Even if we had information about food intake, we would not know the actual level of arsenic ingested unless each food item is tested for it. This is because food is often purchased in the market and is not labelled for arsenic status.

the 1998 level by adjusting the current arsenic level in the respective TWs to the yearly arsenic increase of about two percent established as a rule in the literature (see van Geen et al., 2003). Table 6 shows the results of regressing the level of arsenic in the closest TW in 1998 on basic household characteristics including the household head and spouse's education, the household head's age, the annual household income, the household size, the number of children 16 years and older, and village fixed effects. The results show no significant relationship between household characteristics and the level of arsenic in the TWs in 1998, which can be seen as a confirmation of a quasi-random distribution of arsenic in 1998 across households.

Next, we turn to the reasons for switching TWs. If we can show that switching TWs primarily depends on the distance to the TW rather than on its arsenic level, we strengthen the position that our baseline results are not biased in the sense that individuals who switched TWs because of arsenic might have a different probability of developing arsenicosis symptoms and at the same time different mental health levels. In that case the results would rather display a spurious relationship between arsenicosis symptoms and mental health. We investigate the determinants of switching TWs first by looking at self-reports on the reasons for TW switching and second by regressing the probability to have switched TWs on the distance between TWs and their arsenic levels in a proposed structural three-equation-system. Table 7 shows the distribution of answers to a survey question on why people switched TWs. All respondents who have ever switched a TW were asked and 96 percent claim that they switched because their current TW is closer to their house than the former one. It is important to note that new TWs are being installed over time so that there are more TWs to choose from today than in, e.g., 1998. Only about three percent of the sample say they have switched because the new TW is arsenic free.

These numbers support the assumption that it is the distance that matters for TW switching. Hence, our conclusion is that the baseline results should be not biased. We nevertheless undertake a few further robustness checks in the next section.

4 Sensitivity Analysis and Policy Debate

4.1 Structural and Instrumental Variable Estimations

In the previous section 3.2, we have proposed to analyze the situation in a recursive three equation system, having our mental health equation as the third equation with the predetermined variables from the two other equations. Such a system is structural, solving the endogeneity issue. As it is well-known (see for instance Dixon, 2008; Roodman, 2009; Wooldridge, 2010), such a system can be identified via seemingly unrelated regression (SUR). Estimating our recursive three-equation-system through SUR accounts for potential residual correlation across the equations. We estimate the following system of equations:

$$Switched\_98_{ij} = \alpha_1 + D'_{ij}\mu + C'_{ij}\gamma + Village\ FE_j + \varepsilon_{1ij}$$

$$Arsen\_Symptom_{ij} = \alpha_2 + Switched\_98_{ij}\delta + Ars\_Level\_98'_{ij}\theta + X'_{ij}\gamma + Village\ FE_j + \varepsilon_{2ij} \quad (2)$$

$$GHQ\text{-}12_{ij} = \alpha_3 + A'_{ij}\beta + X'_{ij}\gamma + Village\ FE_j + \varepsilon_{3ij}$$

The first equation determines the decision to switch TWs after 1998. We again use geographical information of TW location and calculate the difference between the closest TW in 1998 (2003) and the closest TW in 2003 (2014) to get an indicator about how distances change over time, displayed by the vector D_{ij} in the first equation of the system of equations (2). As before, we test whether individuals switch because of distance or arsenic so we also include dummy variables on the level of arsenic in 1998 (2003) above 50 µg/L which is the cutoff for coloring the TW red instead of green, displayed by the vector C_{ij}. We include information about the time span between 1998–2003 and 2003–2014 to have a more informative picture about the distribution of TWs.[19] In the second equation of the equation system we check whether the probability of a symptom depends on whether the individual switched their TW and the (exogenous) arsenic level in the closest TW in 1998, also adding a squared and cubic term of the latter to account for possible non-linearities. The latter three variables are displayed by the vector $Ars\_Level\_98_{ij}$. The vector X_{ij} contains individual characteristics of the respondent as well as his/her household characteristics as in equation (1) in Section 3.1. The third equation is our main regression with mental health as a dependent variable as before, where the vector A_{ij} includes suffering from an arsenicosis symptom (the respondent or another household member), drinking from a red or not tested TW, and the walking distance to the TW in minutes. The vector X_{ij} contains individual

[19] Only the 1998 variables are really exogenous. When estimating these regressions without the information on 2003–2014 for distance and arsenic level, all the results stay the same. Only the dummy on the arsenic level above 50 µg/L in 1998 is significantly negatively related to switching at the 10 percent level when not including village fixed effects.

characteristics of the respondent as well as his/her household characteristics as in equation (1) in Section 3.1.[20]

The number of observations in the SUR estimations decreases to 3,756 due to missing observations of distance measures that are related to unmeasured geographic locations of TWs, e.g. those that are now broken but were in use in 1998.[21] Table 8 shows the SUR results. Indeed, a closer distance to a new TW in 2003 (2014) compared to 1998 (2003) increases the probability to switch TWs, whereas a risky level of arsenic is not related to switching. This confirms the hypothesis that people do not switch TWs because of arsenic and resembles the self-reported reasons for TW switching. Moreover, the results of the second equation with symptom as a dependent variable shows that switching TWs does not significantly affect the probability of developing a symptom, but that the level of arsenic in 1998 does so, in a non-linear way, where the squared term is significantly negative and the cubic term significantly positive. Presumably rather high levels of arsenic contribute to developing an arsenicosis symptom.[22] The negative effect of symptom on mental health is not altered using this SUR specification, and remains significantly negative.

As a further robustness check, we also use an instrumental variable approach. As discussed above, arsenic contamination may vary within short distances (van Geen et al., 2002). We use the quasi-random distribution of arsenic in TW water which was unknown to households prior to 1999 as instruments. Note that we assumed no externalities between non-intention-to-treat households (those who lived close enough to non-contaminated TW) and intention-to-treat households (those who lived far enough to safe TW) because arsenicosis is not contagious. We use a cubic specification plus two dummies for high cutoffs of the arsenic level in 1998 to create an exogenous variation for developing a symptom of arsenicosis. Table 9 presents the two stage least squares results. The effect of the arsenicosis symptom on mental health stays robust using the IV specification. The Hansen's overidentifying restrictions tests provide strong evidence in favor of the validity of the exclusion restriction for the instruments (the Hansen J statistic (overidentification test of all instruments) is 4.207 with a p-value of 0.379).

Our finding of a larger IV coefficient compared to the OLS coefficient is a common finding in the empirical literature and can arise because of OLS bias (see, for examples, estimates reported in Card (1995), Angrist (2006), and Oreopoulos (2006)). The F statistic of a joint test of the several instruments in our first stage is 9 which suggests that our instruments seem to have reasonable power, but could be considered a low F-statistic given the common cutoff point of 10. However, the findings of Cruz and Moreira (2005) suggest that the F-statistic does not seem to be a reliable measure of the quality of instrumental variable estimates and

[20] Please see Table A2 for descriptive statistics of the newly introduced variables hereafter.

[21] To check the representativeness of the smaller sample, we estimated our baseline regression with the smaller sample. The results are robust.

[22] Though arsenic level influences symptom positively, there is an irregularity at around arsenic level 350 μg/L, which might be driven by few outliers.

the authors suggest applied researchers to instead rely on the conditional approach to construct informative confidence intervals even when instruments are weak. Similarly, Stock et al. (2002) and Andrews and Stock (2005) provide reviews of literature devoted to finding tests about the coefficient of β on the single included endogenous regressor that are valid in the presence of potentially weak instruments. In order to deal with the potential weak instrument problem, we follow Mikusheva and Poi (2006) and construct confidence sets for the coefficient on the endogenous variable. As stated by Mikusheva and Poi (2006), the confidence sets have correct coverage probabilities even when the instruments are weak. The coverage-corrected confidence sets and p-values are reported in Table 10. As can be seen, the coefficient of arsenic symptom remains unchanged and statistically significant.

4.2 GHQ-12 Separately and Potential Sorting due to Arsenic

In this section we present the results of two types of sensitivity checks: first, we investigate the GHQ-12 items separately and second, we take into account potential sorting due to arsenic.[23]

Table 11 shows the results of the first robustness check. Here we estimate a separate regression for each of the 12 GHQ questions with the usual covariates. One can see that having an arsenicosis symptom is strongly negatively significant in all regressions except for the question 'Felt you couldn't overcome your difficulties', see Column (6); but even in that case the coefficient has the right sign. All coefficients have about the same sizes around -0.2, only the one non-significant coefficient and the one strongly significant but only -0.131 for 'Felt capable of making decisions about things' are different, see Column (4). Therefore, it does not seem that a certain cluster of GHQ questions is driving the results related to the arsenicosis symptom. This is an unusually strong finding in the literature.

Moreover, the results show that people drinking out of a TW that was tested red by the government or NGOs have a higher probability to lose much sleep over worry. The negative effect of an untested TW that we found in earlier regressions is driven mainly by unhappy feelings and the feeling to lose confidence in oneself. Finally, the negative effect of distance to TW (in minutes) is driven by about half of the GHQ questions.

Lastly, in Table 12 we present the results on comparing households that never moved with those that have. With this robustness check we test whether sorting, potentially due to arsenic, might change the results. Only about one eighth of the sample has ever moved. We see that the effect of an arsenicosis symptom is even stronger for people who have moved

[23] We also vary the dependent variable's definition with Table A3 presenting the results. First, we apply a 12-point instead of the 36-point scale definition of the GHQ score, which is known as the GHQ-12 'caseness' definition. Moreover, we create a dummy of this 12-point scale variable. Individuals are regarded as a 'case' and need to receive further attention for psychiatric treatment if the GHQ-12 Caseness Dummy is equal to 0 (Jackson, 2007). We also estimate separate regressions for the negatively and positively phrased items. The results stay rather robust.

(see Column (2)). If individuals were moving away from arsenic we should find the opposite result. We therefore conclude that sorting does not present a threat to our results.

4.3 Policy Discussion and Evaluation

In order to get a sense of the costs of arsenic contamination for wellbeing, we calculate the financial compensation one would need to pay the average individual to account for the decrease in mental health due to arsenicosis symptoms. Such comparisons have often been used to evaluate the damage of health shocks (see Ferrer-i-Carbonell and van Praag, 2002; Groot et al., 2004) or other factors such as log GDP per capita or earnings of neighbors to study relative income effects (see Akay et al., 2016; Akay and Martinsson, 2011; Ferrer-i-Carbonell, 2005; and Luttmer, 2005). Our estimated log income effect is statistically highly significant and consistent in size with the findings in this literature. The log income change needed to compensate the loss caused by symptoms according to column 1 of Table A1 is equal to minus the coefficient of symptom (2.367) divided by the coefficient of log household income (0.221). The ratio of these coefficients gives a value of 10.71.

This means that the average individual would need to be compensated for suffering from an arsenicosis symptom by an amount of money over 10 percent of annual household income to keep his or her mental health constant. Moreover, when only including the effect of other household members' symptoms, the compensation is a bit less (7.65) and combining these two effects of an own symptom and another household member's symptom gives a value of 18.36. Note that these effects are very relevant, since they add up for the various household members. Studying life satisfaction instead of mental health and using data for West-German workers, Ferrer-i-Carbonell and van Praag (2002) report that hearing impediments imply an income reduction of about 20 percent and that heart or blood problems one of 47 percent. These calculations provide a rough indication about the dimension of arsenic poisoning and mental health in Bangladesh.

We see the compensation analysis here not primarily as a basis for an actual compensation policy, but as a method to judge the relevance of the problem. Another concern is that provided the evidence that the various measures of wellbeing from happiness, mental health and lifetime satisfaction may be subject of considerable hedonic adaption over time, the issue of compensation could achieve less relevance. Clark et al. (2008) have discussed hedonic adaption for happiness data in the context of the well-known Easterlin paradox (see also Easterlin, 2010). Riis et al. (2005), Oswald and Powdthavee (2008) and Akay et al. (2016) have provided empirical examples for the phenomenon of hedonic adaption more generally, although context and used measures vary considerably. However, there are also contradictory findings: For instance, lottery winners have been shown to exhibit only a much delayed increase in wellbeing (Kuhn et al., 2011; Winkelmann et al., 2011). The study of Andresen et al. (1994) support the robustness of mental health measures between shorter versus longer versions as well as stability 12 months later.

While we cannot observe any change in mental health over time given the cross-sectional nature of the mental health data, we believe that the effects that we report here are non-transitory and may not dissipate over time. As described in the introduction, while arsenic contamination of drinking water remained unknown for a considerable period, by 2002, all existing TWs were tested for arsenic and labelled either as green (hence safe) or red (hence unsafe). Therefore, by 2002, households knew about the problem of arsenic poisoning, the related physical symptoms and if they were drinking from safe or unsafe TWs. Hence, the effect due to arsenic was known, and finding its persistence after 12 years signifies that the effect has not dissipated.

5 Conclusions

This paper aims to investigate the effect of drinking arsenic contaminated water on mental health. We use household survey data from Bangladesh, where there is widespread arsenic contamination of groundwater. Drinking contaminated water for a prolonged period can lead to severe health problems, including different forms of cancer and an increased mortality rate. We construct several measures for arsenic contamination that include the respondent's physical health as well as the actual arsenic level in their tubewell (TW) and the color of the TW they are using. The Bangladeshi government and NGOs tested a number of TWs and marked them green if they were safe for drinking water and red if they were unsafe. We use the GHQ-12 score as a measure for mental health. Using extensive information about the respondents' physical condition and TW usage, we are able to provide a more thorough picture of the relationship between drinking arsenic contaminated water and mental health than what the literature on this topic currently offers.

We find that suffering from an arsenicosis symptom, even more so than other illnesses, is strongly negatively related to mental health. Living with an individual who suffers from arsenicosis also lowers mental health, more so than living with an individual suffering from a different illness. These results point to either a social/stigma channel or a psychological/worry channel through which the effect on mental well-being might work. On the one hand, in rural communities in Bangladesh arsenicosis is often falsely believed to be contagious and affected individuals may suffer social exclusion (see, e.g., Brinkel et al., 2009). On the other hand, arsenicosis symptoms may make the individual start worrying about becoming more seriously ill and about how this might affect him or her, as well as his or her family. Future research should more thoroughly investigate these potential channels. Regression results also show that individuals drinking from an untested TW have lower mental health than those drinking from tested TWs.

Furthermore, we are able to show that TW switching behavior is basically only determined by distance to the TW rather than its level of arsenic. Therefore, endogeneity issues related to the fact that households using contaminated TWs are likely to differ from households refraining from the usage, which in turn might be related to mental health, prove not to be severe. A structural recursive system estimated by the seemingly unrelated regression technique further confirmed the robustness of our findings. However, we also provide results using an instrumental variable specification. Prior to 1999, arsenic was quasi randomly distributed across households – afterwards the government started information campaigns on the contamination and tested all then-existing TWs for arsenic. So, pre-1999 TW usage could only be affected by distance to the TW since the level of contamination was not known. By using this pre-1999 exogenous distribution of arsenic as an instrument for developing an arsenicosis symptom, we are able to confirm that having an arsenicosis symptom reduces mental health.

This paper's findings show that arsenic contamination of drinking water is negatively related to mental health. Calculations of the costs of arsenic contamination reveal that the average individual in an affected household would need to be compensated for suffering from an arsenicosis symptom by an amount higher than 10 percent of the annual household income. Implications of these findings include on the one hand actions to reduce the risks of contamination through providing information both about safe TWs that are relatively close and about ways to filter water for safe drinking usage. On the other hand if a stigma channel drives the effect, such that individuals with arsenicosis symptoms suffer from social exclusion, information campaigns clarifying facts about arsenicosis, such as not being contagious, could increase awareness and empathy and thus reduce psychological suffering of arsenicosis patients.

Mental health in general, but especially regarding drinking contaminated water, is a widely under-researched area, particularly in developing countries. In addition, the expenditure on mental health and proper mental health legislation to legally reinforce policy goals is much lower in low income countries than in high income countries (WHO, 2011). Public awareness of this issue in developing countries, particularly Bangladesh, therefore needs to be increased.

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Table 1: Descriptive Statistics of Main Variables

Variable	Mean	Std. Dev.	Min.	Max.
GHQ-12 scale (0 to 36)	24.342	5.203	0	36
GHQ-12 scale (0 to 12)	9.421	3.002	0	12
GHQ-12 Caseness Dummy	0.698	0.459	0	1
Arsen. symptom	0.046	0.209	0	1
Other HH member with arsen. symptom	0.070	0.255	0	1
Drinking from green TW	0.168	0.374	0	1
Drinking from red TW	0.112	0.315	0	1
Drinking from unlabeled TW	0.720	0.449	0	1
TW tested: Green	0.288	0.453	0	1
TW tested: Red	0.186	0.389	0	1
TW not tested	0.526	0.499	0	1
TW color observed: Green	0.053	0.223	0	1
TW color observed: Red	0.042	0.201	0	1
TW no color observed	0.379	0.485	0	1
Level of arsenic in TW (μg/L)	98.897	106.019	0	720
More than 50 μg/L in TW	0.525	0.499	0	1
Distance to TW (minutes)	1.167	2.050	0	20
Duration of TW usage (years)	9.607	9.431	0	90
TW water used for drinking	0.994	0.079	0	1
TW water used for cooking	0.594	0.491	0	1
HH owns TW/ TW on compound	0.467	0.499	0	1
Female	0.664	0.472	0	1
Household Head	0.328	0.469	0	1
Spouse of HH head	0.591	0.492	0	1
Other HH member	0.081	0.273	0	1
Married	0.916	0.278	0	1
Widowed	0.045	0.207	0	1
Unmarried/divorced	0.039	0.194	0	1
Age	38.765	13.000	16	90
Number of children in HH	2.277	1.349	0	9
Illiterate	0.417	0.493	0	1
Education: None	0.414	0.493	0	1
Education: Lower than SSC	0.503	0.500	0	1
Education: SSC or higher	0.083	0.276	0	1
Worked in the last 7 days	0.847	0.360	0	1
Annual HH income (Taka)	141,740.823	188,625.584	1	2,529,350
Log. of annual HH income (Taka)	10.965	1.967	0	14.743
Anyone in HH migrated in last year	0.504	0.500	0	1
Nb. of relatives in village	19.867	16.622	0	210
BMI	20.941	3.418	14	39.256
Illness in last 30 days	0.364	0.481	0	1
Other HH member with illness	0.399	0.490	0	1
Nb. of sick days (last year)	11.168	14.490	0	250
N		4,099		

Source: Dataset on Arsenic Contamination, Labor Supply, Health and Wellbeing, own calculations.

Note: There are only 4,098 and 4,097 observations for the variables 'TW water used for drinking' and 'TW water used for cooking', respectively.

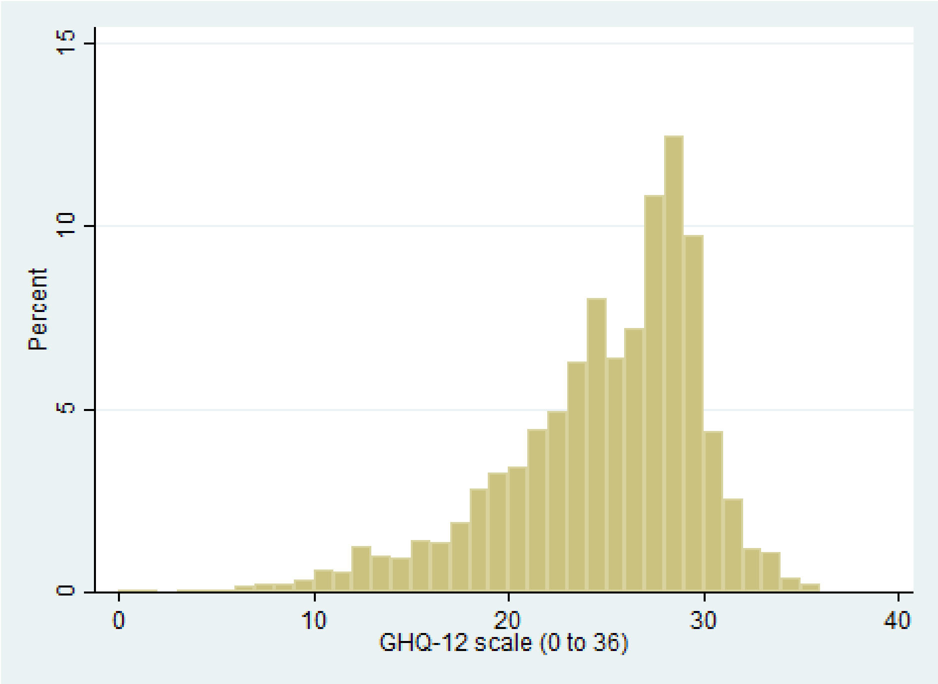

Figure 1: Distribution of GHQ-12 Scale (0-36)

Source: Dataset on Arsenic Contamination, Labor Supply, Health and Wellbeing, own calculations.
Note: The number of observations is 4,099.

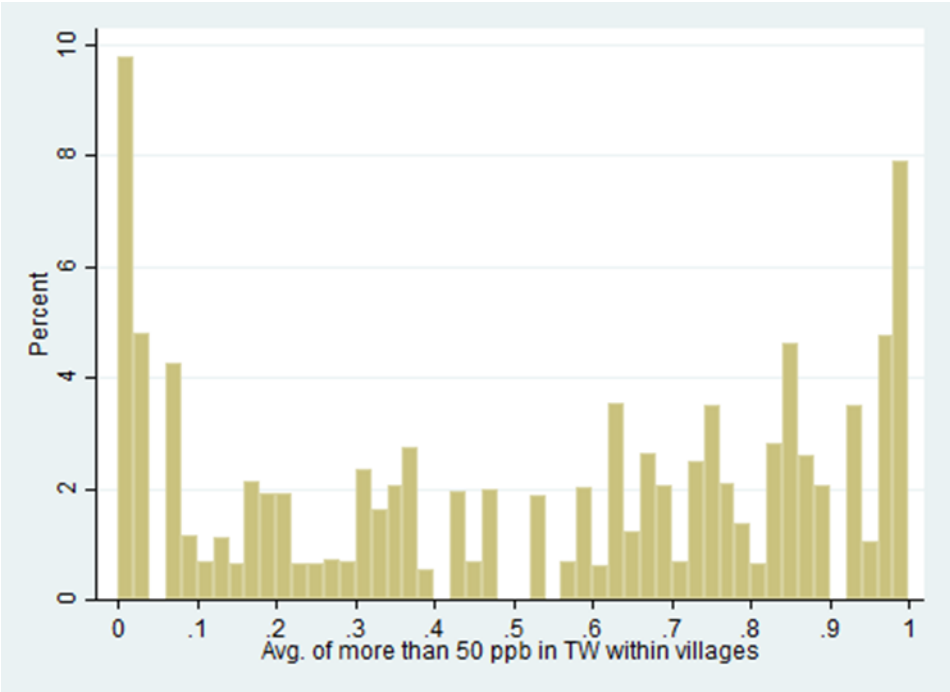

Figure 2: Distribution of Contaminated TWs within Villages

Source: Dataset on Arsenic Contamination, Labor Supply, Health and Wellbeing, own calculations.
Note: The number of observations is 4,099.

Table 2: Mental Health Regressions: Arsenic Information

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Arsen. symptom	-3.283							-2.240						
	(0.493)***							(0.461)***						
Drinking from red TW		0.006							-0.168					
		(0.324)							(0.320)					
Drinking from		-0.197							-0.289					
unlabeled TW		(0.261)							(0.252)					
TW tested: Red			-0.166							-0.249				
			(0.284)							(0.254)				
TW not tested			-0.397	0.150						-0.426	0.070			
			(0.182)**	(0.435)						(0.179)**	(0.409)			
TW color observed:				-0.535							-0.747			
Red				(0.547)							(0.523)			
TW no color observed				0.607							0.527			
				(0.445)							(0.415)			
Level of arsenic in TW					0.000							0.000		
(µg/L)					(0.001)							(0.001)		
Distance to TW						-0.198							-0.165	
(minutes)						(0.047)***							(0.046)***	
Duration of TW usage							0.002							0.003
(years)							(0.012)							(0.012)
Control Variables	No	No	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.11	0.09	0.10	0.10	0.09	0.10	0.09	0.19	0.18	0.18	0.18	0.18	0.18	0.18
N	4,099	4,099	4,099	4,099	4,099	4,099	4,099	4,099	4,099	4,099	4,099	4,099	4,099	4,099

Source: Dataset on Arsenic Contamination, Labor Supply, Health and Wellbeing, own calculations.

Notes: OLS regressions. Village fixed effects are included in all regressions. Standard errors clustered at the village level in parentheses. Dependent variable: GHQ-12 scale (0 to 36) defined from 0 to 36, higher values indicate higher SWB.

For the list of control variables, see Table A1.

*** significant at 1%; ** significant at 5%; * significant at 10%.

Table 3: Mental Health Regressions: Other Household Members

	(1)	(2)	(3)
Arsen. symptom	-2.366	-2.222	-2.367
	(0.470)***	(0.452)***	(0.467)***
Illness in last 30 days	-1.168	-1.686	-1.669
	(0.188)***	(0.234)***	(0.230)***
Other HH member with arsen. symptom	-1.746		-1.691
	(0.383)***		(0.380)***
Other HH member with illness		-0.828	-0.773
		(0.198)***	(0.198)***
TW tested: Red	-0.215	-0.271	-0.211
	(0.254)	(0.256)	(0.254)
TW not tested	-0.429	-0.434	-0.422
	(0.176)**	(0.177)**	(0.176)**
Distance to TW (minutes)	-0.157	-0.169	-0.159
	(0.046)***	(0.045)***	(0.045)***
Control Variables	Yes	Yes	Yes
R^2	0.20	0.19	0.20
N	4,099	4,099	4,099

Source: Dataset on Arsenic Contamination, Labor Supply, Health and Wellbeing, own calculations.

Notes: OLS regressions. Village fixed effects are included. Standard errors clustered at the village level in parentheses. Dependent variable: GHQ-12 scale (0 to 36) defined from 0 to 36, higher values indicate higher SWB. For the list of control variables, see Table A1.

*** significant at 1%; ** significant at 5%; * significant at 10%.

Table 4: Mental Health Regressions: Female vs. Male

	(1) Female Subsample	(2) Male Subsample
Arsen. symptom	-2.111	-2.544
	(0.635)***	(0.730)***
Illness in last 30 days	-1.648	-1.572
	(0.291)***	(0.344)***
Other HH member with arsen. symptom	-1.561	-1.730
	(0.455)***	(0.622)***
Other HH member with illness	-0.959	-0.497
	(0.261)***	(0.332)
TW tested: Red	-0.537	0.413
	(0.324)	(0.436)
TW not tested	-0.449	-0.369
	(0.223)**	(0.309)
Distance to TW (minutes)	-0.174	-0.105
	(0.059)***	(0.070)
Control Variables	Yes	Yes
R^2	0.22	0.28
N	2,721	1,378

Source: Dataset on Arsenic Contamination, Labor Supply, Health and Wellbeing, own calculations.

Notes: OLS regressions. Village fixed effects are included. Standard errors clustered at the village level in parentheses. Dependent variable: GHQ-12 scale (0 to 36) defined from 0 to 36, higher values indicate higher SWB. For the list of control variables, see Table A1.

*** significant at 1%; ** significant at 5%; * significant at 10%.

Table 5: Mental Health Regressions: TW Water Usage

	(1)
Arsen. symptom	-2.368
	(0.465)***
Illness in last 30 days	-1.663
	(0.231)***
Other HH member with arsen. symptom	-1.693
	(0.378)***
Other HH member with illness	-0.774
	(0.198)***
TW tested: Red	-0.166
	(0.257)
TW not tested	-0.404
	(0.178)**
Distance to TW (minutes)	-0.156
	(0.045)***
TW water used for drinking	-0.137
	(1.081)
TW water used for cooking	0.480
	(0.291)
Control Variables	Yes
R^2	0.20
N	4,097

Source: Dataset on Arsenic Contamination, Labor Supply, Health and Wellbeing, own calculations.

Notes: OLS regressions. Village fixed effects are included. Standard errors clustered at the village level in parentheses. Dependent variable: GHQ-12 scale (0 to 36) defined from 0 to 36, higher values indicate higher SWB. For the list of control variables, see Table A1.

*** significant at 1%; ** significant at 5%; * significant at 10%.

Table 6: Quasi Random Distribution of Arsenic in 1998

Dep. Var.: Arsenic level in closest TW in 1998	(1)
Education: Lower than SSC (Household head)	0.011
	(0.012)
Education: SSC or higher (Household head)	0.005
	(0.022)
Education: Lower than SSC (Spouse)	0.008
	(0.011)
Education: SSC or higher (Spouse)	0.005
	(0.026)
Age (Household head)	0.000
	(0.000)
Log. of annual HH income (Taka)	0.003
	(0.002)
Household Size	0.004
	(0.004)
Children 16 years or older	-0.005
	(0.008)
R^2	0.67
N	3,756

Source: Dataset on Arsenic Contamination, Labor Supply, Health and Wellbeing, own calculations.

Notes: OLS regressions. Village fixed effects are included. Standard errors clustered at the village level in parentheses.

*** significant at 1%; ** significant at 5%; * significant at 10%.

Table 7: Reasons for TW Switching (Survey Question)

	Percent
It is nearer	96.21
It is arsenic free	2.71
It is nearer & arsenic free	0.58
Was not using TW before	0.03
High rate of iron	0.48
N	3,769

Source: Dataset on Arsenic Contamination, Labor Supply, Health and Wellbeing, own calculations.
Notes: Only respondents who have ever switched TWs were asked this question.

Table 8: SUR Estimation

Dep. Var.	Indep. Var.	(1)
Switched after 1998	Difference betw. distance of closest TW in 1998 and 2003	0.157 (0.040)***
	Difference betw. distance of closest TW in 2003 and 2014	0.220 (0.053)***
	Arsenic level in closest 1998 TW above 50 μg/L	-0.014 (0.028)
	Arsenic level in closest 2003 TW above 50 μg/L	0.021 (0.027)
	Control Variables	No
Arsen. symptom	Switched after 1998	-0.0059 (0.0088)
	Arsenic level in closest 1998 TW	34.0391 (24.2256)
	Arsenic level in closest 1998 TW Squared	-0.2894 (0.1216)**
	Arsenic level in closest 1998 TW Cubic	0.0006 (0.0002)***
	Control Variables	Yes
GHQ-12 scale (0 to 36)	Arsen. symptom	-2.552 (0.384)***
	Control Variables	Yes
N		3,756

Source: Dataset on Arsenic Contamination, Labor Supply, Health and Wellbeing, own calculations.
Notes: SUR (seemingly unrelated regression) results. Village fixed effects are included. "Switched after 1998" is equal to 1 if the household switched TWs after 1998. "GHQ-12 scale (0 to 36)" is defined from 0 to 36, higher values indicate higher SWB. Higher values of "Difference betw. distance of closest TW in 1998/2003 and 2003/2014" indicate that the closest TW in 2003/2014 is closer than the closest TW in 1998/2003. "Arsenic level in closest 1998 TW (Squared/Cubic)" is scaled by a factor of 100,000. For the list of control variables, see Table A1.
*** significant at 1%; ** significant at 5%; * significant at 10%.

Table 9: Instrumental Variable Regression

	(1) OLS	(2) IV First Stage (Dep. Var.: Arsen. Symptom)	(3) IV
Arsenic level in closest 1998 TW		22.2218	
		(25.7366)	
Arsenic level in closest 1998 TW Squared		-0.4480***	
		(0.1318)	
Arsenic level in closest 1998 TW Cubic		0.0009***	
		(0.0002)	
Ars. level in closest 1998 TW above 100 µg/L		0.0395**	
		(0.0194)	
Ars. level in closest 1998 TW above 200 µg/L		0.0598**	
		(0.0236)	
Arsen. symptom	-2.367		-6.606***
	(0.467)***		(2.5172)
Control Variables	Yes	Yes	Yes
F Test		8.99	
R^2	0.20	0.11	0.17
N	4,099	3,756	3,756

Source: Dataset on Arsenic Contamination, Labor Supply, Health and Wellbeing, own calculations.

Notes: Standard errors clustered at the village level in parentheses. Village fixed effects are included. "Arsenic level in closest 1998 TW (Squared & Cubic)" is scaled by a factor of 100,000. Dep. Var. in (1) and (3): GHQ-12 scale (0 to 36) defined from 0 to 36, higher values indicate higher SWB. For the list of control variables, see Table A1.

*** significant at 1%; ** significant at 5%; * significant at 10%.

Table 10: Coverage-corrected Confidence Sets and p-values

Coverage-corrected confidence sets and p-values for Ho: _b[symptom] = 0		
LIML estimate of _b[symptom] = -6.61		
Test	Confidence Set	p-value
Conditional LR	[-17.3983, 2.728598]	0.0000
Anderson-Rubin	[-17.57244, 2.858886]	0.0000
Score (LM)	(-inf, -2982] U [-18.15, 3.285] U [61.44, +inf)	0.0000

Source: Dataset on Arsenic Contamination, Labor Supply, Health and Wellbeing, own calculations.

Table 11: Separate Regression for each GHQ-12 Question

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Arsen.	-0.256	-0.279	-0.189	-0.131	-0.274	-0.058	-0.214	-0.157	-0.232	-0.213	-0.222	-0.142
symptom	(0.060)***	(0.068)***	(0.047)***	(0.047)***	(0.079)***	(0.062)	(0.071)***	(0.055)***	(0.075)***	(0.065)***	(0.058)***	(0.061)**
Illness in	-0.143	-0.158	-0.088	-0.104	-0.240	-0.117	-0.162	-0.136	-0.212	-0.165	-0.072	-0.073
last 30 days	(0.028)***	(0.034)***	(0.030)***	(0.027)***	(0.042)***	(0.034)***	(0.031)***	(0.028)***	(0.041)***	(0.035)***	(0.032)**	(0.036)**
Other HH	-0.196	-0.118	-0.180	-0.137	-0.083	0.051	-0.159	-0.147	-0.176	-0.142	-0.132	-0.272
member with arsen. symptom	(0.039)***	(0.049)**	(0.047)***	(0.044)***	(0.063)	(0.047)	(0.042)***	(0.042)***	(0.056)***	(0.048)***	(0.045)***	(0.046)***
Other HH	-0.027	-0.130	-0.028	-0.057	-0.115	-0.049	-0.041	-0.041	-0.119	-0.097	-0.047	-0.022
member with illness	(0.027)	(0.030)***	(0.027)	(0.027)**	(0.037)***	(0.029)*	(0.032)	(0.027)	(0.037)***	(0.030)***	(0.026)*	(0.032)
TW	-0.036	-0.093	0.014	0.054	-0.047	-0.021	-0.007	0.027	-0.051	-0.020	-0.006	-0.025
tested: Red	(0.031)	(0.036)**	(0.036)	(0.035)	(0.052)	(0.040)	(0.037)	(0.036)	(0.047)	(0.036)	(0.031)	(0.034)
TW not	-0.038	-0.039	-0.014	-0.021	-0.061	-0.028	0.017	0.006	-0.109	-0.066	-0.016	-0.052
tested	(0.025)	(0.026)	(0.026)	(0.026)	(0.033)*	(0.028)	(0.023)	(0.024)	(0.034)***	(0.029)**	(0.023)	(0.026)**
Distance	-0.010	-0.020	-0.013	-0.018	-0.026	-0.014	-0.009	-0.004	-0.011	-0.004	-0.018	-0.012
to TW (minutes)	(0.007)	(0.007)***	(0.006)**	(0.007)**	(0.007)***	(0.006)**	(0.007)	(0.005)	(0.008)	(0.008)	(0.008)**	(0.007)*
Control V.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.13	0.10	0.12	0.11	0.10	0.08	0.16	0.11	0.15	0.18	0.20	0.15
N	4,099	4,099	4,099	4,099	4,099	4,099	4,099	4,099	4,099	4,099	4,099	4,099

Source: Dataset on Arsenic Contamination, Labor Supply, Health and Wellbeing, own calculations.

Notes: OLS regressions. Village fixed effects are included. Standard errors clustered at the village level in parentheses. Dependent variable (defined between 1 and 4, where higher values refer to better mental health) in (1): Been able to concentrate on whatever you are doing, (2): Lost much sleep over worry, (3): Felt that you are playing a useful part in things, (4): Felt capable of making decisions about things, (5): Felt constantly under strain, (6): Felt you couldn't overcome your difficulties, (7): Been able to enjoy your normal day to day activities, (8): Been able to face up to your problems, (9): Been feeling unhappy and depressed, (10): Been losing confidence in yourself, (11): Been thinking of yourself as a worthless person, (12): Been feeling reasonably happy, all things considered. For the list of control variables, see Table A1.

*** significant at 1%; ** significant at 5%; * significant at 10%.

Table 12: Stayers vs. Movers

	Stayers	Movers
	(1)	(2)
Arsen. symptom	-2.241	-3.327
	(0.486)***	(1.632)**
Illness in last 30 days	-1.643	-1.554
	(0.236)***	(0.828)*
Other HH member with arsen. symptom	-1.744	-0.967
	(0.401)***	(1.223)
Other HH member with illness	-0.853	-0.568
	(0.213)***	(0.966)
TW tested: Red	-0.126	0.585
	(0.261)	(1.248)
TW not tested	-0.465	0.406
	(0.184)**	(0.717)
Distance to TW (minutes)	-0.198	-0.264
	(0.054)***	(0.124)**
Control Variables	Yes	Yes
R^2	0.21	0.43
N	3,578	519

Source: Dataset on Arsenic Contamination, Labor Supply, Health and Wellbeing, own calculations.

Notes: OLS regressions. Village fixed effects are included. Standard errors clustered at the village level in parentheses. Dependent variable: GHQ-12 scale (0 to 36) defined from 0 to 36, higher values indicate higher SWB. For the list of control variables, see Table A1. Movers are defined as individuals who currently live more than 0km away from the house/village in which they were born. Only male household heads were taken into account in this definition since females often move due to marriage, which we do not want to capture in this definition.

*** significant at 1%; ** significant at 5%; * significant at 10%.

Table A 1: Mental Health Regressions: Control Variables

	(1) All	(2) Female Subsample	(3) Male Subsample
Arsen. symptom	-2.367	-2.111	-2.544
	(0.467)***	(0.635)***	(0.730)***
Illness in last 30 days	-1.669	-1.648	-1.572
	(0.230)***	(0.291)***	(0.344)***
Other HH member with arsen. symptom	-1.691	-1.561	-1.730
	(0.380)***	(0.455)***	(0.622)***
Other HH member with illness	-0.773	-0.959	-0.497
	(0.198)***	(0.261)***	(0.332)
TW tested: Red	-0.211	-0.537	0.413
	(0.254)	(0.324)	(0.436)
TW not tested	-0.422	-0.449	-0.369
	(0.176)**	(0.223)**	(0.309)
Distance to TW (minutes)	-0.159	-0.174	-0.105
	(0.045)***	(0.059)***	(0.070)
HH owns TW/ TW on compound	0.059	-0.190	0.508
	(0.193)	(0.240)	(0.368)
Female	-2.413		
	(0.610)***		
Spouse of HH head	1.638	1.918	
	(0.636)**	(1.232)	
Other HH member	0.742	0.751	0.298
	(0.425)*	(0.959)	(0.582)
Married	1.056	0.899	0.651
	(0.454)**	(0.978)	(0.633)
Widowed	-0.378	-0.582	-1.963
	(0.847)	(1.116)	(1.688)
Age	-0.057	-0.132	-0.084
	(0.045)	(0.070)*	(0.088)
Age squared	0.000	0.001	0.000
	(0.001)	(0.001)	(0.001)
Number of children in HH	-0.159	-0.207	0.034
	(0.070)**	(0.093)**	(0.105)
Education: Lower than SSC	0.097	0.256	-0.360
	(0.186)	(0.217)	(0.302)
Education: SSC or higher	0.720	0.909	0.301
	(0.308)**	(0.470)*	(0.446)
Worked in the last 7 days	0.334	0.083	1.264
	(0.233)	(0.269)	(0.492)**
Log. of annual HH income (Taka)	0.221	0.218	0.253
	(0.049)***	(0.060)***	(0.096)***
Anyone in HH migrated in last year	-0.330	-0.365	-0.136
	(0.167)**	(0.212)*	(0.281)
Nb. of relatives in village	-0.027	-0.033	-0.009
	(0.008)***	(0.012)***	(0.009)
BMI	0.498	0.489	0.762
	(0.225)**	(0.280)*	(0.348)**
BMI Squared	-0.009	-0.009	-0.015
	(0.005)*	(0.006)	(0.008)*
Nb. of sick days (last year)	-0.038	-0.038	-0.040
	(0.008)***	(0.009)***	(0.012)***
R2	0.13	0.12	0.18
N	4,099	2,721	1,378

Source: Dataset on Arsenic Contamination, Labor Supply, Health and Wellbeing, own calculations.

Notes: OLS regressions. Village fixed effects are included. Standard errors clustered at the village level in parentheses. Dependent variable: GHQ-12 scale (0 to 36) defined from 0 to 36, higher values indicate higher SWB.

*** significant at 1%; ** significant at 5%; * significant at 10%.

Table A 2: Descriptive Statistics of TW History

Variable	Mean	Std. Dev.	Min	Max
Arsenic level of the nearest TW in 1998	113.033	112.229	0	648
Switched after 1998	0.777	0.416	0	1
Difference betw. distance of closest TW in 1998 and 2003	0.109	0.581	0	6
Difference betw. distance of closest TW in 2003 and 2014	0.363	3.436	0	43
Arsenic level in closest 1998 TW above 50 μg/L	0.584	0.493	0	1
Arsenic level in closest 2003 TW above 50 μg/L	0.609	0.488	0	1
Arsenic level in closest 1998 TW above 100 μg/L	0.352	0.478	0	1
Arsenic level in closest 1998 TW above 200 μg/L	0.228	0.420	0	1
N		3,756		

Source: Dataset on Arsenic Contamination, Labor Supply, Health and Wellbeing, own calculations.

Notes: The minimum values for the variables 'Difference betw. distance of closest TW in 1998 (2003) and 2003 (2014)' are marginally below zero.

Table A 3: Modifications of GHQ-12 Score as Dependent Variable

	(1) GHQ (0-12)	(2) GHQ Dummy	(3) Negative Phrasing	(4) Positive Phrasing
Arsen. symptom	-1.363	-0.136	-1.278	-0.817
	(0.275)***	(0.038)***	(0.286)***	(0.197)***
Illness in last 30 days	-0.993	-0.125	-0.964	-0.606
	(0.134)***	(0.021)***	(0.154)***	(0.088)***
Other HH member with arsen. symptom	-0.864	-0.098	-0.599	-0.636
	(0.218)***	(0.031)***	(0.213)***	(0.160)***
Other HH member with illness	-0.502	-0.051	-0.557	-0.243
	(0.114)***	(0.017)***	(0.128)***	(0.075)***
TW tested: Red	-0.173	-0.018	-0.237	-0.062
	(0.142)	(0.025)	(0.164)	(0.093)
TW not tested	-0.119	-0.017	-0.319	-0.082
	(0.104)	(0.017)	(0.113)***	(0.070)
Distance to TW (minutes)	-0.083	-0.012	-0.093	-0.055
	(0.027)***	(0.004)***	(0.028)***	(0.020)***
Control Variables	Yes	Yes	Yes	Yes
R^2	0.19	0.15	0.17	0.19
N	4,099	4,099	4,099	4,099

Source: Dataset on Arsenic Contamination, Labor Supply, Health and Wellbeing, own calculations.

Notes: OLS regressions. Village fixed effects are included. Standard errors clustered at the village level in parentheses. Dep. Var. in (1): *GHQ-12 scale (0-12)*, defined from 0 to 12, higher values equal higher SWB. Dep. Var. in (2): *GHQ-12 Caseness Dummy* is equal to 1 if *GHQ-12 scale (0-12)* is higher than 8. Individuals are regarded as a 'case' and receive further attention for psychiatric treatment if *GHQ-12 Caseness Dummy* is equal to 0 (Jackson, 2007). Dep. Var. in (3): negatively phrased GHQ-12 items, defined from 0 to 18, higher values indicate higher SWB. Negatively phrased items include: Lost much sleep over worry, constantly under strain, couldn't overcome difficulties, feeling unhappy/depressed, losing confidence in yourself, thinking of yourself as a worthless person. Dep. Var. in (4): positively phrased GHQ-12 items, defined from 0 to 18, higher values indicate higher SWB. Positively phrased items include: Able to concentrate, felt that you are playing a useful part in things, capable of making decisions, enjoy day-to-day activities, able to face up to your problems, and feeling happy, all things considered. For the list of control variables, see Table A1.

*** significant at 1%; ** significant at 5%; * significant at 10%.