# Evaluation of the Kanchan™ Arsenic Filter Under Various Water Quality Conditions of the Nawalparasi District, Nepal

Claudia M. Espinoza

Mater of Engineering
Massachusetts Institute of Technology
Department of Civil and Environmental Engineering

## Abstract

In 2002, the Massachusetts Institute of Technology Department of Civil and Environmental Engineering partnered with the Environment & Public Health Organization to develop and disseminate the Kanchan™ Arsenic Filter (KAF) for the low-cost removal of arsenic from drinking water in rural Nepal. In this system, arsenic is removed via absorption onto the surface of ferric hydroxide, or rust, by integrating locally available iron nails with a bio-sand filter.

The KAF filter has been successfully disseminated to approximately 24,000 households, corresponding to about 200,000 Nepalese, since 2002. However, recent studies have indicated that KAF may poorly remove arsenic concentrations, to filtered water arsenic levels above the Nepali government guideline (50 µg/L), under certain raw water conditions. The present study focused on identifying and determining the impact of raw water parameters on the arsenic removal efficiency of the KAF. These parameters included: arsenic, ferrous iron, dissolved oxygen, silica, phosphate, pH, hardness, chloride, manganese, and electrical conductivity concentrations. In addition, filter flow rate, installation date, location and a user survey was recorded. A total of 100 filters, of ages <1 years to 7 years, from 79 groundwater sources and 15 villages, primarily in the Nawalparasi District, were tested.

Groundwater conditions that did not promote the corrosion of the iron nails were found to relate to a poorly performing KAF. These conditions included groundwater Fe(II) concentrations (<3mg/L), Fe(II) concentrations after having passed though nails (<1.1 mg/L), groundwater chloride concentrations (<7 mg/L), and high hardness concentrations. In addition, low groundwater arsenic concentrations (<200µg/L) were observed to relate to filtered water arsenic concentrations lower than the Nepali standard. It is recommended to research ways to increase iron corrosion in the KAF system so that it can be promoted in areas with various groundwater conditions.

## Introduction

Naturally-occurring high arsenic concentrations in groundwater are a recognized problem in many regions of south and eastern Asian countries, including: Bangladesh, India, Vietnam, Cambodia and Nepal. High arsenic concentrations in groundwater are dependent on the geological, hydrogeolocial and geochemical conditions of the aquifers. Long-term consumption of high arsenic concentrations can lead to serious health effects such as arsenicosis and skin cancer. The World Health Organization (WHO) standard for allowable arsenic concentrations in drinking water is 10 µg/L (WHO: Guidelines for Drinking-water Quality, 2008). Many South Asian countries such as Nepal have set their own standard for allowable arsenic concentrations in drinking water to 50µg/L. However, concentrations as high as 5 mg/L have been detected in groundwater tube wells of East Asian countries (Smedley, 2003).

Arsenic contamination in the groundwater of the Terai was discovered in 1999 during exploratory arsenic testing project lead by the Department of Water Supply and Sewerage (DWSS) and the WHO (Panthi et al., 2006). Since this discovery, many efforts have been made by agencies involved in rural water supply to assess the occurrence of arsenic in Nepali groundwater. The combined sampling studies of over 740,000 tube wells by 12 separate institutions or organizations found that about 8% and 3% of the samples had arsenic concentrations that exceeded the WHO standard and the Nepali standard, respectively (Thakur et al., 2011). Overall, from these studies the District of Nawalparasi is observed to be the most affected area with the highest arsenic concentrations throughout the Terai (**Figure 1**).

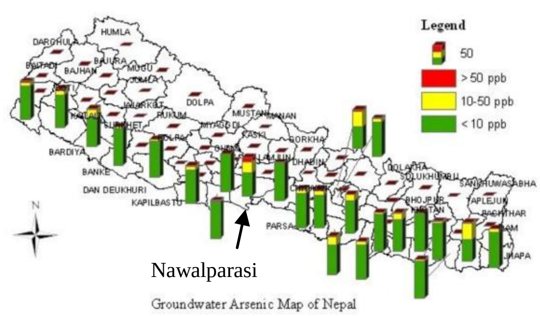


**Figure 1:** Arsenic concentrations in the Terai Region of Nepal from combined studies of over 740,000 tube wells. The Nepali standard for arsenic levels in drinking water is 50 ppb (µg/L). Source: Thakur et al., 2011.

A widespread implementation of tube wells beginning the 1980s as a pathogen-safe drinking water source exposed millions of people to arsenic contaminated drinking water. Two proposed solutions are finding alternative sources of water that are both pathogen and arsenic free and also treating arsenic contaminated water with appropriate technologies.

**Kanchan™ Arsenic Filter**

The Nepal Water Project (NWP) in the Civil and Environmental Engineering (CEE) Department at MIT began in 1999, in collaboration with the local NGO the Environment and Public Health Organization (ENPHO). The two primary objectives of the NWP were: (1) to quantify the water quality issues with specific data and analysis, and (2) to make recommendations on a point-of-use water treatment system that is both culturally and technically accepted and effective (Halsey, 2000). The second phase of this pilot study from 2002-2003 found the arsenic biosand filter, which was branded and trademarked as the Kanchan™ Arsenic Filter (KAF) in 2004, to be the most appropriate technology for the removal of arsenic in rural Nepal (Tabbal, 2003). From 2003- 2004 about 1,000 KAF filers were deployed throughout Nepal. Currently, the KAF filter has been disseminated to approximately 24,000 households.

The KAF is a modified Bio-sand Filter (BSF) for the removal of arsenic. The BSF, designed in the 1980s by the University of Calgary, is designed to operate on the principles of slow-sand filtration while incorporating a layer of standing water, typically 2 inches above the top fine sand layer. This layer of standing water facilitates the formation of a biofilm (*schmutzdecke*) layer for the predation of microbial contamination in the influent water (Ngai et al., 2006).

The KAF incorporates an arsenic removal mechanism into the BSF by adding a layer of iron nails into a diffuser basin above the BSF. In the KAF, arsenic is removed via adsorption onto the surface of iron species. As water is poured into the diffuser basin, it oxidizes the iron nails from Fe(0) to Fe(II). Dissolved oxygen in the water further oxidizes Fe(II) into Fe(III) which complexes as ferric hydroxide, $Fe(OH)_3$, more commonly known as rust. These dissolved ferric hydroxide particles then bind to the arsenic in the water creating an iron arsenic complex. This complex can then bind to the sand in the filter, removing it from the effluent water. This mechanism is similar to arsenic adsorption on zero-valent iron reported by Nikolaidis et al. 2003 and arsenic adsorption on hydrous ferric oxides reported by Hussam et al. 2003. It should be noted that though the KAF was designed to have the arsenic adsorb onto the $Fe(OH)_3$ still bonded to the nails, the complex made would then be flushed down by the water into the sand layers. However, the exact location of the oxidation mechanisms and the point where the iron and the arsenic complexes (on the nails or in the sand layers) in the KAF is not known.

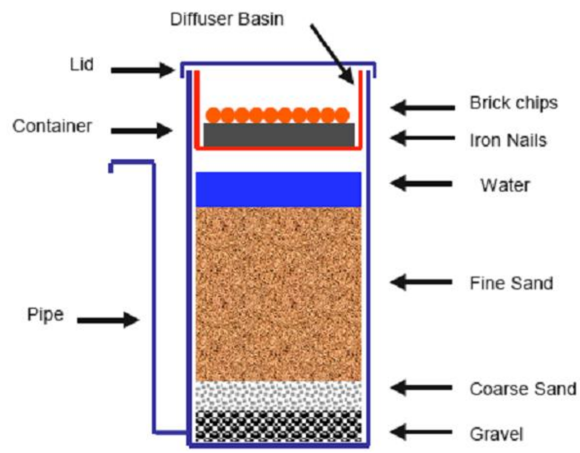


**Figure 2:** Diagram of the KAF, showing the location and arrangement of its components. Source: Murcott, 2010


**Figure 3**: KAF versions developed over the years. (Left to right) concrete square, 2002; concrete round, 2003; plastic hilltake, 2003; plastic GEM505, 2004. Source: Ngai, 2005.

Several models of the KAF have been developed over the years with an aim of improving the arsenic removal performance and the social acceptability of the filter: concrete square, concrete round, plastic square and GEM505 (**Figure 3**). The concrete KAF and the GEM505 KAF models were designed to provide a filtration rate of 25 and 15 L/hour, respectively, sufficient enough to supply water for a large family according the WHO guidelines (Howard, G. and Bartram, J., 2003). From February 2004 and 2005 ENPHO conducted a blanket testing of 1000 KAF systems, both concrete and plastic, throughout the Terai (ENPHO, 2008). This study showed the KAF to have a removal efficiency of 85-99% for total coliform and of 90-93% for arsenic concentrations. In addition, 95% of the filters produced drinking water with arsenic concentrations below the Nepali guideline of 50 µg/L (Ngai et al, 2006). For more information on the KAF's materials, cost and dissemination efforts in Nepal see Ngai et al., 2006 and Ngai et al., 2007.

**Problems with the KAF**

The National Drinking Water Quality Steering Committee (NDWQSC) of Nepal issued a 3rd party evaluation study of about 700 KAFs in 2009. This study found that the arsenic removal efficiency of the KAF was about 99% for influent arsenic concentrations less than 100 µg/L; however, for inlet arsenic concentrations greater than 100 µg/L, effluent arsenic concentrations were typically above the Nepali arsenic drinking water standard of 50 µg/L. In addition, the calendar year age of the KAF was observed to influence the arsenic removal performance of the filter. KAFs operating for less than one year had an arsenic removal efficiency of about 95%; however, 30% of the KAFs operating between 1-3 years and about 15% of the KAFs operating after 3 years had efficiency levels of <75%. Nonetheless, this 3rd party study found the KAF to be well performing (effluent arsenic concentrations below the Nepali standard) in all but 5% of the total sample size. The study observed that well performing and poorly performing filters were typically found within the same clusters. In particular, many of the clusters of poorly performing filters were located in the Nawalparasi District.

Another 3rd party study conducted by Chiew et al., 2009 in Cambodia tested the arsenic removal performance of 3 concrete square KAFs over the course of 5 and 1/2 months. This study found that none of the filters tested removed inlet arsenic concentrations to below the Nepali standard. The main reason behind the poor arsenic removal performance of the KAF was attributed to a combination of high influent phosphate concentrations and low iron concentrations. Other internal studies of the KAF in Bangladesh showed percent arsenic removal performance between 76% - 90 % in six GEM505 KAF models with influent iron groundwater concentrations of 6 mg/L.

**Nepal Water Project 2011**

The present study was developed in response to the reported poor performance of the KAF in particular areas of Nepal (i.e. the Nawalparasi district) and also in other South Asian countries. The uncertain performance of the KAF is presumed to be due to the different chemical composition of influent groundwater from location to location. The Nawalparasi District, in addition to having clusters of poorly performing filters, has some of the highest arsenic groundwater concentrations in all of Nepal. Thus, the first objective of this study was to evaluate the arsenic removal performance of the KAF under the different groundwater conditions of the Nawalparasi district to determine if the influent groundwater was impeding the KAF mechanism in this area. The second objective was to make recommendations on design improvements and operating limits for the dissemination of the KAF within and outside of Nepal based on the findings of the evaluation.

The studied parameters included: arsenic, ferrous iron, dissolved oxygen, pH, silica, phosphate and hardness. High arsenic concentrations (> 100 µg/L) were seen to affect the KAF performance (NDWQSC, 2009; ENPHO, 2008). Since iron is the adsorption media for the arsenic removal of the filter, low concentrations of iron may lead to poor filter performance. Low dissolved oxygen levels and high pH levels promote the more soluble species of iron and arsenic, therefore, impacting the adsorption mechanism of the KAF. Phosphate and silicate are competing ions for adsorptions sites at the surface of iron oxides, thus the presence of either ion impedes the sorption of the other competing ions (Meng et al., 2000; Su and Puls, 200; Meng et al., 2002; Roberts et al., 2004). High hardness concentrations can precipitate out a calcium buildup on the nails, possibly preventing the oxidation process of the iron and obstructing the arsenic removal mechanism of the KAF. In addition, to account for other outside variables in the filter performance not related to the water chemistry conditions, the filter flow rate, installation date, location and a user survey was also recorded.

## Experimental Section

**Site Selection**

The Nawalparasi District has some of the highest reported arsenic levels in Nepal; thus, it is a targeted region for filter distribution by many NGOs. Also, the NDWQSC study in 2009 identified this District as having clusters of poor performing filters. Individual villages within Nawalparasi were identified based on archived filter distribution lists recorded previously in a blanket KAF study in 2004-2005 by ENPHO. In addition, sale lists provided by local entrepreneurs of the KAF and contacts from ENPHO team members who previously distributed the KAF via non-affiliated parties were an aid to the study. The targeted villages were in areas where the reported KAF effluent arsenic concentrations were above 50 µg/L. In total, filters and groundwater sources in 15 different villages in the Nawalparasi District and 3 villages in the Rupandehi District were tested.

**Selection of Filter Types**

This study focused on the arsenic removal performance of the KAF for different groundwater parameters; therefore, to avoid the influence of structural or mechanical failures on the KAF's performance, filters were chosen based on the following criteria:

(1) *No cracks or leakage*: Structural failures in the KAF could allow inflows of untreated water. Also, leakages could affect the filter flow rate, which is an indication of filter performance, as discussed below.
(2) *Groundwater arsenic concentration greater than 50 µg/L*: The Nepali standard for arsenic concentrations in drinking water is 50 µg/L; therefore, filters were only tested with groundwater concentrations above this standard.
(3) *Maximum flow rate of 30 liters/hour*: Flow rates greater than 30 L/hour were seen in ENPHO, 2008 to lead to significant decreases in the percentage of arsenic removal by the KAF. This is presumed to be due to low water contact time with the nails or sand layers.
(4) *Sufficient sand*: The KAF was designed to have a 2-inch gap between the diffuser basin and the top sand layer. The consumer sometimes removes too much sand during cleaning or to increase flow rate, but this is not recommended and can lead to decreased filter life and increased filter flow rate.
(5) *Nails present and evenly spread*: The contact of iron nails with the groundwater is essential for the arsenic removal mechanism of the KAF, especially with naturally low levels of iron in the groundwater. Therefore, large gaps in the iron layer, or the absence of nails altogether, will let the groundwater drip through the diffuser basin and out the effluent without the proper arsenic treatment.
(6) *No tap*: Many consumers of the KAF like to install a tap into the outlet of the filter to control the volume of source water that is filtered or stored inside the KAF. This alteration allows them to collect the filtered water as needed throughout the day without adding in more source water continuously. However, this alteration will also inadvertently increase the standing water level above the sand, which is designed to be 2-inches such that sufficient oxygen from the air can diffuse into the biofilm layer in the sand. The biofilm layer will otherwise consume all of the oxygen in the sand layers of the filter. A lack of oxygen in the KAF can change the oxidation state of arsenic and iron in the sand layers to its more soluble forms, As(III) and Fe(II), thus possibly leading to "spiked" arsenic concentrations in the effluent water.

From these criteria, only the KAF concrete square, concrete round and GEM505 models were tested in this study. KAF model 3 (plastic square) was widely distributed in the Nawalparasi District but it was not included in this study due to structural failures noted in the side bulging of the plastic container, thus it is no longer promoted or distributed by ENPHO.

**Testing Method**

*Arsenic*

Arsenic concentrations in the influent groundwater and effluent filtered water were measured using the Wagtech Arsenator® Digital Arsenic Test Kit[1]. Studies show that the Arsenator can measure reliable arsenic concentration readings with a correlation of 0.95 and 0.96 with laboratory measurements of arsenic concentrations 0-100 µg/L (Sankararamakrishnan et al. 2008) and 0-250ug/L (Shukla et al., 2010) respectively. Testing methodology followed the Arsenator's instructional manual attached in **Appendix C**. The Arsenator used in the present study was borrowed from the Center for Affordable Water and Sanitation Technology (CAWST) of Canada.

*Iron*

Ferrous iron concentrations (Fe(II)) were measured in the influent groundwater, the water passing through the nails and dripping out of the diffuser basin ("nail water", **Figure 6**), and the effluent filtered water. Ferrous iron concentrations were measured using the HACH DR 27000 Portable Spectrophotometer[2] and HACH Ferrous Iron Reagent Powder Pillows[3]. The composition of the HACH reagent is about 10% 10-Phenanthroline and 90% sodium bicarbonate (HACH: MSDS-Ferrous Iron Reagent, 2009). If ferrous iron concentrations were present, the solution

[1] Product number: WAG-WE10500. Web: http://www.wagtech.co.uk/
[2] Product number: DR2700-01B1. Web: http://www.hach.com/
[3] Product number: 103769. Web: http://www.hach.com/

would turn orange and the spectrophotometer would calculate the concentration of Fe(II) from the color intensity within a range of 0.02 to 3.00 mg/L. If the solution surpassed the detection limit, the sample would be diluted by ½ (since our measurements of Fe(II) never exceeded 6 mg/l) using purchased bottled water, which indicated that it was reverse osmosis treated. Testing methodology followed the HACH Method 8186.

**Figure 4:** Collecting water sample after it has passed through the nails and is dripping from the diffuser basin into the sand layers. Hari Budhathoki (left) and Tirtha Raj Sharma Dhungana (right).

*Silica*

Silica concentrations were measured from only the groundwater sources using the HACH DR 2700 Portable Spectrophotometer and three silica reagents: citric acid, sodium molybdate, and the acid reagent[4]. The latter reagent has a composition of sulfamic acid and sodium chloride (HACH: MSDS-Acid Reagent, 2010). In the presence of silica concentrations, the sample will turn green with the reagents and the spectrophotometer can then calibrate the color intensity with the concentration within a range of 1 to 100 mg/L. Samples did not surpass the detection limit for silica, so dilution was not necessary. Testing methodology followed the HACH Method 8185.

*Phosphate*

Phosphate concentrations were only measured for the groundwater sources. Previous studies indicate that field kits for measuring phosphate concentrations do not prove to be very accurate. Therefore, groundwater samples were collected for each source and brought to ENPHO for laboratory analyses of phosphate concentrations. In the lab, phosphate was measured using an ammonium molybdate ascorbic acid reagent and a spectrophotometric instrument. Samples did not need to be preserved according to standard methods (“Standard Methods,” 1995).

*Dissolved Oxygen (DO)*

DO concentrations were measured for the effluent water from each of the filters of interest. This testing took place in the field using the HACH Dissolved Oxygen Test kit, model OX-2P[5]. This field kit measures dissolved oxygen concentrations using the drop count titration method. The detection range is 0.2-4 mg/L (in increments of 0.2 mg/L) and 1-20 mg/L (in increments of 1mg/L). Testing methodology followed the HACH Method 8215.

*Hardness*

Hardness concentrations were measured for the influent groundwater and the effluent filtered water. Samples were collected from each tube well source and brought back to the ENPHO Lab for more accurate and precise measurement ranges than field kits can provide. Samples did not need to be preserved according to standard methods (“Standard Methods,” 1995). In the lab, hardness was measured using the ethylenediaminetetraacetic acid (EDTA) titrimetric method. In addition, in the field, hardness measurements were estimated using the HACH 5 in 1 Water Quality Test strips[6] for total hardness concentrations as $CaCO_3$ (0, 250 or 425 mg/L).

*pH*

The pH levels for both the influent groundwater and effluent filtered water were measured using the WaterWorksTM Extended Range pH Check Strips. The WaterWorksTM strips have a detection sensitivity in increments of 1 for pH 1-5 and 10-12 and in increments of 0.5 for pH 6-9.5. The total test time per sample is 30 seconds. In addition, the HACH 5 in 1 Water Quality Strips were also used to measure pH with a detection range pH 6.2-8.4 in increments of pH 0.6.

In addition, split samples for arsenic (16), total iron (16), dissolve oxygen (14) and silica (15) concentrations were collected in polyethylene bottles and brought back to the ENPHO lab for testing. Samples were preserved and tested in accordance to standard methods (“Standard Methods”, 1995).

[4] Product number (for all three reagents): 2429600. Web: http://www.hach.com/

[5] Product number: 146900. Web: http://www.hach.com/

[6] Product number: 2755250. Web: http://www.hach.com/

## Sampling Methodology

After the filters were evaluated based on the criteria described in the section **Selection of Filter Types**, a systematic sampling procedure was followed to minimize sampling time and error from inconsistencies in sampling collection, as shown in **Figure 7** and described below:

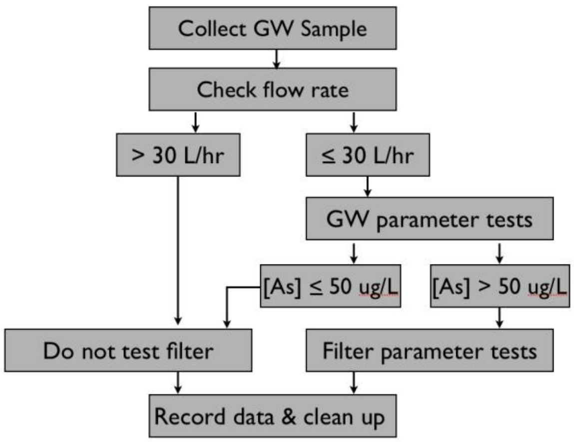


**Figure 5**: Flowchart of the Nepal 2011 field study sampling methodology. Note: GW = groundwater.

*Groundwater collection*
Groundwater was collected directly from private or public tube wells. Some tube wells needed to be "primed" prior to use, meaning prepared by pouring in a small amount of water into the pump and applying suction so that the mechanism of the tube well would work. However, groundwater samples collected directly after the priming procedure would be a poor representation of the groundwater conditions, since it would contain a mixture of the "priming water". Thus, for consistency each tube well was pumped for a minimum of 60 seconds prior to collecting the groundwater sample in 500mL plastic beakers.

*Measuring flow rate*
The groundwater sample would then be used fill up the corresponding filter for flow rate measurements. The filter flow rates were measured using a 500mL plastic graduated cylinder and a stopwatch was used. If the flow rate was above 30 L/hour (or above 500mL/minute) the filter would not be included for testing. If the flow rate was less than or equal to 30 L/hour field testing would proceed.

*Testing parameters in groundwater*
The parameters tested in each groundwater sample were: arsenic, pH, ferrous iron and silica concentrations. In addition, groundwater samples would be collected and stored in 500mL polyethylene bottles for hardness and phosphate testing in the ENPHO lab. All groundwater tests per tube well would take an estimated 25 minutes to complete, with the arsenic test results (~20 minutes to complete) being the determining factor in order to continue testing. If the arsenic concentrations in the groundwater were less than the Nepali Standard for drinking water (50 µg/L), all further testing for the corresponding filter would discontinue. On the other hand, if the groundwater concentration of arsenic was above 50 µg/L filtered water collection would proceed.

*Filtered water collection*
For direct comparison of the arsenic removal performance of the KAFs, it was important to flush the filter out completely before collecting the filtered water sample, so that it corresponded to the tested groundwater source. Assuming a plug flow nature for the bio-sand filters (neglecting any dispersion), the volume of water poured into the filter would need to be greater than the filter pore volume in order to collect newly filtered water. Since both the GEM505 and the concrete square KAF models have a pore volume of about 5L, the filtered water sample would be collected after at least 5 L of the groundwater sample had passed though. The measured flow rate of each filter would allow us to know when enough time had passed (corresponding to 5 L of filtered water) before collecting the filter samples in 500 mL plastic beakers. The "nail water" sample would be taken by lifting up the basin holding the nails and collecting the dripping water (**Figure 4**).

*Testing parameters in filtered water*
The parameters tested from the filtered water sample were: arsenic, pH, and ferrous iron concentrations. The water sample for dissolved oxygen would be collected directly from the filter outlet and tested immediately. In addition, a filtered water sample would be collected and stored in a 250mL polyethylene bottle for hardness testing in the ENPHO lab.

If a tube well source was servicing more than one KAF filter, the groundwater from the source would be tested only once and the filtered water would be tested for each individual filter. In this step, it was assumed that the groundwater source would not change drastically over the course of a few hours. Resulting data from each groundwater and filtered water sample would be documented in a notebook and later updated into an electronic spreadsheet. In addition, user survey results would be collected by ENPHO staff personnel in Nepali and later translated to English. Also, the stored groundwater and filtered water samples would be labeled to match the corresponding test serial number on the data sheet. The testing instruments would then be cleaned and re-supplied for the next round of testing.

## Results and Discussion

**Effects of chemical parameters**

This section will present the results of all chemical parameters tested in the field. Filter performance was determined by the effluent filtered water arsenic concentrations relative to the Nepali standard for arsenic in drinking water of 50 µg/L. The parameters measured were graphed against the effluent arsenic concentrations to observe any relationship and correlation between the two data sets. Also, the KAFs were evaluated based on the percent arsenic removal and the effluent arsenic concentration levels relative to the Nepali standard. The parameter measurements corresponding to each filter were graphed against the percent arsenic removal to observe any correlation. A regression analysis was performed to determine the significance of any perceived correlation. An $R^2$ value above 0.0645 for 100 samples was taken to be significant to the 0.01 (Downie and Heath, 1965). Associated errors in measured values were estimated using previous studies and calibration curves against standards and split sample values tested by ENPHO (**Appendix D**). Overall, 100 separate KAFs were tested, corresponding to 79 groundwater sources and 101[7] filtered water samples. Thus, the total sample size for all parameters was 101, with the exception of ferrous iron (N=100), phosphate (N=97), and hardness (N=97) readings. Raw data collected is presented in **Appendix G**.

*Arsenic*

Arsenic concentration measurements ranged from 0 non-detectable (ND)[8] to a maximum of 500 µg/L (upper detection limit). **Figure 6** displays an overview of the arsenic concentration ranges for both influent groundwater and effluent filtered water sources. Most filters were observed to remove some fraction of influent groundwater arsenic concentrations. There was a 58:43 ratio between well performing and poorly performing filters. Well performing filters removed on average 91% of the inlet arsenic concentration, while poorly performing filters removed on average only 50% of the inlet arsenic concentration. However, there was no correlation ($R^2$ = 0.0288) between inlet groundwater arsenic concentration and arsenic removal performance (**Figure 7**). There was, though, an observed relationship between influent arsenic concentrations below 200µg/L and effluent arsenic concentrations below the Nepali standard (**Figure 8**). About 93% of the samples (N=27) with groundwater concentrations below 200µg/L correspond to a filtered water arsenic concentration below 50µg/L.

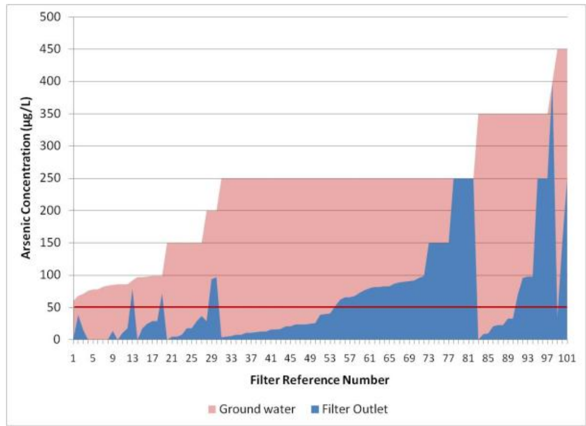


**Figure 6**: Arsenic concentrations in groundwater and filtered water samples. Error: +/- 25% (As ≤ 100 µg/L) and +/- 50 µg/L (As >100 µg/L). Solid red line: Nepali arsenic drinking water standard (50 µg/L).

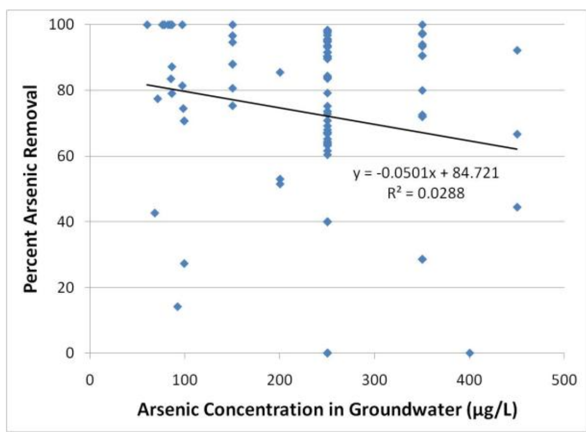


**Figure 7**: Groundwater arsenic concentrations vs. percent arsenic removal of the KAFs. Error: +/- 25%

[7] Filter number 43 and 53 are the same GEM505 filter tested with the same groundwater source on two separate days.

[8] Below detection limit of the measuring instrument

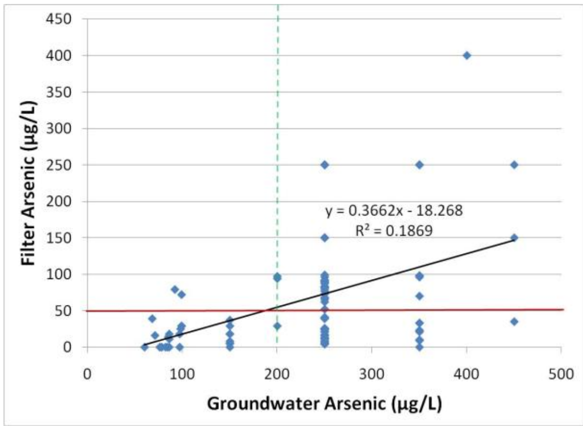


**Figure 8**: Groundwater arsenic concentrations vs. filtered water arsenic concentrations. Error: +/-25% (As ≤ 100 µg/L) and +/-50 µg/L (As >100 µg/L). Solid red line: Nepali arsenic drinking water standard (50 µg/L). Dotted green line: shift from mostly well performing filters (left) to both poor and well performing filters (right).

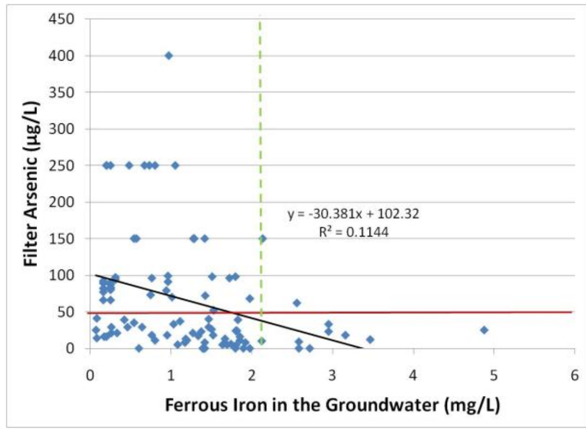


**Figure 9**: Fe(II) concentrations in groundwater vs. filtered water arsenic concentrations. Error: +/-25% (As ≤ 100 µg/L), +/- 50 µg/L (As >100 µg/L), +/- 0.03 mg/L (Fe ≤ 1mg/L), and +/- 20% (Fe > 1mg/L). Solid red line: Nepali arsenic drinking water standard (50 µg/L). Dotted green line: shift from mostly well performing filters (right) to both poor and well performing filters (left).

*Iron*

Ferrous iron (Fe(II)) concentrations ranged from 0 ND to 7.4 mg/L in groundwater, 0 ND to 1.8 mg/L in filtered water, and 0 ND to 3 mg/L in the nail water sources. Overall, Fe(II) concentrations in the groundwater and nail water were higher in the well performing filters than the poorly performing filters. Also, high groundwater Fe(II) concentration correlate significantly with low effluent arsenic concentrations ($R^2$=0.114) and with high percent arsenic removal ($R^2$=0.153) (**Figure 9** and **Figure 10**). Similarly, high nail water Fe(II) concentrations correlate significantly with low effluent arsenic concentrations ($R^2$=0.085) and with high percent arsenic removal ($R^2$=0.133) (**Figure 11** and **Figure 12**). In addition, a strong relationship between effluent arsenic concentrations below the Nepali standard and both Fe(II) concentrations >3mg/L in groundwater and >1.1 mg/L in nail water samples was observed. Furthermore, most of the Fe(II) concentrations after the nails were due to influent groundwater Fe(II) concentrations but there was no correlation with delta Fe(II) values (groundwater minus nail water Fe(II) concentrations) and effluent arsenic concentrations (**Figure 13**). Fe(II) concentrations in the effluent filtered water of well performing filters were on average lower than the WHO standard for total iron concentrations in drinking water (0.3 mg/L), but higher for poorly performing filters (WHO: Guidelines for Drinking-water Quality, 2008). Regression analysis showed that Fe(II) concentrations in the filter water were not significantly correlated to effluent arsenic concentrations (**Appendix E**).

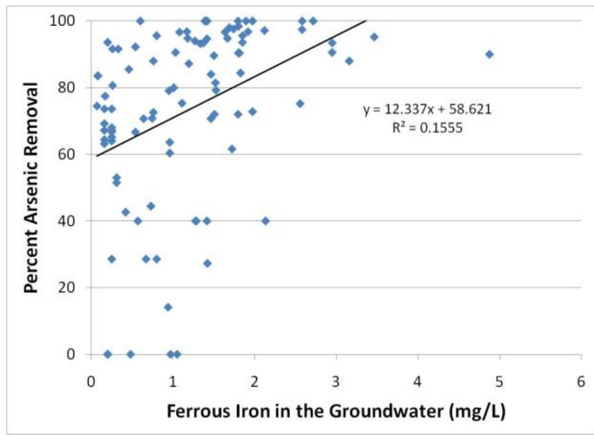


**Figure 10**: Fe(II) concentrations in groundwater vs. percent arsenic removal. Error: +/- 25% (As), +/- 0.03 mg/L (Fe ≤ 1mg/L), and +/- 20% (Fe > 1mg/L).

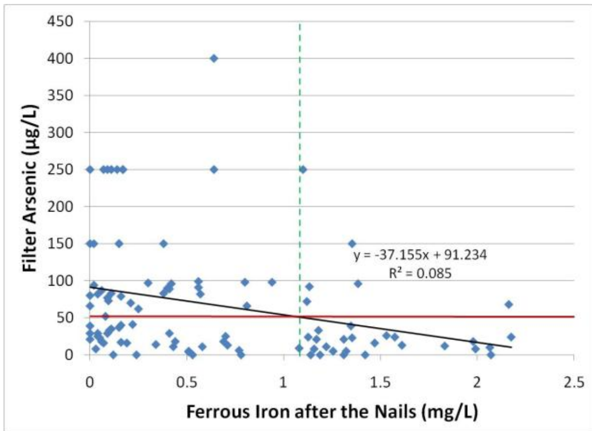


**Figure 11**: Fe(II) concentrations after the nails vs. arsenic concentrations in the effluent filtered water. Error: +/-25% (As ≤ 100 µg/L), +/- 50 µg/L (As >100 µg/L), +/- 0.03 mg/L (Fe ≤ 1mg/L), and +/- 20% (Fe > 1mg/L). Solid red line: Nepali arsenic drinking water standard (50 µg/L). Dotted green line: shift from mostly well performing filters (right) to both poor and well performing filters (left).

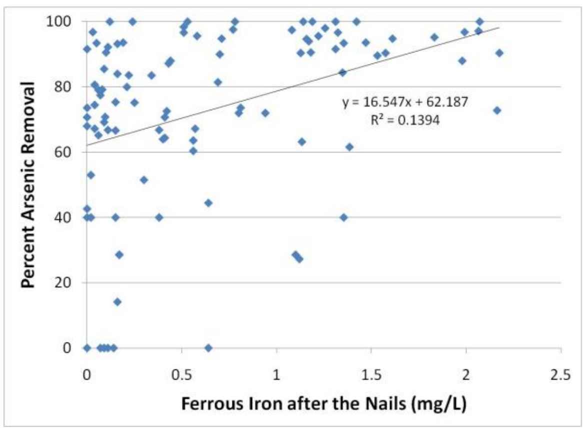


**Figure 12**: Fe(II) concentrations in the nail water vs. percent arsenic removal. Error: +/- 25% (As), +/- 0.03 mg/L (Fe ≤ 1mg/L), and +/- 20% (Fe > 1mg/L).

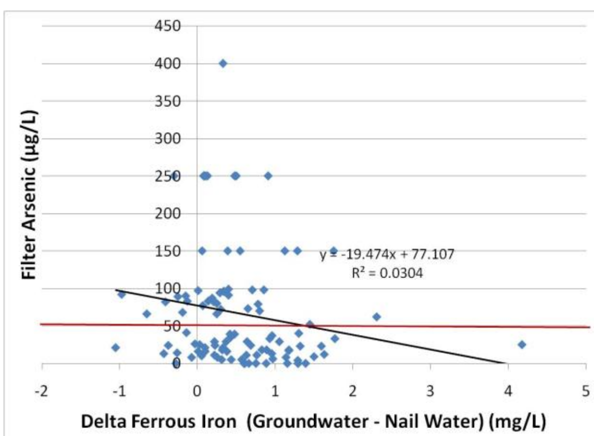


**Figure 13**: Delta Fe(II) concentrations (Groundwater minus Nail Water) vs. percent arsenic removal. Error: +/- 25% (As), +/- 0.03 mg/L (Fe ≤ 1mg/L), and +/- 20% (Fe > 1mg/L).

*Hardness*

Measurements of hardness as $CaCO_3$ ranged from 140 mg/L to 508 mg/L. Stored samples were measured in the ENPHO Lab using the EDTA titration method with a reported analytical error of 10%. Average hardness concentrations were not significantly different between the groundwater and filtered water sources or between the well performing and poorly performing filters. Regression analysis showed that there is not a significant correlation between hardness concentrations in the groundwater and arsenic concentrations in the filtered water ($R^2$=0.056) (**Figure 14**). However, there is an observed relationship in hardness concentrations in the groundwater above 350 mg/L and arsenic concentrations in the filtered water below the Nepali standard. In addition, there was a high significant correlation between groundwater hardness concentrations and percent arsenic removal ($R^2$= 0.135) (**Figure 15**). In part, the relationships observed between hardness and arsenic could be due the high correlation ($R^2$=0.422) seen between groundwater hardness concentrations and Fe(II) levels after the nails (**Figure 16**).

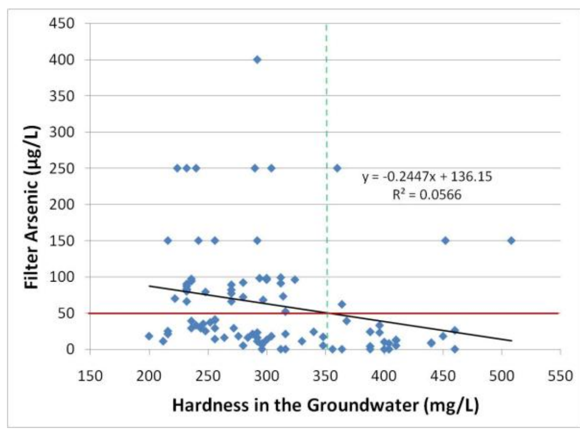


**Figure 14**: Total hardness concentration in groundwater vs. filtered water arsenic concentrations. Error: +/- 25% (As ≤ 100 µg/L), +/-50 µg/L (As >100 µg/L), and +/-10% mg/L (hardness). Solid red line: Nepali arsenic drinking water standard (50 µg/L). Dotted green line: shift from mostly well performing filters (right) to both poor and well performing filters (left).

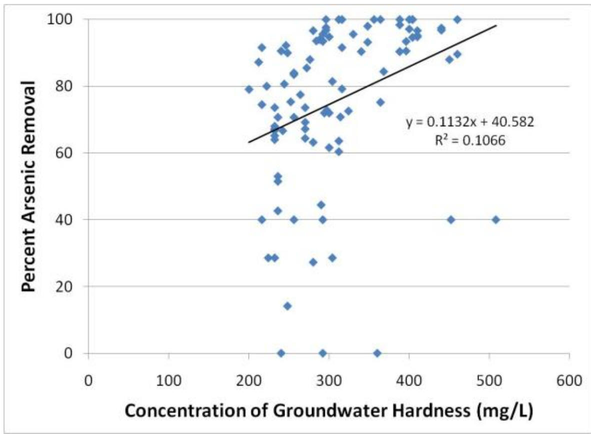


**Figure 15**: Hardness concentrations in the groundwater vs. percent arsenic removal. Error: +/- 25% (As) and +/- 10% (hardness).

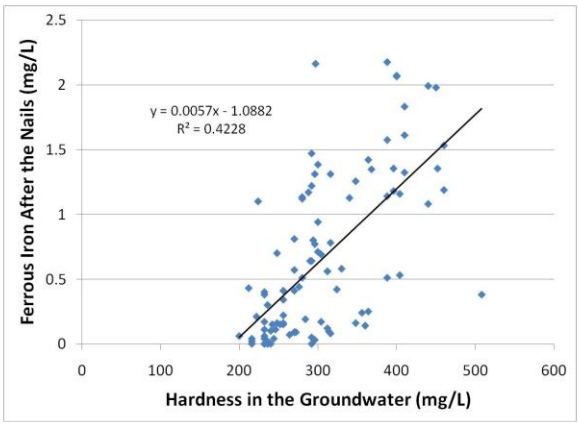


**Figure 16**: Groundwater Hardness vs. Fe(II) concentrations after the nails. Error: +/-0.03 mg/L (Fe ≤ 1mg/L), +/-10% (Fe >1mg/L), and +/-10% (hardness).

Total phosphorus, silica and dissolved oxygen did not have any correlation or relationship with the percent arsenic removal performance of the KAF and the effluent arsenic concentrations, relative to the Nepali standard. Low groundwater pH values did show a slight relationship with effluent arsenic concentrations below the Nepali standard, however there was not enough data points or any significant correlation in the data set. Also, location and social factors were not observed to strongly affect the filter performance. Figures and tables for these measurements are found in **Appendix E** and **Appendix F**. Raw data for the collected user survey is presented in **Appendix H**.

Overall, field data analysis suggested that the performance of the KAF was related to the ferrous iron levels of the groundwater and nail water, as well as the hardness of the inlet water source. To further explore the cause of low Fe(II) levels after the nails, new parameters relating to corrosion (chloride, electrical conductivity, and manganese) were tested in the ENPHO lab following the field study. In addition, pH levels were retested from the stored groundwater samples to verify the pH measurements from the pH test strips.

**Effect of corrosion parameters**

Groundwater samples collected in the field for the analysis of hardness and phosphate concentrations in the ENPHO lab were used to measure the new testing parameters. These samples were stored in labeled polyethylene bottles for about 10-12 weeks prior to the new testing. One groundwater sample (corresponding to three poorly performing filters) and a couple other samples were misplaced or missing so the new sample size for the following parameters is 96. The estimated error reported by ENPHO for all new parameter tests is +/-10%. In addition, tested manganese concentrations were mostly all below the instrument detection limit (<0.2 mg/L) so it is not included in the proceeding test results.

*Chloride*

Chloride concentrations in the water were ranged from 0 ND to 91 mg/L. **Figure 17** shows a strong relationship between chloride levels above 7mg/L and effluent arsenic concentrations below the Nepali standard; however, there was no significant correlation between the two parameters. Yet, there was a significant, though small, correlation ($R^2$ = 0.068) between high chloride concentrations and high dissolved iron concentrations ($R^2$=0.68) (**Figure 18**). Thus, these observations show that chloride may be a notable measure for dissolved iron concentrations but not directly related to arsenic concentrations or KAF performance.

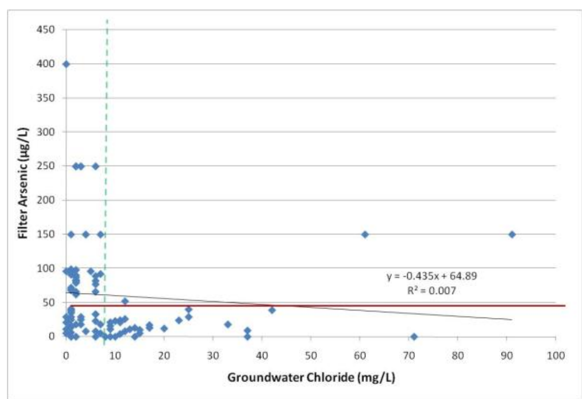


**Figure 17**: Groundwater chloride concentrations vs. effluent arsenic concentrations. Error: 25% (As ≤ 100 μg/L), +/- 50 μg/L (As >100 μg/L) and +/- 10% (chloride). Solid red line: Nepali arsenic drinking water standard (50 μg/L). Dotted green line: shift from mostly well performing filters (right) to both poor and well performing filters (left).

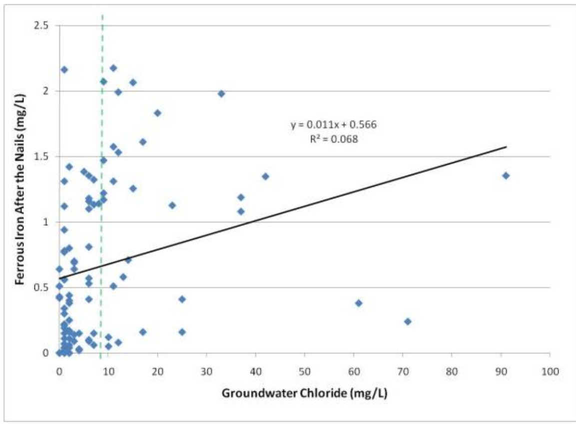


**Figure 18**: Groundwater chloride concentrations vs. Fe(II) concentrations after the nails. Error: +/- 0.03 mg/L (Fe ≤ 1mg/L), +/- 10% (Fe > 1mg/L) and +/- 10% (chloride). Dotted green line: shift from mostly well performing filters (right) to both poor and well performing filters (left) from the previous graph.

**Statistical Analysis of All Parameters**

Factor analysis is a statistical method used to describe the variability among a large set of observed parameters to identify the number and loadings of unobserved variables referred to as factors. For this data, a factor of one was assumed in order to calculate the factor loading matrix of the model to observe any joint variations among our parameter outputs that would identify interdependencies between the measured parameters and the arsenic removal performance. The "factoran" syntax in MATLAB was used to calculate the maximum likelihood estimate of the factor loading matrix (A) in the factor analysis model. The computed factor loading and variance values are shown in **Table 1**. This analysis shows a notable interdependence relationship between Fe(II) (groundwater, filtered water and nail water), hardness (groundwater and filtered water), groundwater chloride and percent arsenic removal. This further confirms our graphical findings that identified the relationship between Fe(II), hardness and chloride, and how they can be related to the KAF performance.

**Table 1**: Factor loading and variance for each parameter using one common factor (N=96).

| Parameter | Factor Loading | Variance |
|---|---|---|
| % Arsenic Removal | 0.4613 | 0.7872 |
| GW Arsenic | 0.0007 | 0.9999 |
| FW Arsenic | -0.3762 | 0.8584 |
| GW Fe(II) | 0.6894 | 0.5247 |
| FW Fe(II) | 0.5185 | 0.7312 |
| Nail Fe(II) | 0.7144 | 0.4896 |
| GW Hardness | 0.8859 | 0.2151 |
| FW Hardness | 0.8815 | 0.2229 |
| GW Silica | 0.0563 | 0.9968 |
| GW Phosphate | 0.0981 | 0.9904 |
| FW Dissolved Oxygen | -0.3906 | 0.8474 |
| GW pH | -0.1718 | 0.9705 |
| FW pH | -0.0934 | 0.9913 |
| Flow | -0.1563 | 0.9756 |
| Age | -0.0017 | 0.9999 |
| GW Electrical Conductivity | 0.0855 | 0.9927 |
| GW Chloride | 0.5207 | 0.7289 |

GW = groundwater; FW = filtered water; Shaded parameters are shown to be related.

In addition, the Generalized Linear Model (GLM) was used to find the linear relationship between a dependent (or response) variable *Y*, and a set of predictor variables, the *X*'s, such that:

$$Y = b_0 + b_1X_1 + b_2X_2 + ... + b_nX_n$$

Where $b_0$ is the intercept coefficient and the $b_i$ values are the regression coefficients (for variables 1 through *n*). The MATLAB syntax "glmfit" was used to compute t he *bo* and *bi* values. For this analysis the Y vector was the arsenic removal performance of each filter and the X matrix was only the measured groundwater parameters (**Table 2**).

**Table 2:** Regression coefficients for the groundwater parameters using the GLM model (N=96). Note: GW = groundwater

| Parameter | b (regression coefficient) |
|---|---|
| (bo) coefficient | 98.72 |
| GW Arsenic | -0.0424 |
| GW Fe | 4.4456 |
| Nail Fe | 4.9664 |
| GW Hardness | 0.0466 |
| Silica | 0.2168 |
| Phosphorous | -12.2943 |
| GW pH | -4.8597 |
| conductivity | -0.0058 |
| chloride | -0.1325 |

This analysis shows that the groundwater arsenic, phosphorus, groundwater pH, conductivity and chloride concentrations negatively affect the percent arsenic removal performance with an increase in concentration. Similarly, groundwater iron, nail water iron, groundwater hardness and silica all contribute positively to the arsenic removal performance of the filter with an increase in concentration. Though these models give us a more sophisticated analysis of our large data set, it should be looked at with consideration of the sample size and the variability of other factors not accounted for, such as the social and filter specific characteristics (i.e. flow rate, age), in non-controlled testing environment.

## Conclusion and Recommendations

The data points to three major groundwater parameters that may affect the arsenic removal performance of the KAF: the influent groundwater ferrous iron concentration, the ferrous iron concentration present after contact with the nails, and the inlet groundwater hardness concentrations. In addition, it was observed that the KAF typically fails when the groundwater arsenic concentrations are ≥ 200µg/L, the ferrous iron concentrations of the nails are < 1.1mg/L and the groundwater chloride concentrations are < 7mg/L. This range contained 82% of the studied poorly performing filters (N=39) as opposed to only 15% of the well performing filters (N=58). Thus, these findings suggest that groundwater conditions that do not promote the corrosion of the iron nails and have high inlet arsenic concentrations may result in a poorly performing KAF.

The corrosiveness of the groundwater was observed though the measured hardness ($Ca^{+}$ ions) and chloride concentrations. There was a significant correlation ($R^2$=0.422) between high ferrous iron concentrations after contact with the nails and high hardness concentrations in the groundwater. There was also a significant correlation ($R^2$=0.068) between high ferrous iron concentrations after contact with the nails and high chloride groundwater concentrations. In addition, it was observed visually from **Figure 17** that the filters were likely to perform well with chloride levels in the groundwater higher than 7 mg/L. Also, observed was a relationship between groundwater arsenic concentrations ≥200µg/L and filtered water arsenic levels below the Nepali standard. For groundwater arsenic concentrations ≥200µg/L, the minimum percent arsenic removal required is 75% to meet the Nepali standard. The average percent arsenic removal of the poorly performing filters in this study (N=42) was 50+/-26 % (with a range of 0-80 % removal); therefore, some of the labeled "poorly performing" filters could meet the Nepali standard with inlet arsenic concentrations <200µg/L. Since the average groundwater arsenic concentration from the samples observed in this study (N=79) was >200µg/L, filter performance should be evaluated with regards to these high inlet arsenic concentrations for the dissemination of the filter into various locations.

Groundwater pH concentrations observed in this study did not have a significant correlation between arsenic concentrations in the effluent water. Yet, it is important to note that low groundwater pH levels (< pH=6) were related to arsenic effluent concentrations below the Nepali standard; however, low groundwater levels only accounted for 7% of the total measured groundwater pH data. Further studies are recommended to confirm this observation and to determine the effect of pH on KAF's performance. Other studies are necessary to pin-point the location where the different oxidation states of the iron occur within the KAF mechanism. Particularly, it is not known if low ferrous iron concentrations after contact with the nails correspond to low production of ferrous iron by the nails or the fast oxidation of ferrous iron to ferric iron. Considering that the corrosion rate of the nails was seen to be an influential factor in the filter's performance, resolving this ambiguity will further help to identify the critical parameters that may drive the KAF's arsenic removal mechanism.

In addition, further studies are necessary to see how the KAF performs in groundwater conditions with high levels of competing ions. The groundwater observed in Nepal on average had very low concentrations of phosphate (0.2 mg/L) compared to the average groundwater concentrations in other South Asian countries (>1mg/L). Since high concentrations of phosphate or silicate have been previously observed to impede the adsorption of arsenic onto ferric oxides, more research should be done on how to improve the filter with groundwater conditions that do not promote iron corrosion and have high concentrations of phosphate and silicate. This is especially recommended for the safe dissemination of this filter into other South Asian countries with more complex groundwater conditions.

Lastly, it is recommended to study and incorporate the use of new local components in the KAF system to increase iron corrosion. Due to the observed correlations between high dissolved iron and high hardness or high chloride concentrations, researching the possible incorporation and effect of adding local hardness or chloride sources (i.e. limestone or rock salt) is an advised. This includes studying the quantity and frequency of incorporating the new component such that it is safe for the users to consume, socially or economically desirable and is effective for the removal of arsenic from raw groundwater, prior to distribution.

## Acknowledgements

Firstly, many thanks to Raju Shretha who passed away before the present study was complete. Raju was a dear friend and key component of the execution of this study – we couldn't have done it without him. Thank you Raju for all your hard work and dedication, you will truly be missed. I would also like to thank all of those parties involved in the making, execution and publication of this study: Raju Shretha, Chintu Thapa, Hari Budhathoki, Tirta Sharma, Bipin Dangol, Susan Murcott, Tommy Ngai, Harry Hemond, the entire ENPHO Staff, the MIT MEng program, the MIT Legatum Center, and the wonderful people of Nepal. In addition, I would like to thank my family and friends, in particular: Mami, Papi, Jito, Stephen, Dorothy, and Polina. Literally, I could not have done this without you.

## References

Chiew, H., Sampson, M. L., Huch, S., Ken, S., and Bostick, B. C. (2009). Effect of Groundwater Iron and Phosphate on the Efficacy of Arsenic Removal by Iron-Amended BioSand Filters. *Environmental Science and Technology*, 43, 6295-6300.

Downie, N. M. and Heath, R. W. (1959). Basic Statistical Methods. New York: Harper & Row

Eaton, A. D., Clesceri, L. S., and Greenberg, A. E. (Eds.). (1995). *Standard Methods for the Examination of Water and Wastewater.* Washington, DC: American Public Health Association, American Water Works Association, and Water Environment Federation.

Environment and Public Health Organization. (2008). *DM evaluation database analysis Jan08 full* [Data file]. Retrieved from: Tommy K. K. Ngai

HACH (2009). Material Safety Data Sheet (MSDS) for Ferrous Iron Reagent. MSDS No: M00024. Retrieved from: HACH.

HACH (2010). Material Safety Data Sheet (MSDS) for Acid Reagent (Silica reagent 3). MSDS No: M00025. Retrieved from: HACH.

Halsey, P. M., (2000) . *Arsenic Contamination Study of Drinking Water in Nepal*. (Master of Engineering thesis). Massachusetts Institute of Technology, Cambridge, MA, USA.

Howard, G. and Bartram, J. (2003). Domestic Water Quantity: Service Level and Health, World Health Organization WHO/SDE/WSH 03.02.

Hussam, A., Habibuddowla, M., Alauddin, M., Hossain, Z. A., Munir, A. K. M., and Khan, A. H. (2003). Chemical fate of arsenic and other metals in groundwater of Bangladesh: experimental measurement and chemical equilibrium model. *Journal of Environmental Science and Health*, A38(1), 71–86.

Meng, X., Bang, S., and Korfiatis, G. P. (2000). Effects of silicate, sulfate, and carbonate on arsenic removal by ferric chloride. *Water Research*, 34(4), 1255-1261.

Meng, X., Korfiatis, G. P., Bang, S., and Bang, K. W. (2002). Combined effects of anions on arsenic removal by iron hydroxides. *Toxicology Letters*, 133 (1), 103-111.

Murcott, S. (2010). *MEng 2011 Nepal Susan intro presentation* [PDF File]. Retrieved from: Susan Murcott.

National Drinking Water Quality Steering Committee (NDWQSC) and CEMAT Laboratory Pvt. Ltd. (2009). *Preliminary findings of KAF evaluation study* [PowerPoint Slides]. Meeting, 2 February, 2009, DWSS, Meeting Hall. Retrieved from: Susan Murcott.

Ngai, T. K. K., Murcott, S., Shrestha, R. R., Dangol, B., and Maharjan, M., (2006). Development and Dissemination of Kanchan$^{TM}$ Arsenic Filter in Rural Nepal. *Water Science & Technology: Water Supply*, 6(3), 137-146.

Ngai, T. K. K. (2005). *Kanchan$^{TM}$ Arsenic Filter: Research Findings* [PowerPoint Slides]. Center for Affordable Water and Sanitation Technology (CAWST), Lunch and Learn #4. 18 October 2005. Calgary, Canada.

Ngai, T. K. K., Shrestha, R. R., Dangol, B., Maharjan, M., and Murcott, S. E. (2007). Design for sustainable development – Household drinking water filter for arsenic and pathogen treatment in Nepal. *Journal of Environmental Science and Health Part A*, 42, 1879-1888.

Nikolaidis, N. P. ; Dobbs, G. M. ;Lackovic, J. A. Arsenic removal by zero-valentiron: field, laboratory and modeling studies. *Water Resour*. 2003, 37(6),1417–1425.

Roberts, L. C., Hug, S. J., Ruettimann, T., Billah M., Khan, A. W. and RahmanM. T. (2004). Arsenic Removal with Iron(II) and Iron(III) in Waters with High Silicate and Phosphate Concentrations. *Environmental Science and Technology*, 38, 307-315.

Sankararamkrishnan, N., Chauhan D. C., Nickson, R. T., Tripathi, R.M. and Iyengar, L. (2008). Evaluation of two commercial field test kits used for screening of groundwater for arsenic in Northern India. *Science of The Environment*, 401(1-3), 162-167

Shukla, D. P., Dubey, C. S., Singh, N. P., Tajbakhsh, M., and Chaudhry, M. (2010). Sources and controls of arsenic contamination in groundwater of Rajnandgaon and Kanker District, Chattisgarh Central India. *Journal of Hydrology*, 395 (1-2), 49-66.

Smedley, P. (2003). Chapter 7: Arsenic in groundwater – south and east Asia. *British Geological Survey*, Maclean Building, Wallingford, Oxfordshire, OX10 8BB, UK

Su C. and Puls. R. W. (2001). Arsenate and Arsenite Removal by Zerovalent Iron: Effects of Phosphate, Silicate, Carbonate, Borate, Sulfate, Chromate, Molybdate, and Nitrate, Relative to Chloride. *Environmental Science and Technology*, 35, 4562-4568.

Tabbal, G., (2003). *Technical and Social Evaluation of Three Arsenic Removal Technologies in Nepal*. (Master of Engineering thesis). Massachusetts Institute of Technology, Cambridge, MA, USA

Thakur, J. K., Thakur, R. K., Ramanathan, A. L., Kumar, M., and Singh, S. K. (2010). Arsenic Contamination of Groundwater in Nepal – An Overview. *Water*, 3, 1-20

Wagtech, WTD (2011). Arsenator Digital Arsenic Test Kit. Retrieved from: http://www.wagtech.co.uk/products/water-and-environmental/water-test-kits/arsenator%C2%AE-digital-arsenic-test-kit

World Health Organization (WHO). (2008). Guidelines for Drinking-water Quality, 3rd edition incorporating the 1st and 2nd Addenda, 1(Recommendations). Geneva, Switzerland.

**Appendix A:** Abbreviations

| | |
|---|---|
| MIT | – Massachusetts Institute of Technology |
| CEE | – Civil and Environmental Engineering |
| ENPHO | – Environment and Public Health Organization |
| KAF | – Kanchan™ Arsenic Filter |
| NWP | – Nepal Water Project of MIT |
| NGO | – Non-governmental Organization |
| NDWQSC | – National Drinking Water Quality Steering Committee |
| As | – Arsenic |
| Fe | – Iron |
| P | – Phosphorous (refers to phosphate in this context) |
| Si | – Silicon (refers to silica/silicate in this context) |
| DO | – Dissolved oxygen |
| WHO | – World Health Organization |
| mg/L | – milligrams per Liter |
| μg/L | – micrograms per Liter |
| L/hour | – Liters per hour |
| Lab | – Laboratory |
| ND | – Non-detectable |
| BSF | – Bio-Sand Filter |
| DWSS | – Department of Water Supply and Sewerage |
| Fe(II) or $Fe^{2+}$ | – Ferrous iron |
| Fe(0) or $Fe^{0}$ | – Zero valent iron |
| Fe(III) or $Fe^{3+}$ | – Ferric iron |
| CAWST | – Center for Affordable Water and Sanitation |
| VDC | – Village Development Committees |
| EDTA | – Ethylenediaminetetraacetic acid |
| GW | – Groundwater |
| L | – liter |

**Appendix B** : User Survey

The following survey was used to document the user and location of each studied KAF. In addition, other details related to the type of KAF and reported or observed maintenance was recorded.

| | | |
|---|---|---|
| Date and Time | | |
| District | | |
| VDC | | |
| Ward No. | | |
| Tole | | |
| **KANCHAN ARSENIC FILTER INFORMATION** | | |
| Type of KAF | (1) Concrete, round<br>(2) Concrete square<br>(3) Plastic, round | (4) Plastic, square<br>(5) Gem505<br>(6) Fiberglass |
| KAF Provided by | (1) NRCS<br>(2) RWSSSP<br>(3) RWSSFDB | (4) Others, specify: |
| KAF Installation Date | | |
| qality of iron nails | (1) not rusted | (2) moderatly rusted (3) well rusted |
| Number of KAF Housholds | | |
| Number of KAF Users | | |
| How many liters of water do you filter each day? | (1) less than 10 L<br>(2) 10 to 20 L<br>(3) 20 to 30 L | (4) 30 to 40 L<br>(5) 40 to 50 L<br>(6) over 50 L |
| Filter current in use? | (1) Yes, everyday<br>(2) Yes, sometimes<br>(3) No. I drinking unfiltered water.<br>(4) No.  I use another arsenic-free water source, specify: | |
| Filter Cleaning Frequency | (1) once every week<br>(2) once every two weeks<br>(3) once a month | (4) once every 2-4 months<br>(5) never |
| Date of Last Cleaning | | |

**Appendix C**: Wagtech Arsenator® Digital Arsenic Test Kit Operation Manual

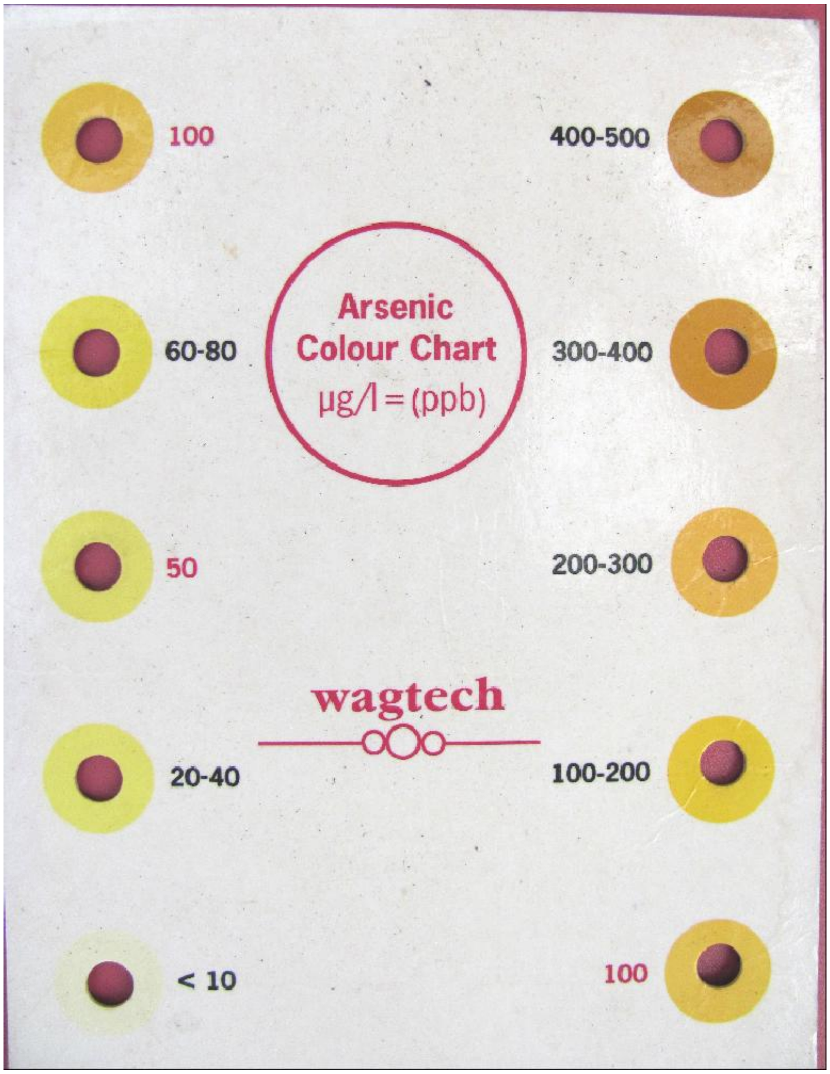


**Figure B-19**: Arsenic color chart for concentrations above 100µg/L.

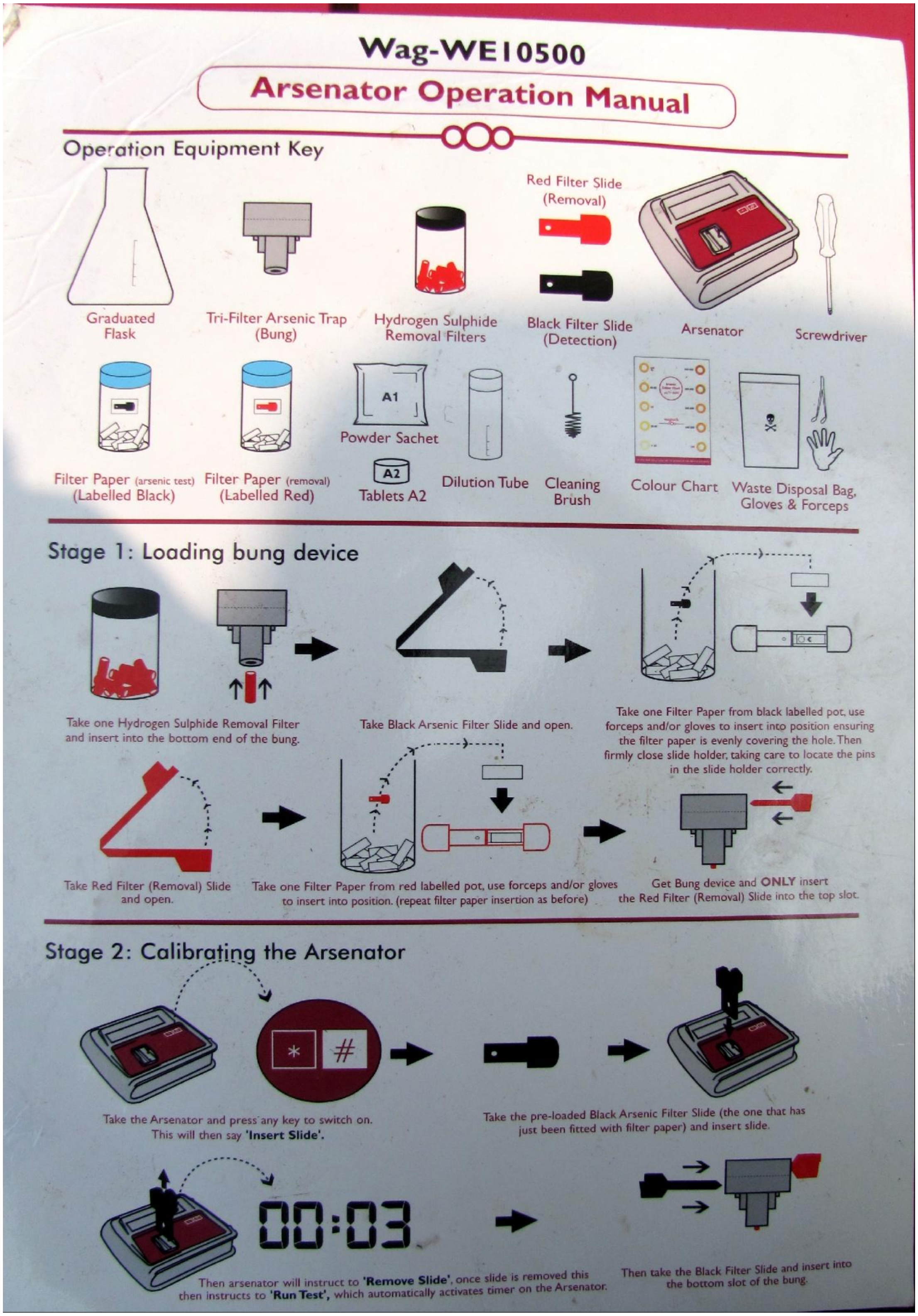


**Figure B-20:** Scanned copy of the Wagtech Arsenator operation manual, part 1

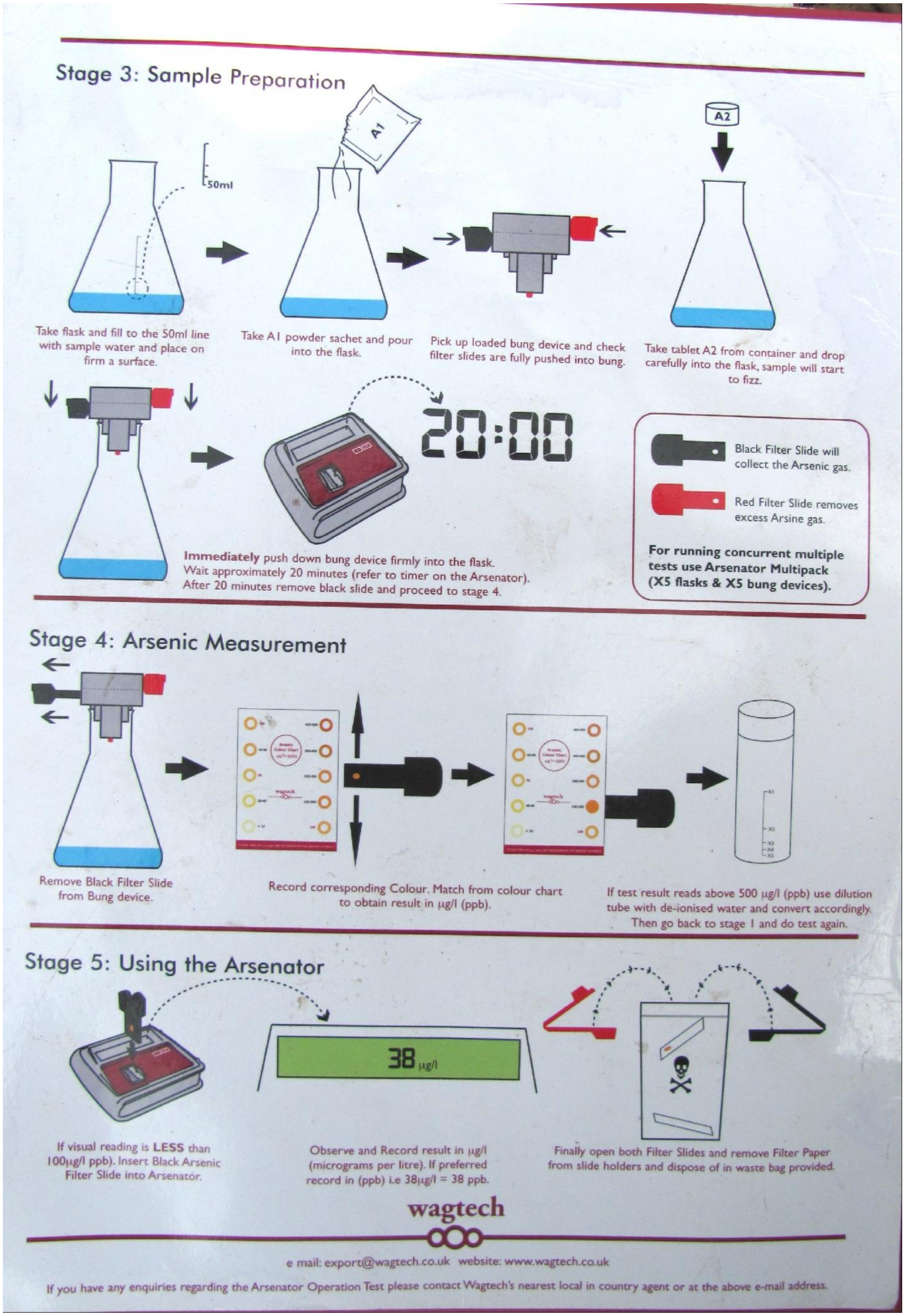


**Figure B-21**: Scanned copy of the Wagtech Arsenator operation manual, part 2

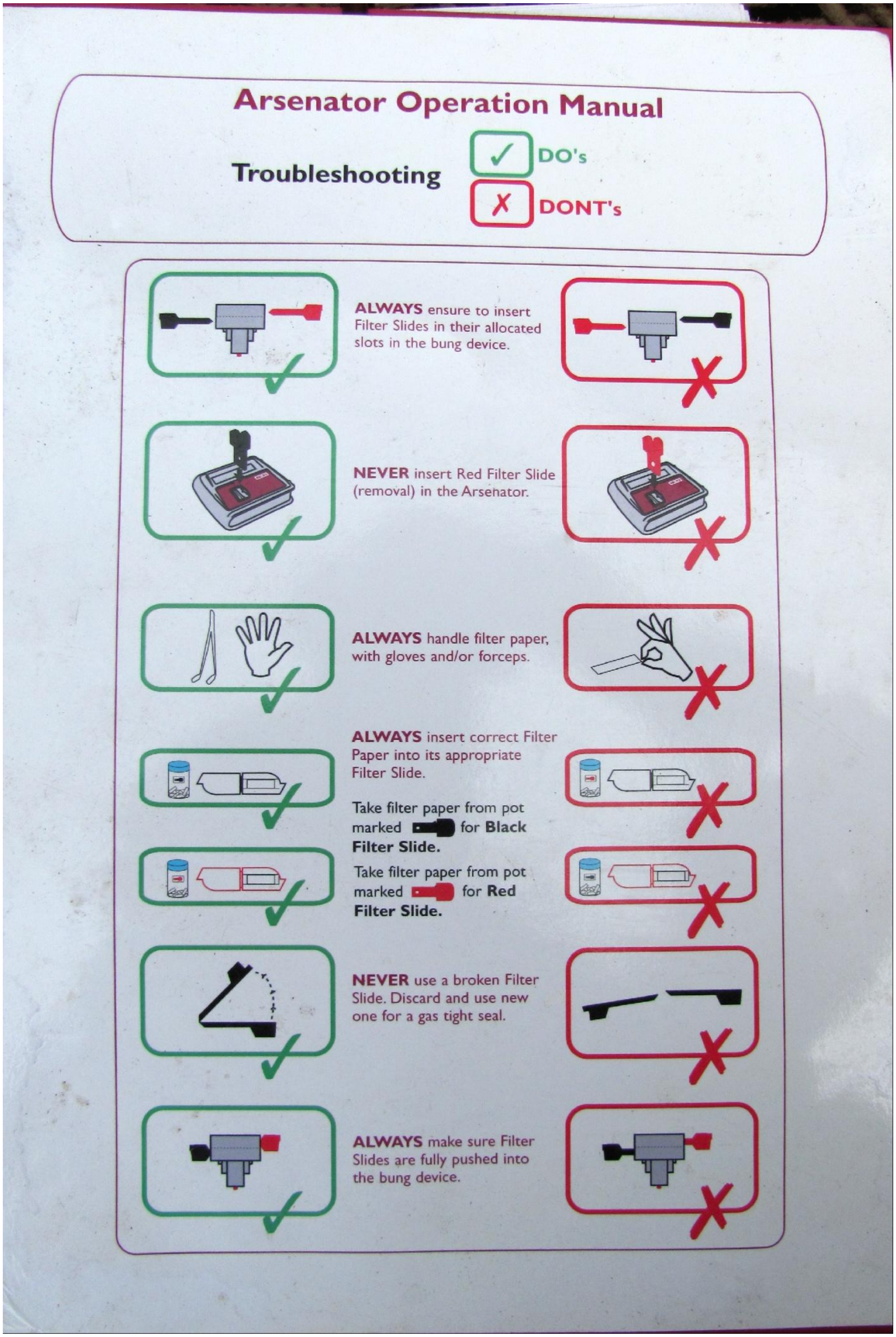


**Figure B-22:** Scanned copy of the Wagtech Arsenator operation manual, part 3

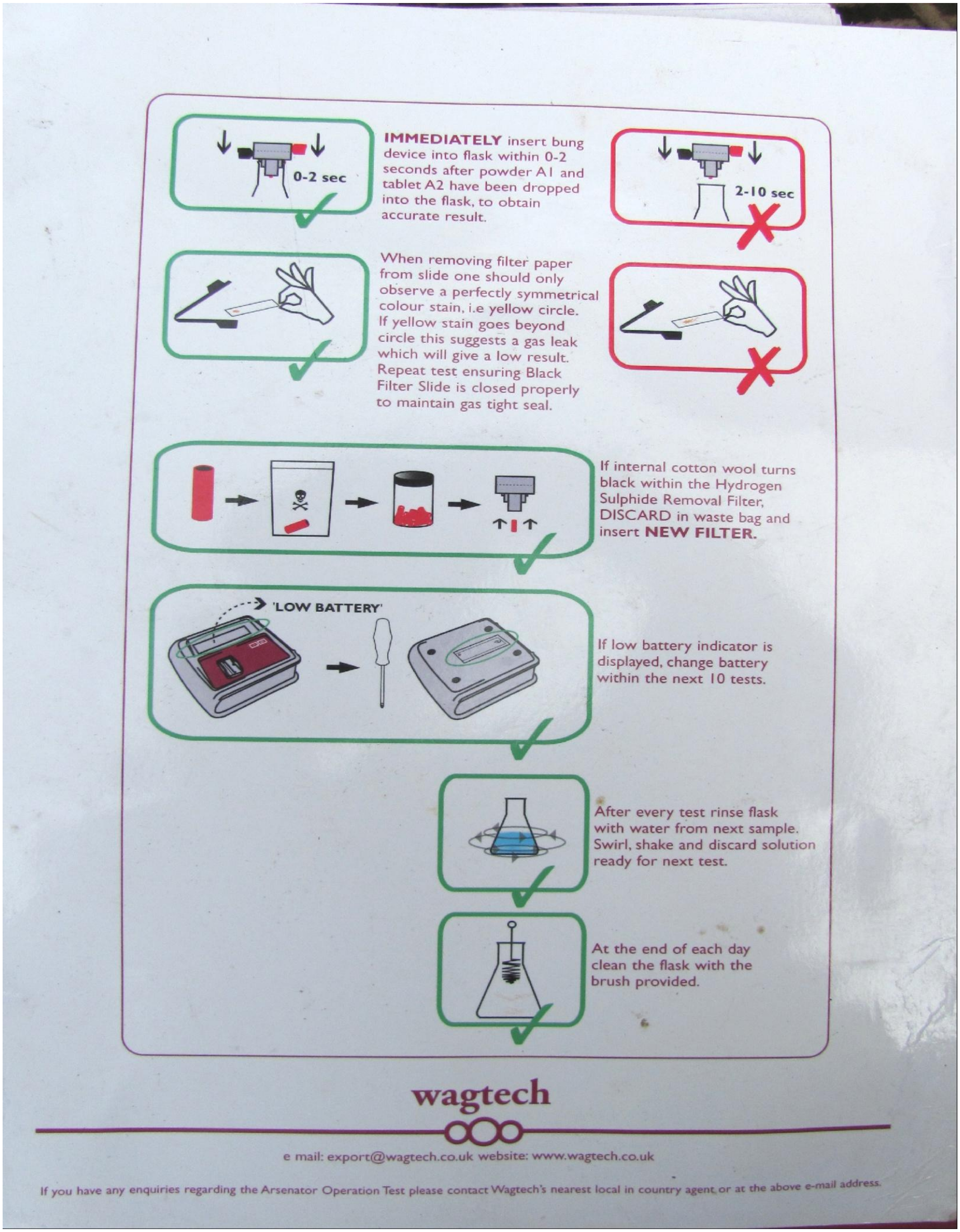


**Figure B-23: Scanned copy of the Wagtech Arsenator operation manual, part 4**

**Appendix D**: Calibrations and split sample analysis

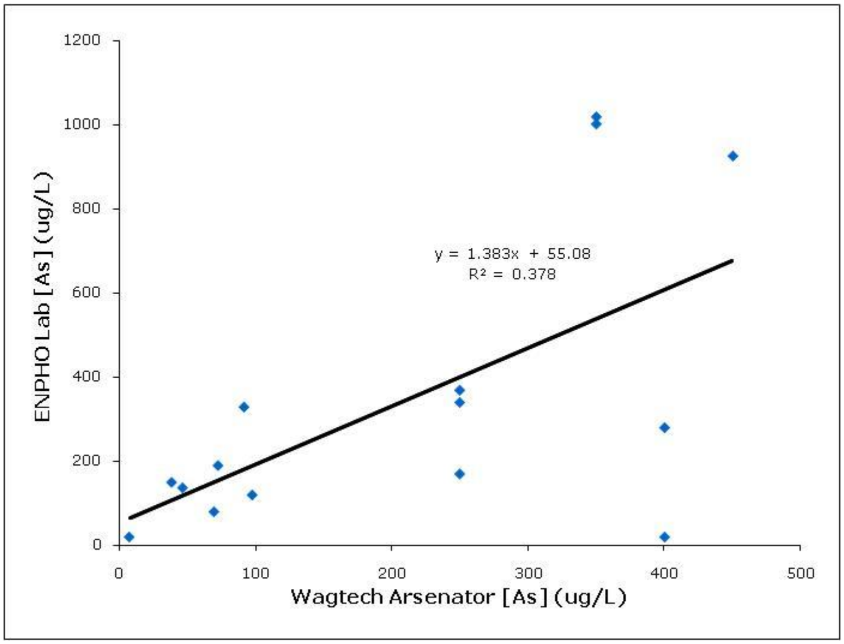


**Figure D-1**: Split sample calibration between measured arsenic concentrations in an atomic absorption spectrometer (ENPHO) and the Wagtech Arsenator.

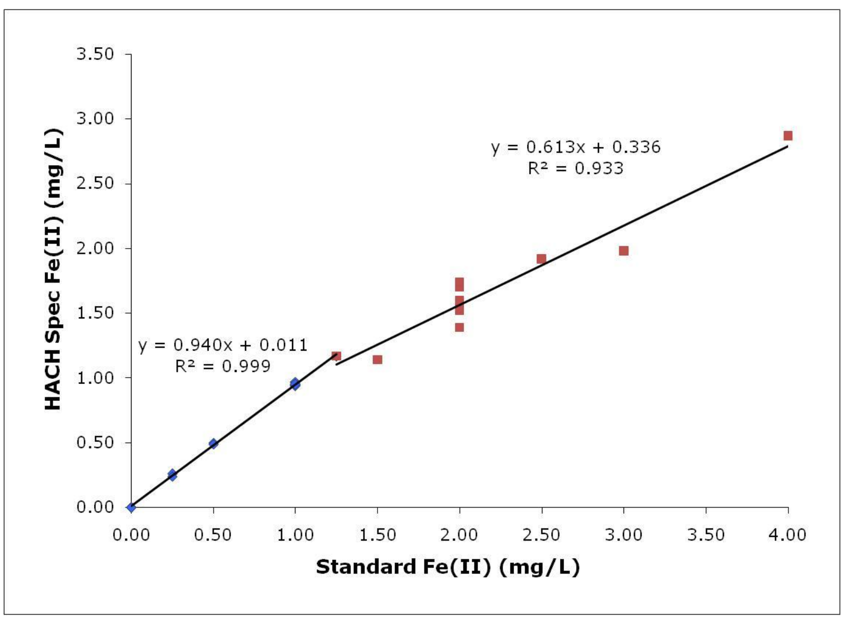


**Figure D-2:** Calibration of Fe(II) readings from the portable HACH spectrometer vs. prepared Fe(II) standards.

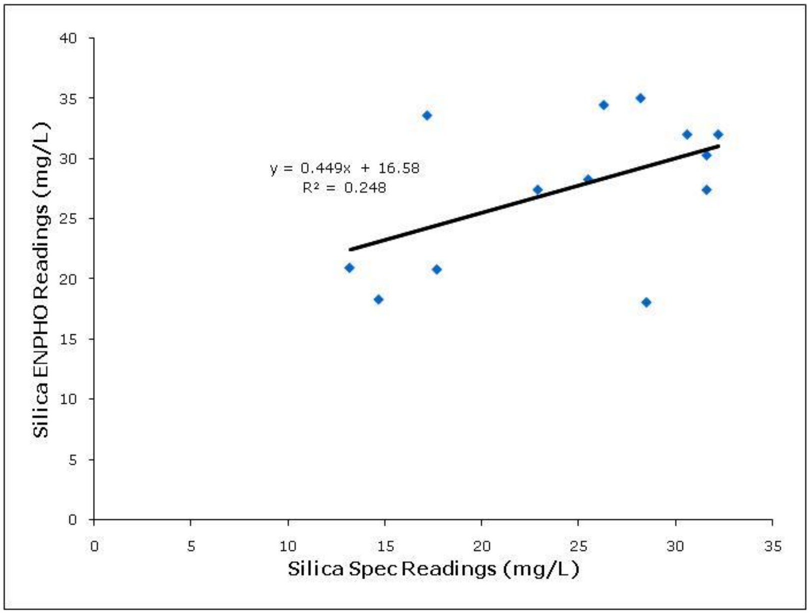


**Figure D-3**: Split sample calibration with ENPHO spectrophotometer and HACH portable spectrophotometer.

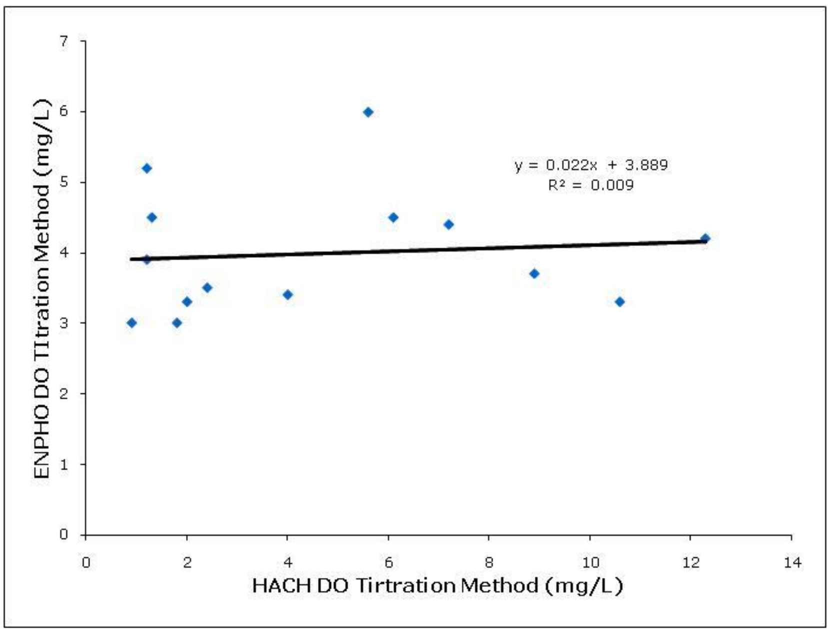


**Figure D-4**: Split sample calibration between the ENPHO Lab standard titration method and the HACH DO titration test kit.

## **Appendix E**: Figures and tables measured chemical parameters

Included below are the tables and figures data results, most notably for the parameters: phosphorous, silica, pH, DO and electrical conductivity, which were not included in the text.

**Table E-3**: Averages and standard deviations of measured arsenic concentrations in the groundwater, effluent filtered water and the percent arsenic removal by the filters.

| | # Samples | GW [As] | | Filtered [As] | | % [As] removal | |
|---|---|---|---|---|---|---|---|
| | | Average | σ** | Average | σ** | Average | σ** |
| Well performing* | 58 | 204 | 98 | 17 | 12 | 91 | 10 |
| Poorly performing* | 43 | 270 | 71 | 134 | 80 | 50 | 26 |
| **Total filter Samples** | **101** | **232** | **93** | **67** | **79** | **73** | **27** |

*Based on Nepali drinking water standard of [As]<50 µg/L

**Values above 100 µg/L of arsenic had an error of +/- 50 µg/L so standard deviations may be higher

**Table E-4**: Average and standard deviations of measured ferrous iron concentrations in the groundwater, effluent filtered water and the water after passing through the nails.

| | **GW [Fe(II)] (mg/L)** | | **Filtered [Fe(II)] (mg/L)** | | **Nail [Fe(II)] (mg/L)** | |
|---|---|---|---|---|---|---|
| | Average | σ | Average | σ | Average | σ |
| Well performing* | 1.90 | 0.87 | 0.13 | 0.32 | 0.46 | 0.59 |
| Poorly performing* | 0.92 | 1.42 | 0.44 | 0.58 | 0.96 | 0.88 |
| **Total filters** | 1.48 | 1.31 | 0.31 | 0.51 | 0.75 | 0.81 |

*Based on Nepali drinking water standard of [As]<50 µg/L

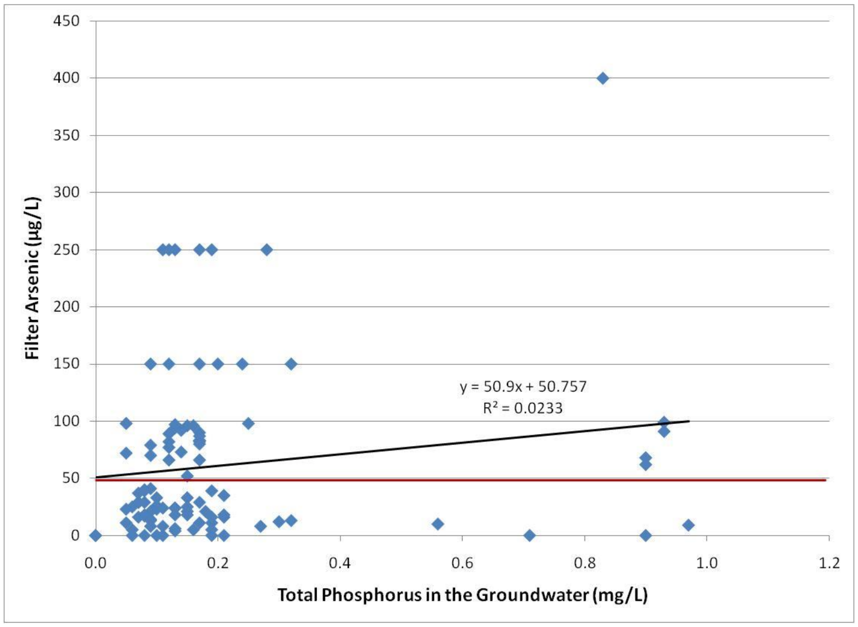


**Figure E-1:** Total phosphorus concentrations in groundwater vs. arsenic concentrations in the filtered water. Error: +/-25% (As values ≤ 100 µg/L), +/- 50 µg/L (As values >100 µg/L), and +/- 10% (P). Solid red line: Nepali arsenic drinking water standard (50 µg/L).

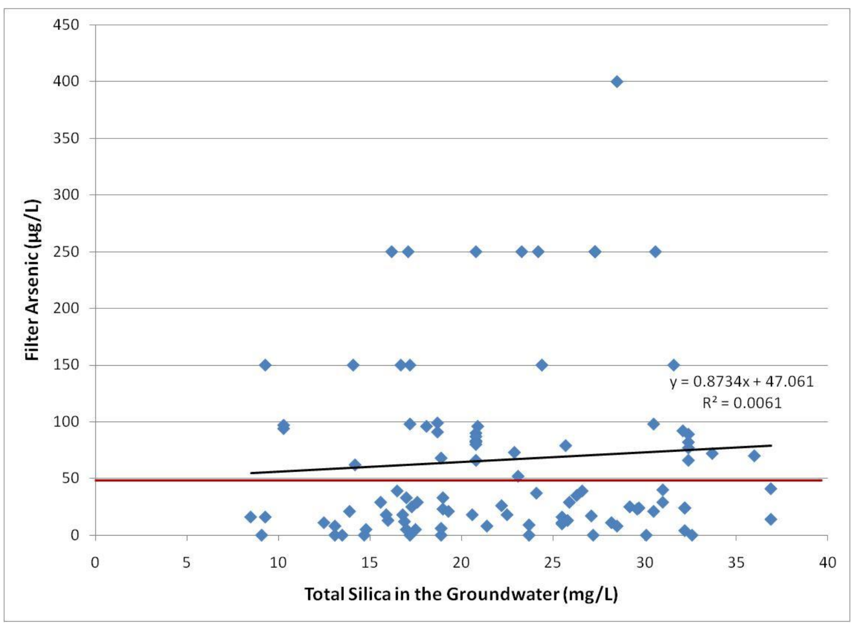


**Figure E-2**: Total silica concentrations in groundwater vs. arsenic concentrations in the filtered water. Error: +/- 25% (As values ≤ 100 µg/L), +/-50 µg/L (As values >100 µg/L), and +/- 10% in Si. Solid red line: Nepali arsenic drinking water standard (50 µg/L).

**Table E-5**: Average and standard deviations of measured pH units in the groundwater and filtered water.

| | GW pH | | Filtered pH | |
|---|---|---|---|---|
| | Average | σ | Average | σ |
| Well performing* | 7.3 | 0.5 | 7.2 | 0.5 |
| Poorly performing* | 7.6 | 0.4 | 7.5 | 0.4 |
| **Total filters** | 7.4 | 0.4 | 7.3 | 0.5 |

*Based on Nepali drinking water standard of [As]<50 µg/L

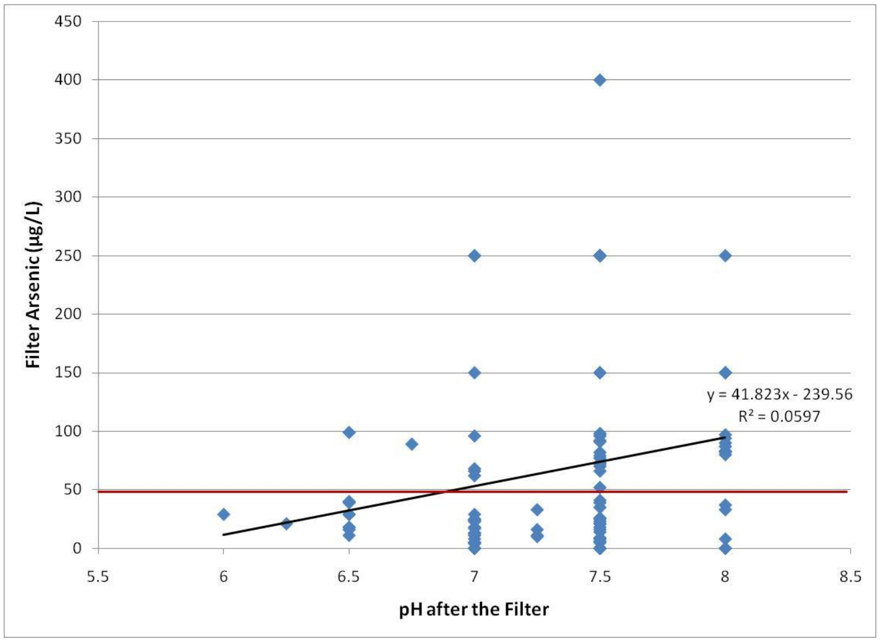


**Figure E-3**: pH levels in the groundwater vs. filtered water arsenic concentration. Error: +/- 25% (As ≤ 100 µg/L), +/-50 µg/L (As >100 µg/L), and +/-0.5 units (pH). Solid red line: Nepali arsenic drinking water standard (50 µg/L).

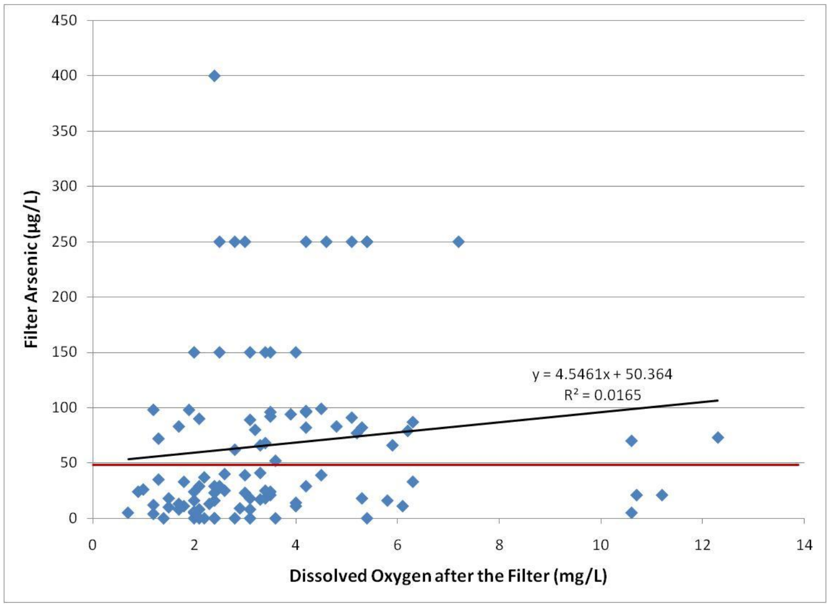


**Figure E-4**: Dissolved oxygen concentration vs. effluent arsenic concentration. Error: +/- 25% (As ≤ 100 µg/L), +/-50 µg/L (As >100 µg/L), and +/- 1 mg/L (DO). Solid red line: Nepali arsenic drinking water standard (50 µg/L).

**Table E-6:** Average and standard deviations of hardness concentrations as $CaCO_3$ in groundwater and filtered effluent water.

| | **GW Hardness (mg/L)** | | **Filtered Hardness (mg/L)** | |
|---|---|---|---|---|
| | Average | σ | Average | σ |
| Well performing* | 325 | 73 | 316 | 68 |
| Poorly performing* | 278 | 59 | 260 | 51 |
| **Total filters** | 305 | 71 | 292 | 67 |

*Based on Nepali drinking water standard of [As]<50 µg/L

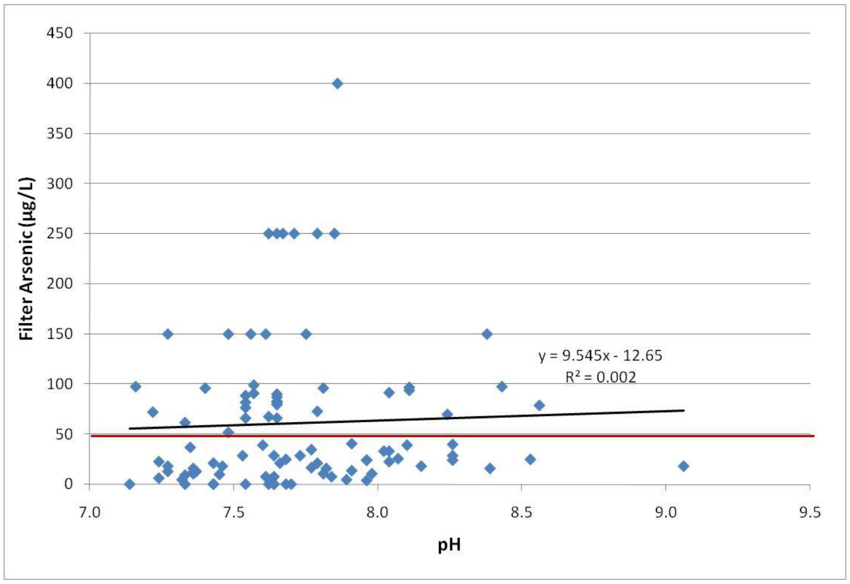


**Figure E-5**: New groundwater pH concentrations vs. effluent arsenic concentrations. Error: 25% (As ≤ 100 µg/L), +/- 50 µg/L (As >100 µg/L) and +/- 10% (pH). Solid red line: Nepali arsenic drinking water standard (50 µg/L). No real correlation can be seen between these two data sets.

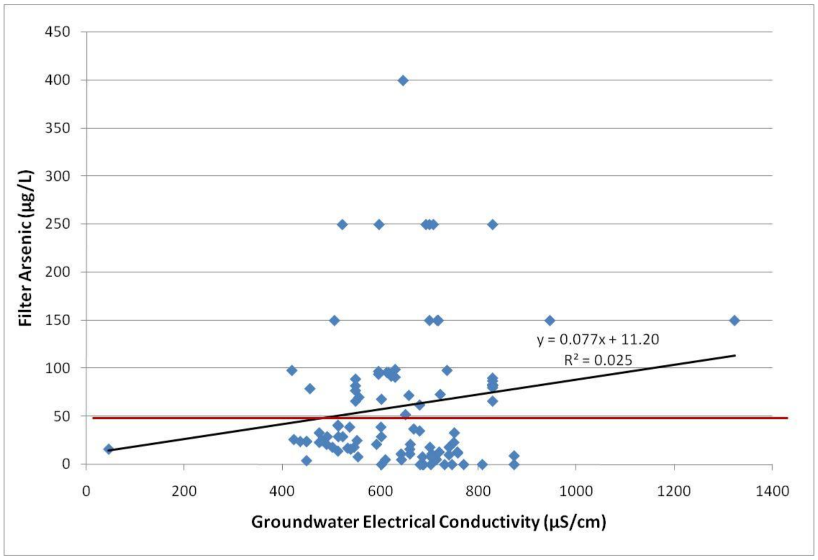


**Figure E-6**: Groundwater electrical conductivity vs. effluent arsenic concentrations. Error: 25% (As ≤ 100 µg/L), +/- 50 µg/L (As>100 µg/L), and +/- 10% (conductivity). Solid red line: Nepali arsenic drinking water standard (50 µg/L).

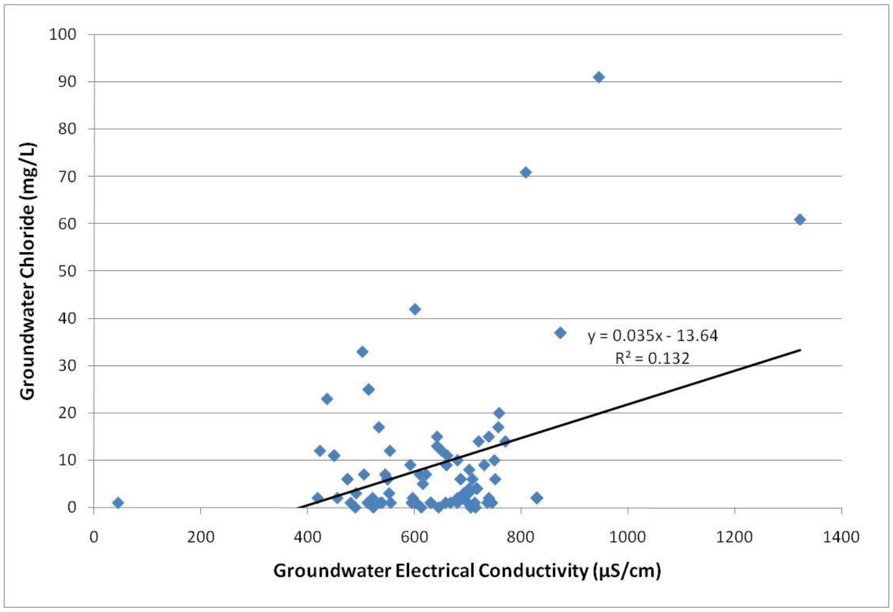


**Figure E-7**: Groundwater electrical conductivity vs. groundwater chloride concentration. Error: +/- 10% (chloride) and +/- 10% (conductivity).

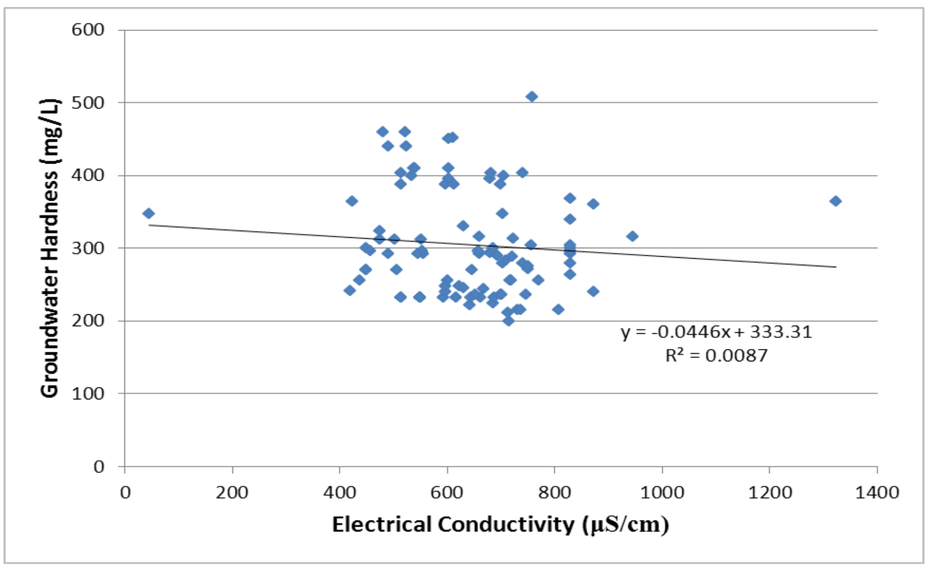


**Figure E-8:** Groundwater hardness concentrations (as $CaCO_3$) vs. electrical conductivity. Error: +/- 10% (hardness) and +/-10% (conductivity).

# **Appendix F**: Results of other measured parameters:

The correlations of filter flow rate and filter age against effluent filtered water arsenic concentrations are shown in Figure F-1 and Figure F-3. The user survey (**Appendix B**) was recorded to observe if there were any social, geographical or distribution factors also associated with the performance of the KAF. Clusters of well performing or poor performing filters were observed in 8 out of a total of 15 villages tested (**Figure F-4).** There were no observed correlations with the filter performance and the distribution organization of the KAF, the reported number of users and the reported volume of water filtered per day (**Figures F-5**, **Figure F-6** and **Figure F-7**). However, a reported cleaning frequency greater than 3 months did indicate lower filer performance (**Figures F-8**). It is also important to note that 2 of the 3 well performing filters with low reported cleaning frequencies were 3 months old so they may have not needed cleaning yet.

Also, all filters were reported to have well rusted nails by the observation of ENPHO staff. In addition, each filter corresponded to only one household and all but a few households reported to use the filter each day. Those households that did not use the filter each day stated that this was only in the winter season since the raw groundwater was much warmer than the filtered water.

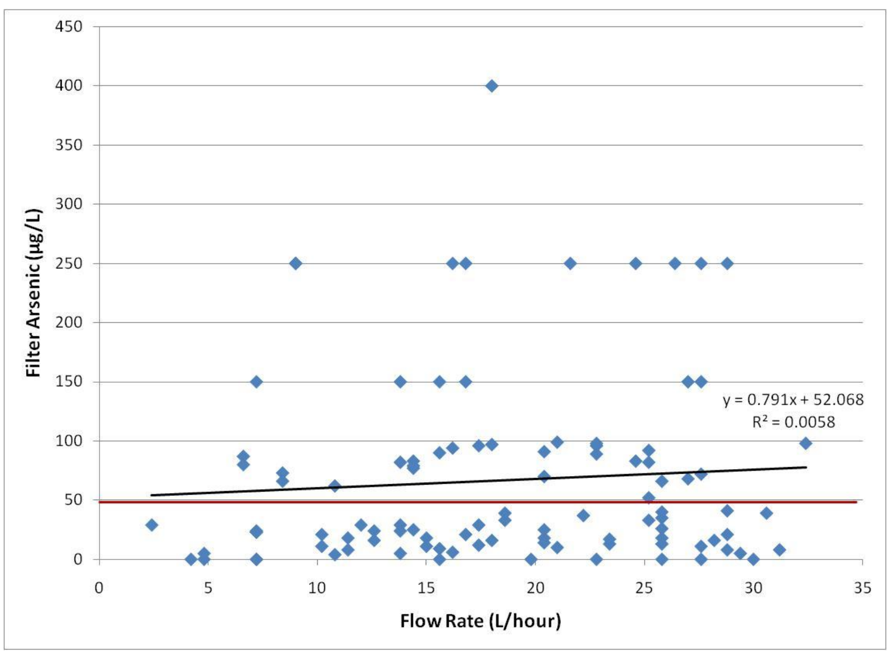


**Figure F-24**: Filter flow rate vs. filtered water arsenic concentrations. Error: +/- 25% (As ≤ 100 µg/L), +/-50 µg/L (As >100 µg/L), and +/- 0.5 L/hour (flow). Solid red line: Nepali arsenic drinking water standard (50 µg/L).

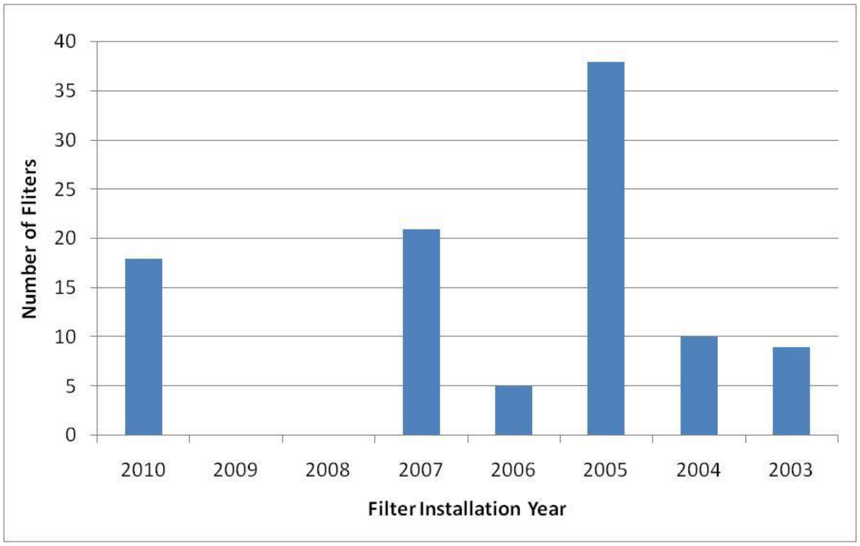


**Figure F-25**: Histogram of filter age groups (years).

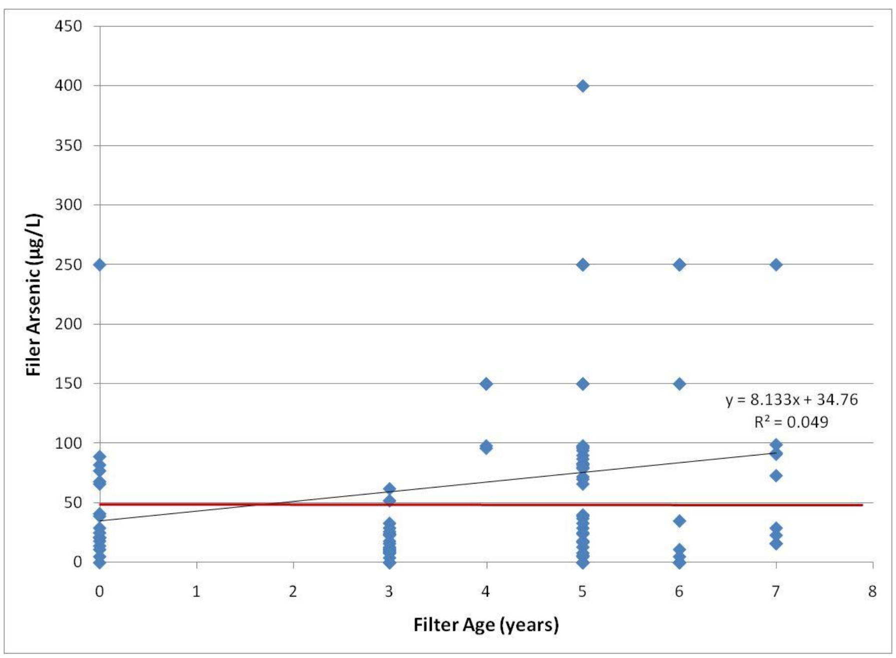


**Figure F-26**: KAF age vs. arsenic concentrations in the filtered water. Error: +/- 25% (As ≤ 100 µg/L), +/-50 µg/L (As >100 µg/L), and +/- 0.5 years (age). Solid red line: Nepali arsenic drinking water standard (50 µg/L). Note: filters of age "0" refer to filters under a year old and installed in 2010.

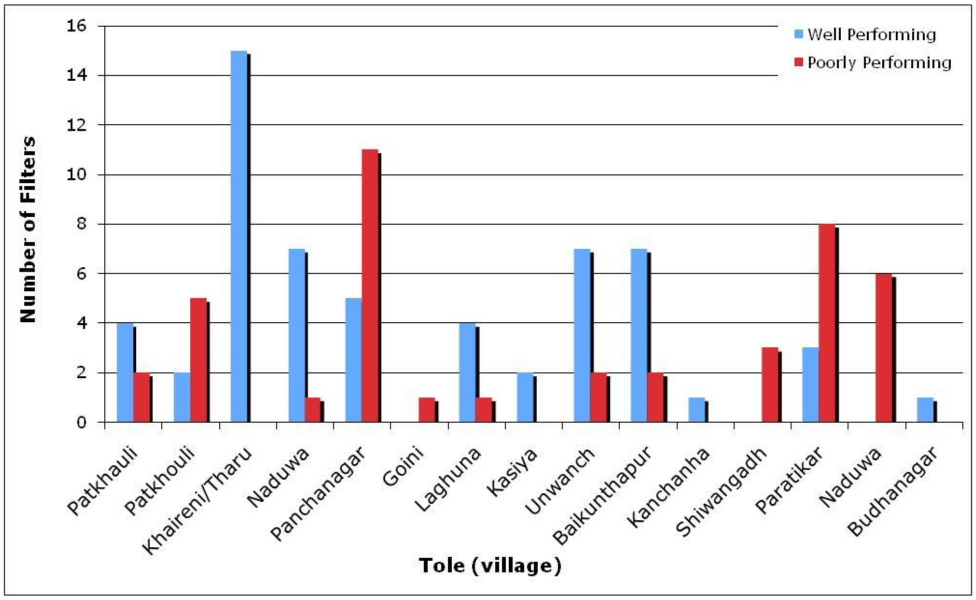


**Figure F-27**: Arsenic removing performance of the KAF in each tested village. Performance was measured though the effluent arsenic concentrations compared to the Nepali standard of 50 µg/L.

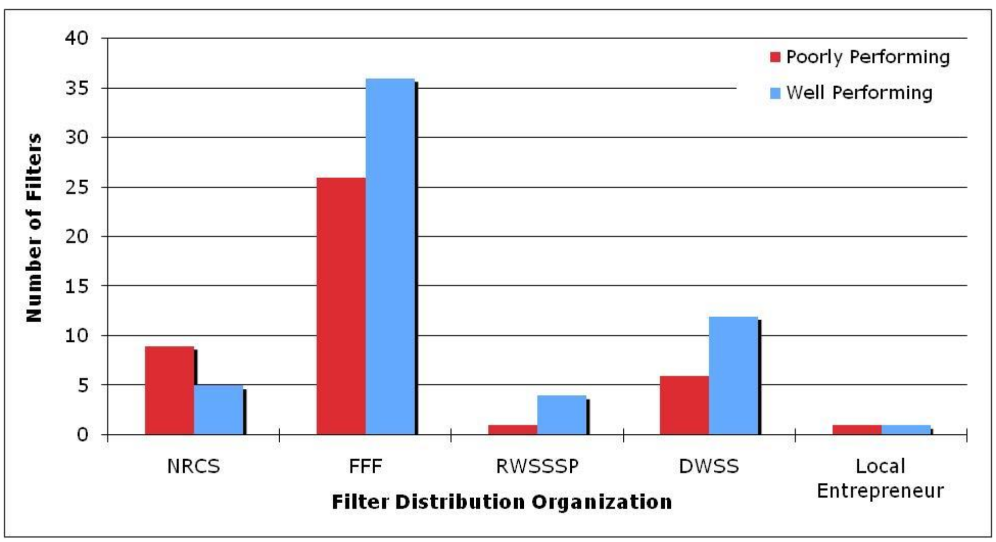


**Figure F-28**: Arsenic removing performance of the KAF by distribution organization. NRCS = National Red Cross Society (Nepal); FFF = Filters for Families (Nepal); RWSSSP = Rural Water Supply and Sanitation Support Programme (Nepal); DWSS = Department of Water Supply and Swearage (Nepal).

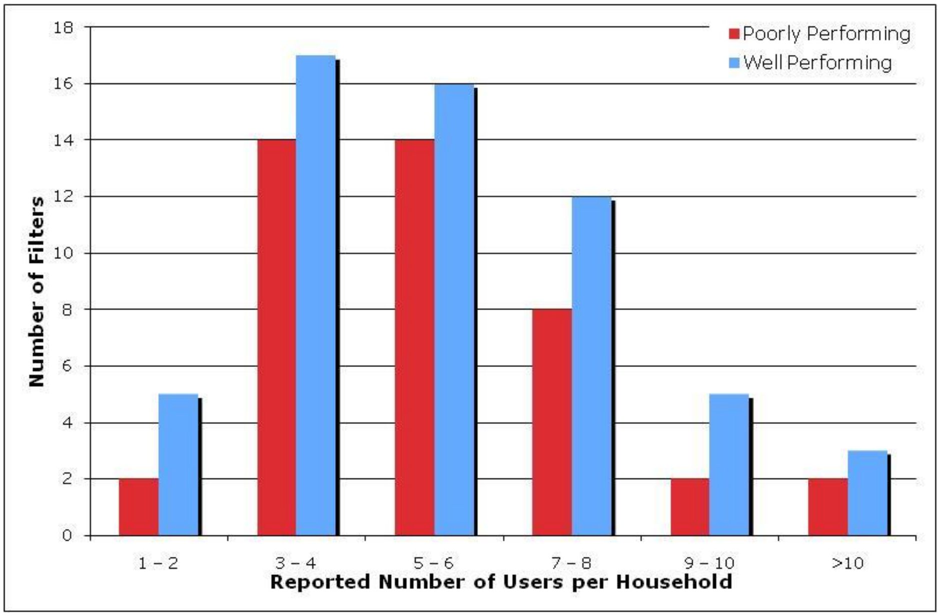


**Figure F-29**: Arsenic removing performance of the KAF by reported number of users per household.

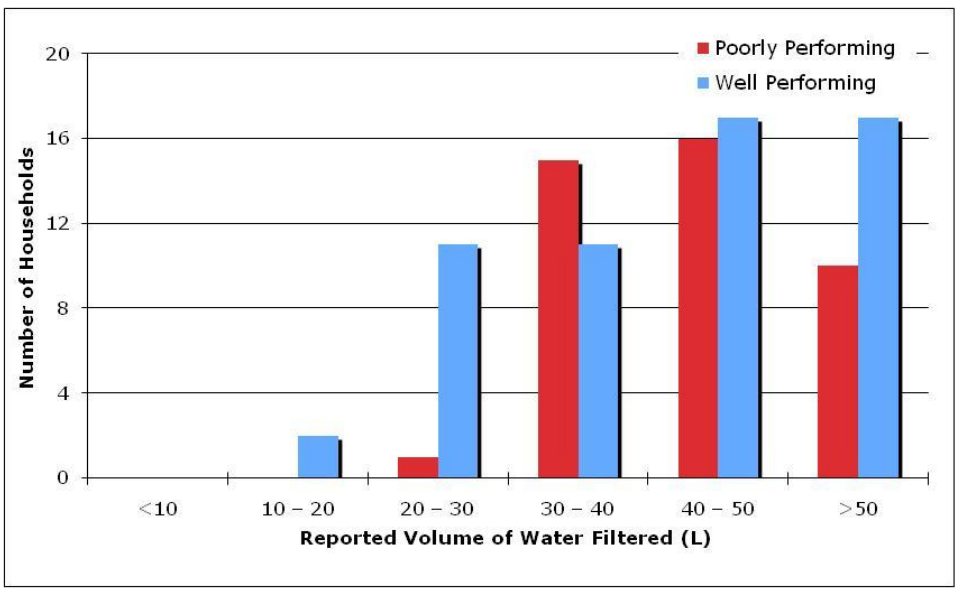


**Figure F-30**: Arsenic removing performance of the KAF by reported volume of water filtered.

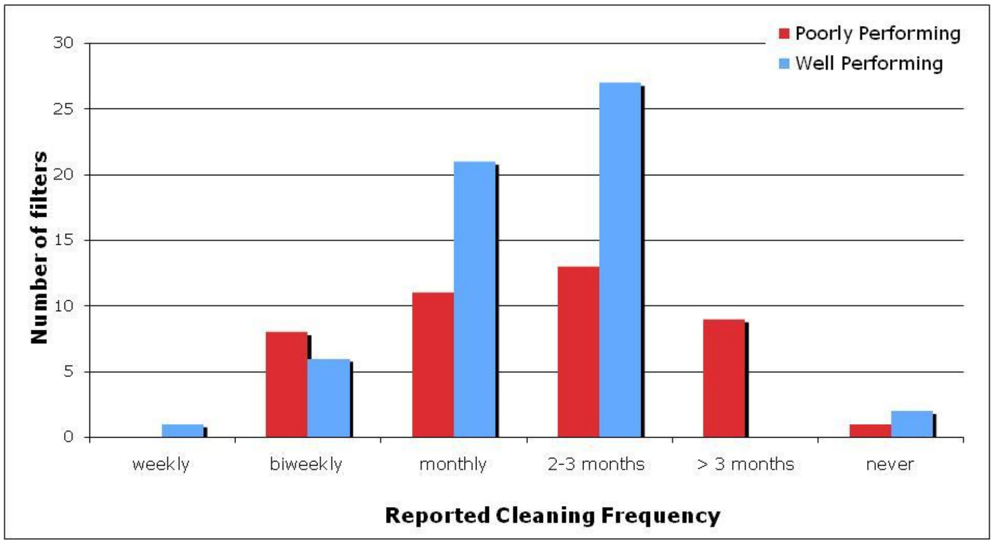


**Figure F-31:** Arsenic removing performance of the KAF by reported cleaning frequency.

## **Appendix G**: Raw Data Used in Filter Analysis

The following data in pages 35-38 includes the 101 filtered water (FW) samples and 79 groundwater (GW) samples corresponding to the 100 different KAF tested on the field. Filters that were not included in the analysis due to low influent arsenic concentrations, high flow rate, or mechanical malfunctions are not included in this data sheet.

| Filter Number | FW Arsenic (µg/L) | GW Arsenic (µg/L) | Ferrous Iron After Nails (mg/L) | GW Ferrous Iron (mg/L) | FW Ferrous Iron (mg/L) | GW Total Phosporus (mg/L) | GW Silica (mg/L) | FW pH (field) - |
|---|---|---|---|---|---|---|---|---|
| 4 | 73 | 250 | 0.10 | 0.75 | 0.32 | 0.1 | 22.9 | 7.5 |
| 5 | 250 | 450 | 0.64 | 0.73 | 0.85 | 0.1 | 30.6 | 7.5 |
| 6 | 11 | 250 | 0.58 | 0.80 | 0.03 | 0.2 | 28.2 | 7.25 |
| 7 | 35 | 450 | 0.11 | 0.54 | 0.36 | 0.2 | 26.3 | 7.5 |
| 8 | 70 | 350 | 0.21 | 1.01 | 0.33 | 0.1 | 36 | 7.5 |
| 9 | 98 | 350 | 0.80 | 1.51 | 0.01 | 0.3 | 17.2 | 7.5 |
| 10 | 400 | 400 | 0.64 | 0.97 | 1.10 | 0.8 | 28.5 | 7.5 |
| 11 | 150 | 450 | 0.15 | 0.54 | 0.02 | 0.2 | 31.6 | 8 |
| 13 | 24 | 250 | 2.18 | 1.80 | 1.21 | 0.1 | 32.2 | 7 |
| 14 | 24 | 250 | 1.57 | 1.80 | 0.96 | 0.1 | 32.2 | 7 |
| 15 | 4 | 250 | 0.51 | 1.80 | 1.04 | 0.1 | 32.2 | 7 |
| 17 | 11 | 250 | 1.22 | 1.85 | 0.42 | 0.2 | 25.5 | 7 |
| 18 | 16 | 250 | 1.47 | 1.85 | 1.09 | 0.2 | 25.5 | 7.25 |
| 19 | 10 | 350 | 2.06 | 2.12 | 0.57 | 0.6 | 25.5 | 7.25 |
| 21 | 18 | 150 | 1.98 | 3.16 | 1.19 | 0.2 | 20.6 | 7 |
| 22 | 33 | 350 | 1.18 | 2.95 | 1.08 | 0.1 | 19 | 7.25 |
| 23 | 23 | 350 | 1.35 | 2.95 | 1.21 | 0.1 | 19 | 7 |
| 24 | 9 | 350 | 1.08 | 2.58 | 0.00 | 1.0 | 23.7 | 7.5 |
| 25 | 13 | 250 | 1.61 | 1.18 | 1.23 | 0.3 | 16 | 7 |
| 26 | 8 | 250 | 1.99 | 1.92 | 0.98 | 0.3 | 28.5 | 8 |
| 27 | 26 | 250 | 1.53 | 1.50 | 1.37 | 0.1 | 22.2 | 7.5 |
| 28 | 0 | 350 | 1.19 | 2.58 | 1.27 | 0.1 | 23.7 | 7.5 |
| 29 | 12 | 250 | 1.83 | 3.46 | 1.34 | 0.3 | 16.9 | 7 |
| 31 | 5 | 150 | 1.32 | 1.64 | 0.01 | 0.2 | 17.5 | 7 |
| 32 | 0 | 84 | 1.14 | 1.89 | 0.01 | 0.1 | 9.1 | 8 |
| 33 | 0 | 150 | 0.53 | 1.41 | 0.01 | 0.1 | 13.1 | 7.5 |
| 34 | 8 | 150 | 1.16 | 1.41 | 0.01 | 0.1 | 13.1 | 7 |
| 35 | 0 | 76 | unknown | 0.60 | 0.01 | 0 | 17.2 | 7.5 |
| 36 | 0 | 86 | 2.07 | 1.79 | 0.02 | 0.1 | 14.7 | 7.5 |
| 37 | 0 | 82 | 1.42 | 2.71 | 0.32 | 0 | 13.5 | 7 |
| 41 | 21 | 250 | 1.31 | 0.26 | 0.02 | 0.2 | 19.3 | 7.5 |
| 42 | 66 | 250 | 0.81 | 0.16 | 0.02 | 0.1 | 32.4 | 7 |
| 43 | 82 | 250 | 0.57 | 0.16 | 0.01 | 0.1 | 32.4 | 7.5 |
| 44 | 77 | 250 | 0.09 | 0.16 | 0.01 | 0.1 | 32.4 | 7.5 |
| 45 | 89 | 250 | 0.41 | 0.16 | 0.00 | 0.1 | 32.4 | 6.75 |
| 46 | 5 | 250 | 1.26 | 1.69 | 0.02 | 0.2 | 14.8 | 7 |
| 47 | 41 | 250 | 0.22 | 0.08 | 0.01 | 0.1 | 36.9 | 7.5 |
| 48 | 14 | 85 | 0.34 | 0.08 | 0.01 | 0.1 | 36.9 | 7.5 |
| 49 | 21 | 350 | 1.17 | 1.27 | 0.01 | 0.2 | 30.5 | 7.5 |
| 50 | 96 | 250 | 1.38 | 1.72 | 0.02 | 0.2 | 18.1 | 7 |
| 51 | 52 | 250 | 0.08 | 1.53 | 0.01 | 0.2 | 23.1 | 7.5 |
| 52 | 150 | 250 | 0.00 | 1.29 | 0.00 | 0.3 | 17.2 | 7 |
| 53 | 92 | 250 | 1.13 | 0.16 | 0.01 | 0.1 | 32.1 | 7.5 |
| 54 | 99 | 250 | 0.56 | 0.96 | 0.01 | 0.9 | 18.7 | 6.5 |
| 55 | 91 | 250 | 0.56 | 0.96 | 0.00 | 0.9 | 18.7 | 7.5 |
| 56 | 96 | 350 | 0.42 | 0.76 | 0.00 | 0.2 | 20.9 | 7.5 |
| 58 | 250 | 250 | 0.14 | 1.05 | 0.01 | 0.1 | 24.2 | 7.5 |
| 60 | 250 | 350 | 0.17 | 0.67 | 0.90 | 0.1 | 23.3 | 7 |
| 61 | 29 | 200 | 0.09 | 0.46 | 0.01 | 0.1 | 15.6 | 6.5 |
| 62 | 18 | 86 | 0.06 | 0.95 | 0.01 | 0.1 | 15.9 | 6.5 |

| Filter Number | FW Arsenic (µg/L) | GW Arsenic (µg/L) | Ferrous Iron After Nails (mg/L) | GW Ferrous Iron (mg/L) | FW Ferrous Iron (mg/L) | GW Total Phosporus (mg/L) | GW Silica (mg/L) | FW pH (field) - |
|---|---|---|---|---|---|---|---|---|
| 63 | 11 | 86 | 0.43 | 1.19 | 1.01 | 0.1 | 12.5 | 6.5 |
| 65 | 0 | 78 | 1.31 | 1.97 | 0.00 | 0.9 | 18.9 | 7 |
| 66 | 68 | 250 | 2.16 | 1.97 | 0.00 | 0.9 | 18.9 | 7 |
| 70 | 62 | 250 | 0.25 | 2.56 | 0.01 | 0.9 | 14.2 | 7 |
| 71 | 21 | 250 | 0.00 | 0.33 | 0.01 | 0.1 | 13.9 | 6.25 |
| 72 | 39 | 68 | 0.00 | 0.42 | 0.01 | 0.2 | 16.5 | 6.5 |
| 73 | 29 | 99 | 0.00 | 0.64 | 0.00 | 0.2 | 25.9 | 7 |
| 74 | 25 | 98 | 0.04 | 0.07 | 0.01 | 0.1 | 29.2 | 7 |
| 76 | 250 | 250 | 0.00 | 0.48 | 0.00 | 0.2 | 17.1 | 7 |
| 79 | 29 | 150 | 0.04 | 0.26 | 0.01 | 0.1 | 17.6 | 6 |
| 80 | 16 | 250 | 0.19 | 0.20 | 0.00 | 0.1 | 8.5 | 6.5 |
| 81 | 40 | 250 | 0.16 | 1.46 | 0.08 | 0.1 | 31 | 6.5 |
| 82 | 29 | 99 | 0.41 | 1.46 | 0.39 | 0.1 | 31 | 6.5 |
| 83 | 18 | 150 | 0.44 | 0.76 | 0.01 | 0.1 | 16.8 | 6.5 |
| 84 | 0 | 60 | 0.12 | 1.41 | 0.01 | 0.2 | 27.2 | 7 |
| 85 | 17 | 250 | 0.16 | 1.34 | 0.00 | 0.1 | 27.1 | 7 |
| 86 | 150 | 250 | 0.38 | 2.13 | 0.00 | 0.2 | 24.4 | 7.5 |
| 87 | 150 | 250 | 1.35 | 1.41 | 0.01 | 0.2 | 16.7 | 7.5 |
| 91 | 16 | 71 | 0.07 | 0.17 | 0.00 | 0.2 | 9.3 | 7.5 |
| 92 | 24 | 250 | 1.13 | 1.81 | 0.01 | 0.1 | 29.7 | 7 |
| 93 | 39 | 250 | 1.35 | 1.83 | 0.01 | 0.1 | 26.6 | 7.5 |
| 94 | 13 | 250 | 0.71 | 1.67 | 1.41 | 0.1 | 25.8 | 7 |
| 95 | 23 | 350 | 0.05 | 1.37 | 0.16 | 0.1 | 29.6 | 7.5 |
| 96 | 5 | 150 | 0.51 | 1.08 | 0.46 | 0.1 | 17 | 7.5 |
| 97 | 6 | 250 | 0.77 | 1.74 | 0.82 | 0.1 | 18.9 | 7.5 |
| 98 | 72 | 99 | 1.12 | 1.42 | 1.16 | 0.1 | 33.7 | 7.5 |
| 99 | 98 | 350 | 0.94 | 1.79 | 0.39 | 0.1 | 30.5 | 7.5 |
| 100 | 18 | 97 | 0.69 | 1.52 | 0.21 | 0.2 | 22.5 | 7.5 |
| 101 | 0 | 97 | 0.78 | 1.39 | 1.34 | 0.2 | 32.6 | 7.5 |
| 102 | 0 | 78 | 0.24 | 1.40 | 0.93 | 0.7 | 30.1 | 8 |
| 103 | 37 | 150 | 0.15 | 1.11 | 0.86 | 0.1 | 24.1 | 8 |
| 105 | 250 | 350 | 1.10 | 0.80 | 0.10 | 0.3 | 16.2 | 8 |
| 106 | 150 | 250 | 0.15 | 1.27 | 0.01 | 0.1 | 14.1 | 8 |
| 107 | 150 | 250 | 0.02 | 0.57 | 0.01 | 0.1 | 9.3 | 8 |
| 108 | 33 | 350 | 0.10 | 1.03 | 0.00 | 0.2 | 17 | 8 |
| 109 | 25 | 250 | 0.70 | 4.87 | 0.08 | 0.2 | 17.3 | 7.5 |
| 112 | 8 | 250 | 0.03 | 1.17 | 0.05 | 0.1 | 21.4 | 7.5 |
| 113 | 250 | 350 | 0.17 | 0.25 | 0.01 | 0.2 | 20.8 | 7.5 |
| 114 | 66 | 250 | 0.00 | 0.25 | 0.01 | 0.2 | 20.8 | 7.5 |
| 115 | 83 | 250 | 0.38 | 0.25 | 0.00 | 0.2 | 20.8 | 8 |
| 116 | 83 | 250 | 0.11 | 0.25 | 0.01 | 0.2 | 20.8 | 8 |
| 117 | 90 | 250 | 0.40 | 0.25 | 0.01 | 0.2 | 20.8 | 8 |
| 118 | 82 | 250 | 0.04 | 0.25 | 0.00 | 0.2 | 20.8 | 8 |
| 119 | 87 | 250 | 0.06 | 0.25 | 0.00 | 0.2 | 20.8 | 8 |
| 120 | 80 | 250 | 0.00 | 0.25 | 0.00 | 0.2 | 20.8 | 8 |
| 121 | 250 | 250 | 0.07 | 0.20 | 0.00 | unknown | 27.3 | 7.5 |
| 122 | 250 | 250 | 0.09 | 0.20 | 0.01 | unknown | 27.3 | 7.5 |
| 123 | 250 | 250 | 0.11 | 0.20 | 0.01 | unknown | 27.3 | 7.5 |
| 124 | 94 | 200 | 0.02 | 0.31 | 0.00 | 0.1 | 10.3 | 8 |
| 125 | 97 | 200 | 0.30 | 0.31 | 0.00 | 0.1 | 10.3 | 8 |
| 126 | 79 | 92 | 0.16 | 0.94 | 0.01 | 0.1 | 25.7 | 7.5 |

| Filter Number | GW Hardness (mg/L) | FW Hardness (mg/L) | FW Dissolved Oxygen (mg/L) | Flow Rate (L/hour) | GW pH (Lab) - | GW Electrical Conductivity (µS/cm) | GW Chloride (mg/L) |
|---|---|---|---|---|---|---|---|
| 4 | 314 | 304 | 12.3 | 8.4 | 7.79 | 722 | unknown |
| 5 | 290 | 304 | 7.2 | 9.0 | 7.79 | 693 | 3 |
| 6 | 330 | 360 | 6.1 | 15.0 | 7.98 | 642 | 13 |
| 7 | 246 | 272 | 1.3 | 25.8 | 7.77 | 680 | 1 |
| 8 | 222 | 308 | 10.6 | 20.4 | 8.24 | 556 | 1 |
| 9 | 294 | 244 | 1.2 | 32.4 | 8.43 | 419 | 2 |
| 10 | 292 | 240 | 2.4 | 18.0 | 7.86 | 646 | 0 |
| 11 | 242 | 280 | 4.0 | 7.2 | 8.38 | 506 | 7 |
| 13 | 388 | 372 | 2.0 | 13.8 | 7.96 | 449 | 11 |
| 14 | 388 | 364 | 0.9 | 12.6 | 7.96 | 449 | 11 |
| 15 | 388 | 388 | 1.2 | 10.8 | 7.96 | 449 | 11 |
| 17 | 292 | 396 | 1.8 | 10.2 | 7.36 | 660 | 9 |
| 18 | 292 | 324 | 2.0 | 18.0 | 7.36 | 660 | 9 |
| 19 | 400 | 344 | 1.5 | 21.0 | 7.45 | 740 | 15 |
| 21 | 450 | 396 | 1.5 | 20.4 | 8.15 | 502 | 33 |
| 22 | 396 | 372 | 1.8 | 18.6 | 8.04 | 475 | 6 |
| 23 | 396 | 360 | 3.0 | 7.2 | 8.04 | 475 | 6 |
| 24 | 440 | 328 | 2.9 | 15.6 | 7.33 | 873 | 37 |
| 25 | 410 | 380 | 2.3 | 23.4 | 7.37 | 757 | 17 |
| 26 | 440 | 376 | 2.1 | 31.2 | 7.84 | 554 | 12 |
| 27 | 460 | 496 | 1.0 | 25.8 | 8.07 | 423 | 12 |
| 28 | 460 | 388 | 1.4 | 7.2 | 7.33 | 873 | 37 |
| 29 | 410 | 388 | 1.2 | 17.4 | 7.36 | 758 | 20 |
| 31 | 410 | 372 | 10.6 | 29.4 | 7.89 | 610 | 7 |
| 32 | 388 | 384 | 3.6 | 15.6 | 7.64 | 703 | 8 |
| 33 | 404 | 332 | 3.1 | 4.2 | 7.64 | 686 | 6 |
| 34 | 404 | 392 | 3.1 | 11.4 | 7.64 | 686 | 6 |
| 35 | 404 | 348 | 2.0 | 4.8 | 7.54 | 770 | 14 |
| 36 | 400 | 400 | 2.8 | 7.2 | 7.70 | 731 | 9 |
| 37 | 364 | 356 | 2.2 | 19.8 | 7.43 | 688 | 2 |
| 41 | 316 | 332 | 11.2 | 16.8 | 7.79 | 661 | 11 |
| 42 | 270 | 260 | 3.3 | 8.4 | 7.54 | 549 | 6 |
| 43 | 270 | 272 | 5.3 | 25.2 | 7.54 | 549 | 6 |
| 44 | 270 | 280 | 5.2 | 14.4 | 7.54 | 549 | 6 |
| 45 | 270 | 260 | 3.1 | 22.8 | 7.54 | 549 | 6 |
| 46 | 348 | 332 | 0.7 | 13.8 | 7.63 | 643 | 15 |
| 47 | 256 | 260 | 3.3 | 28.8 | 7.91 | 513 | 1 |
| 48 | 256 | 212 | 4.0 | 20.4 | 7.91 | 513 | 1 |
| 49 | 288 | 240 | 3.5 | 10.2 | 7.43 | 592 | 9 |
| 50 | 300 | 272 | 3.5 | 17.4 | 7.40 | 616 | 5 |
| 51 | 316 | 332 | 3.6 | 25.2 | 7.48 | 651 | 12 |
| 52 | 292 | 244 | 3.5 | 13.8 | 7.75 | 700 | 1 |
| 53 | 280 | 240 | 3.5 | 25.2 | 8.04 | 622 | 7 |
| 54 | 312 | 280 | 4.5 | 21.0 | 7.57 | 630 | 1 |
| 55 | 312 | 272 | 5.1 | 20.4 | 7.57 | 630 | 1 |
| 56 | 324 | 304 | 4.2 | 22.8 | 7.81 | 613 | 0 |
| 58 | 360 | 312 | 4.2 | 9.0 | 7.67 | 700 | 3 |
| 60 | 304 | 272 | 2.5 | 16.2 | 7.85 | 597 | 2 |
| 61 | 272 | 252 | 2.4 | 2.4 | 7.73 | 491 | 3 |
| 62 | 200 | 224 | 5.3 | 25.8 | **9.06** | 546 | 7 |

| Filter Number | GW Hardness (mg/L) | FW Hardness (mg/L) | FW Dissolved Oxygen (mg/L) | Flow Rate (L/hour) | GW pH (Lab) - | GW Electrical Conductivity (µS/cm) | GW Chloride (mg/L) |
|---|---|---|---|---|---|---|---|
| 63 | 212 | 204 | 4.0 | 27.6 | 7.81 | 705 | 0 |
| 65 | 296 | 268 | 5.4 | 30.0 | 7.62 | 602 | 1 |
| 66 | 297 | 268 | 3.4 | 27.0 | 7.62 | 602 | 1 |
| 70 | 364 | 336 | 2.8 | 10.8 | 7.33 | 680 | 2 |
| 71 | 216 | 192 | 10.7 | 28.8 | 7.66 | 490 | 0 |
| 72 | 236 | 216 | 4.5 | 30.6 | 7.60 | 537 | 1 |
| 73 | 236 | 224 | 4.2 | 13.8 | 7.64 | 523 | 0 |
| 74 | 216 | 200 | 2.6 | 20.4 | 7.68 | 480 | 1 |
| 76 | 240 | 212 | 4.6 | 16.8 | 7.71 | 522 | 2 |
| 79 | 244 | 252 | 2.1 | 12.0 | 7.53 | 602 | 1 |
| 80 | 284 | 228 | 2.4 | 12.6 | 7.82 | 539 | 1 |
| 81 | 256 | 332 | 2.6 | 25.8 | 8.26 | 514 | 25 |
| 82 | 256 | 320 | 2.5 | 17.4 | 8.26 | 514 | 25 |
| 83 | 276 | 296 | 3.1 | 15.0 | 7.46 | 740 | 2 |
| 84 | 312 | 296 | 2.4 | 25.8 | 7.43 | 681 | 10 |
| 85 | 348 | 300 | 3.3 | 23.4 | 7.77 | 533 | 17 |
| 86 | 508 | 280 | 2.0 | 15.6 | 7.27 | 1323 | 61 |
| 87 | 452 | 420 | 2.5 | 16.8 | 7.48 | 946 | 91 |
| 91 | 264 | 220 | 5.8 | 28.2 | 8.39 | 45 | 1 |
| 92 | 340 | 312 | 3.5 | 7.2 | 8.26 | 436 | 23 |
| 93 | 368 | 332 | 3.0 | 18.6 | 8.10 | 601 | 42 |
| 94 | 300 | 304 | 1.7 | 25.8 | 7.27 | 720 | 14 |
| 95 | 292 | 348 | 2.4 | 7.2 | 7.24 | 750 | 10 |
| 96 | 280 | 324 | 2.0 | 4.8 | 7.32 | 714 | 0 |
| 97 | 296 | 380 | 2.0 | 16.2 | 7.24 | 713 | 1 |
| 98 | 280 | 300 | 1.3 | 27.6 | 7.22 | 658 | 1 |
| 99 | 300 | 340 | 1.9 | 22.8 | 7.16 | 736 | 1 |
| 100 | 304 | 320 | 3.4 | 11.4 | 7.27 | 701 | 3 |
| 101 | 316 | 352 | 2.1 | 27.6 | 7.14 | 746 | 1 |
| 102 | 356 | 404 | 2.4 | 22.8 | 7.68 | 808 | 71 |
| 103 | 252 | 252 | 2.2 | 22.2 | 7.35 | 668 | 1 |
| 105 | 224 | 240 | 3.0 | 27.6 | 7.62 | 708 | 6 |
| 106 | 256 | 248 | 3.1 | 27.6 | 7.61 | 716 | 4 |
| 107 | 216 | 240 | 3.4 | 27.0 | 7.56 | 718 | 4 |
| 108 | 240 | 200 | 6.3 | 25.2 | 8.02 | 751 | 6 |
| 109 | 248 | 240 | 3.4 | 14.4 | 8.53 | 552 | 3 |
| 112 | 296 | 280 | 1.7 | 28.8 | 7.61 | 703 | 4 |
| 113 | 232 | 140 | 5.4 | 26.4 | 7.65 | 829 | 2 |
| 114 | 232 | 160 | 5.9 | 25.8 | 7.65 | 829 | 2 |
| 115 | 232 | 208 | 4.8 | 24.6 | 7.65 | 829 | 2 |
| 116 | 232 | 236 | 1.7 | 14.4 | 7.65 | 829 | 2 |
| 117 | 232 | 240 | 2.1 | 15.6 | 7.65 | 829 | 2 |
| 118 | 232 | 188 | 4.2 | 13.8 | 7.65 | 829 | 2 |
| 119 | 232 | 168 | 6.3 | 6.6 | 7.65 | 829 | 2 |
| 120 | 232 | 200 | 3.2 | 6.6 | 7.65 | 829 | 2 |
| 121 | unknown | 256 | 5.1 | 24.6 | unknown | unknown | unknown |
| 122 | unknown | 226 | 5.4 | 21.6 | unknown | unknown | unknown |
| 123 | unknown | 260 | 2.8 | 28.8 | unknown | unknown | unknown |
| 124 | 236 | 240 | 3.9 | 16.2 | 8.11 | 596 | 1 |
| 125 | 236 | 248 | 4.2 | 18.0 | 8.11 | 596 | 1 |
| 126 | 248 | 260 | 6.2 | 14.4 | 8.56 | 456 | 2 |

**Appendix G**: User Survey Raw Data

The following data in pages 40-47 includes the survey data for the 100 households corresponding to the 100 different filters. Sample number 53 corresponding to the same filter as sample number 43 was not included. Also, filters that were not included in the analysis due to low influent arsenic concentrations, high flow rate, or mechanical malfunctions are not included in this data sheet.

| Filter Number | Age (Years) | Date | District | VDC | Ward No. | Tole | Type of KAF | Name of the Household owner |
|---|---|---|---|---|---|---|---|---|
| 4 | 7 | Jan. 9, 2011 | Nawalparasi | Tilakpur | 7 | Patkhauli | Gem 505 | Thagey Prasad Chaudhary |
| 5 | 6 | Jan. 10, 2011 | Nawalparasi | Devgaun | 1 | Patkhouli | Gem 505 | Kamalesh Chaudhary |
| 6 | 6 | Jan. 10, 2011 | Nawalparasi | Devgaun | 1 | Patkhouli | Gem 505 | Narsingh Kurmi |
| 7 | 6 | Jan. 10, 2011 | Nawalparasi | Devgaun | 1 | Patkhouli | Gem 505 | Nagendra Kurmi |
| 8 | 5 | Jan. 10, 2011 | Nawalparasi | Devgaun | 1 | Patkhouli | Gem 505 | Hem Narayan Chaudhary |
| 9 | 4 | Jan. 10, 2011 | Nawalparasi | Devgaun | 1 | Patkhouli | Gem 505 | Bharat Thatel |
| 10 | 5 | Jan. 10, 2011 | Nawalparasi | Devgaun | 1 | Patkhouli | Gem 505 | Santosh Jaiswal |
| 11 | 4 | Jan. 10, 2011 | Nawalparasi | Devgaun | 1 | Patkhouli | Gem 505 | Amar singh kurmi |
| 13 | 3 | Jan.11, 2011 | Nawalparasi | Pratappur | 1 | Khaireni/Tharu | Gem 505 | Tika Prasad Chaudhary |
| 14 | 3 | Jan.11, 2011 | Nawalparasi | Pratappur | 1 | Khaireni/Tharu | Gem 505 | Chatraman Chaudhary |
| 15 | 3 | Jan.11, 2011 | Nawalparasi | Pratappur | 1 | Khaireni/Tharu | Gem 505 | Birendra Chaudhary |
| 17 | 3 | Jan.11, 2011 | Nawalparasi | Pratappur | 1 | Khaireni/Tharu | Gem 505 | Bahadur Tharu |
| 18 | 3 | Jan.11, 2011 | Nawalparasi | Pratappur | 1 | Khaireni/Tharu | Gem 505 | Chet Narayan Tharu |
| 19 | 3 | Jan.11, 2011 | Nawalparasi | Pratappur | 1 | Khaireni/Tharu | Gem 505 | Govinda Chaudhary |
| 21 | 3 | Jan.11, 2011 | Nawalparasi | Pratappur | 1 | Khaireni/Tharu | Gem 505 | Ramhari Bidari |
| 22 | 3 | Jan. 12, 2011 | Nawalparasi | Pratappur | 1 | Khaireni/Tharu | Gem 505 | Bal Bahadur Chaudhary |
| 23 | 3 | Jan. 12, 2011 | Nawalparasi | Pratappur | 1 | Khaireni/Tharu | Gem 505 | Om Narayan Chaudhary |
| 24 | 3 | Jan. 12, 2011 | Nawalparasi | Pratappur | 1 | Khaireni/Tharu | Gem 505 | Bishu Prasad Upadhaya |
| 25 | 3 | Jan. 12, 2011 | Nawalparasi | Pratappur | 1 | Khaireni/Tharu | Gem 505 | Madan Chaudhary |
| 26 | 3 | Jan. 12, 2011 | Nawalparasi | Pratappur | 1 | Khaireni/Tharu | Gem 505 | Madari Prasad Chaudhary |
| 27 | 3 | Jan. 12, 2011 | Nawalparasi | Pratappur | 1 | Khaireni/Tharu | Gem 505 | Tularam Chaudhary |
| 28 | 3 | Jan. 12, 2011 | Nawalparasi | Pratappur | 1 | Khaireni/Tharu | Gem 505 | Ashok Kashodhan |
| 29 | 3 | Jan. 12, 2011 | Nawalparasi | Pratappur | 1 | Khaireni/Tharu | Gem 505 | Tek Narayan Chaudhary |
| 31 | 6 | jan. 13,2011 | Nawalparasi | Sunwal | 3 | Naduwa | Concrete square | Sanju Thapa |
| 32 | 6 | jan. 13,2011 | Nawalparasi | Sunwal | 3 | Naduwa | Concrete round | Jay Budhathoki |
| 33 | 3 | jan. 13,2011 | Nawalparasi | Sunwal | 3 | Naduwa | Gem 505 | Khim Raj Rana |
| 34 | 3 | jan. 13,2011 | Nawalparasi | Sunwal | 3 | Naduwa | Gem 505 | Khalzir Budhathoki |
| 35 | 6 | jan. 13,2011 | Nawalparasi | Sunwal | 3 | Naduwa | Concrete square | Baliram Thapa |
| 36 | 6 | jan. 13,2011 | Nawalparasi | Sunwal | 3 | Naduwa | Concrete round | Ganesh Budhathoki |
| 37 | 3 | jan. 13,2011 | Nawalparasi | Sunwal | 3 | Naduwa | Gem 505 | Laxmi Bhusal |
| 41 | 0 | Jan. 14, 2011 | Nawalparasi | Bhutaha | 9 | Panchanagar | Gem 505 | Lila Chaudhary |
| 42 | 0 | Jan. 14, 2011 | Nawalparasi | Bhutaha | 9 | Panchanagar | Gem 505 | Birendra Chaudhary |
| 43 | 0 | Jan. 14, 2011 | Nawalparasi | Bhutaha | 9 | Panchanagar | Gem 505 | Fanendra Chaudhary |
| 44 | 0 | Jan. 14, 2011 | Nawalparasi | Bhutaha | 9 | Panchanagar | Gem 505 | Top Narayan Chaudhary |
| 45 | 0 | Jan. 15, 2011 | Nawalparasi | Bhutaha | 9 | Panchanagar | Gem 505 | Shivanath Chaudhary |
| 46 | 0 | Jan. 15, 2011 | Nawalparasi | Bhutaha | 9 | Panchanagar | Gem 505 | Mohalla Chaudhary |
| 47 | 0 | Jan. 15, 2011 | Nawalparasi | Bhutaha | 9 | Panchanagar | Gem 505 | Dhirendra Chaudhary |
| 48 | 0 | Jan. 15, 2011 | Nawalparasi | Bhutaha | 9 | Panchanagar | Gem 505 | Ramesh Chaudhary |
| 49 | 0 | Jan. 15, 2011 | Nawalparasi | Bhutaha | 9 | Panchanagar | Gem 505 | Naresh Chaudhary |
| 50 | 4 | Jan. 15, 2011 | Nawalparasi | Bhutaha | 9 | Panchanagar | Gem 505 | Ayodhya Chaudhary |
| 51 | 3 | Jan. 15, 2011 | Nawalparasi | Bhutaha | 9 | Panchanagar | Gem 505 | Chedi Chaudhary |
| 52 | 4 | Jan. 15, 2011 | Nawalparasi | Bhutaha | 9 | Panchanagar | Gem 505 | Man Bahadur Chaudhary |
| 53 | 7 | Jan. 15, 2011 | Nawalparasi | Bhutaha | 9 | Panchanagar | Gem 505 | Farendra Chaudhary |
| 54 | 7 | Jan. 16, 2011 | Nawalparasi | Bhutaha | 6 | Panchanagar | Gem 505 | Yam Bahadur Chaudhary |
| 55 | 7 | Jan. 16, 2011 | Nawalparasi | Bhutaha | 6 | Panchanagar | Gem 505 | Rita Chaudhary |
| 56 | 5 | Jan. 16, 2011 | Nawalparasi | Bhutaha | 6 | Panchanagar | Gem 505 | Tara Prasad Chaudhary |
| 58 | 6 | Jan. 16, 2011 | Nawalparasi | Bhutaha | 6 | Panchanagar | Concrete square | Sushila Faudhar |
| 60 | 7 | Jan. 16, 2011 | Nawalparasi | Sarawal | 1 | Goini | Concrete square | Hari Narayan Chaudhary |
| 61 | 0 | Jan. 17, 2011 | Nawalparasi | Tilakpur | 7 | Pathkhouli | Gem 505 | Uday raj Tharu |
| 62 | 0 | Jan. 17, 2011 | Nawalparasi | Tilakpur | 7 | Pathkhouli | Gem 505 | Bhud narayan Tharu |

| Filter Number | Age (Years) | Date | District | VDC | Ward No. | Tole | Type of KAF | Name of the Household owner |
|---|---|---|---|---|---|---|---|---|
| 63 | 0 | Jan. 17, 2011 | Nawalparasi | Tilakpur | 7 | Pathkhouli | Gem 505 | Khel ram kanta Chaudhary |
| 65 | 0 | Jan. 17, 2011 | Nawalparasi | Tilakpur | 7 | Pathkhouli | Gem 505 | Dhani ram Chaudhary |
| 66 | 0 | Jan. 17, 2011 | Nawalparasi | Tilakpur | 7 | Pathkhouli | Gem 505 | Ram chandra Chaudhary |
| 70 | 3 | Jan. 18, 2011 | Nawalparasi | Sunwal | 3 | Naduwa | Gem 505 | Chitra Bahadur Faudar |
| 71 | 0 | Jan. 18, 2011 | Nawalparasi | Makar | 8 | Laghuna | Gem 505 | Tikaram Bashyal |
| 72 | 0 | Jan. 18, 2011 | Nawalparasi | Makar | 8 | Laghuna | Gem 505 | Humanath Bashyal |
| 73 | 3 | Jan. 18, 2011 | Nawalparasi | Makar | 8 | Laghuna | Gem 505 | Balaram Pandey |
| 74 | 0 | Jan. 18, 2011 | Nawalparasi | Makar | 8 | Laghuna | Gem 505 | Mira lal Bashyal |
| 76 | 0 | Jan. 18, 2011 | Nawalparasi | Makar | 8 | Laghuna | Gem 505 | Yadav Aryal |
| 79 | 7 | Jan. 19, 2011 | Nawalparasi | Ramgram Municipality | 12 | Kasiya | Gem 505 | Madhav lal Shrestha |
| 80 | 7 | Jan. 19, 2011 | Nawalparasi | Ramgram Municipality | 12 | Kasiya | Gem 505 | Fagu Yadav |
| 81 | 5 | Jan. 19, 2011 | Nawalparasi | Ramgram Municipality | 8 | Unwanch | Gem 505 | Rishi raj Chaudhary |
| 82 | 5 | Jan. 19, 2011 | Nawalparasi | Ramgram Municipality | 8 | Unwanch | Gem 505 | Gobinda Chaudhary |
| 83 | 5 | Jan. 19, 2011 | Nawalparasi | Ramgram Municipality | 8 | Unwanch | Gem 505 | Om Prakash Chaudhary |
| 84 | 5 | Jan. 19, 2011 | Nawalparasi | Ramgram Municipality | 8 | Unwanch | Gem 505 | Kailash Chaudhary |
| 85 | 5 | Jan. 19, 2011 | Nawalparasi | Ramgram Municipality | 8 | Unwanch | Gem 505 | Padam Narayan Chaudhary |
| 86 | 5 | Jan. 19, 2011 | Nawalparasi | Ramgram Municipality | 8 | Unwanch | Gem 505 | Ganesh Kewat |
| 87 | 5 | Jan. 19, 2011 | Nawalparasi | Ramgram Municipality | 8 | Unwanch | Gem 505 | Ramzya Kewat |
| 91 | 7 | Jan. 20, 2011 | Rupandehi | Dudharakshya | 3 | Budhanagar | Concrete square | Kul Bahadur Tandon |
| 92 | 5 | Jan. 21, 2011 | Nawalparasi | Ramgram Municipality | 8 | Unwanch | Gem 505 | Kailash Sahani |
| 93 | 5 | Jan. 21, 2011 | Nawalparasi | Ramgram Municipality | 8 | Unwanch | Gem 505 | Ramdas Gupta |
| 94 | 5 | Jan. 21, 2011 | Nawalparasi | Ramgram Municipality | 8 | Baikunthapur | Gem 505 | Ramchandra Bhar |
| 95 | 7 | Jan. 21, 2011 | Nawalparasi | Ramgram Municipality | 8 | Baikunthapur | Gem 505 | Rabindra Pd. Bhar |
| 96 | 5 | Jan. 21, 2011 | Nawalparasi | Ramgram Municipality | 8 | Baikunthapur | Gem 505 | Madan Kurmi |
| 97 | 5 | Jan. 21, 2011 | Nawalparasi | Ramgram Municipality | 8 | Baikunthapur | Gem 505 | Sanu Pd. Bhar |
| 98 | 5 | Jan. 21, 2011 | Nawalparasi | Ramgram Municipality | 8 | Baikunthapur | Gem 505 | Kedarnath Gupta |
| 99 | 5 | Jan. 21, 2011 | Nawalparasi | Ramgram Municipality | 8 | Baikunthapur | Gem 505 | Tribhuvan Gupta |
| 100 | 5 | Jan. 22, 2011 | Nawalparasi | Ramgram Municipality | 8 | Baikunthapur | Gem 505 | Ram Harijan |
| 101 | 5 | Jan. 22, 2011 | Nawalparasi | Ramgram Municipality | 8 | Baikunthapur | Gem 505 | Ram Kewal Harijan |
| 102 | 5 | Jan. 22, 2011 | Nawalparasi | Ramgram Municipality | 8 | Baikunthapur | Gem 505 | Jayram Gupta |
| 103 | 5 | Jan. 22, 2011 | Nawalparasi | Ramgram Municipality | 13 | Kanchanha | Gem 505 | Mustakim Ansari |
| 105 | 6 | Jan. 22, 2011 | Nawalparasi | Ramgram Municipality | 13 | Shiwangadh | Gem 505 | Shivalal Aryal |
| 106 | 6 | Jan. 22, 2011 | Nawalparasi | Ramgram Municipality | 13 | Shiwangadh | Gem 505 | Sabitri Aryal |
| 107 | 4 | Jan. 22, 2011 | Nawalparasi | Ramgram Municipality | 13 | Shiwangadh | Gem 505 | Parag Gupta |
| 108 | 5 | Jan. 22, 2011 | Nawalparasi | Ramgram Municipality | 13 | Paratikar | Gem 505 | Babu lal Harijan |
| 109 | 5 | Jan. 22, 2011 | Nawalparasi | Ramgram Municipality | 13 | Paratikar | Gem 505 | Ram abadh Gupta |
| 112 | 5 | Jan. 23, 2011 | Nawalparasi | Ramgram Municipality | 13 | Paratikar | Gem 505 | Radhika Chaudhary |
| 113 | 5 | Jan. 23, 2011 | Nawalparasi | Ramgram Municipality | 13 | Paratikar | Gem 505 | Mohan Chaudhary |
| 114 | 5 | Jan. 23, 2011 | Nawalparasi | Ramgram Municipality | 13 | Paratikar | Gem 505 | Some Tharu |
| 115 | 5 | Jan. 23, 2011 | Nawalparasi | Ramgram Municipality | 13 | Paratikar | Gem 505 | Ash Narayan Chaudhary |
| 116 | 5 | Jan. 23, 2011 | Nawalparasi | Ramgram Municipality | 13 | Paratikar | Gem 505 | Praladh Badhai |
| 117 | 5 | Jan. 23, 2011 | Nawalparasi | Ramgram Municipality | 13 | Paratikar | Gem 505 | Algu Badhai |
| 118 | 5 | Jan. 23, 2011 | Nawalparasi | Ramgram Municipality | 13 | Paratikar | Gem 505 | Ganesh Bahadur Chaudhary |
| 119 | 5 | Jan. 23, 2011 | Nawalparasi | Ramgram Municipality | 13 | Paratikar | Gem 505 | Laxman Sharma |
| 120 | 5 | Jan. 23, 2011 | Nawalparasi | Ramgram Municipality | 13 | Paratikar | Gem 505 | Goli Gupta |
| 121 | 5 | Jan.24, 2011 | Nawalparasi | Sukrauli | 9 | Naduwa | Gem 505 | Gobardhan Chaudhary |
| 122 | 5 | Jan.24, 2011 | Nawalparasi | Sukrauli | 9 | Naduwa | Gem 505 | Man Bahdaur Chaudhary |
| 123 | 5 | Jan.24, 2011 | Nawalparasi | Sukrauli | 9 | Naduwa | Gem 505 | Ani Rudra Tharu |
| 124 | 5 | Jan.24, 2011 | Nawalparasi | Sukrauli | 9 | Naduwa | Gem 505 | Mahabir Bi. Ka. |
| 125 | 5 | Jan.24, 2011 | Nawalparasi | Sukrauli | 9 | Naduwa | Gem 505 | Shree ram Bi. Ka. |
| 126 | 5 | Jan.24, 2011 | Nawalparasi | Sukrauli | 9 | Naduwa | Gem 505 | Shiva Kumar Sahani |

| Filter Number | KAF provided by | KAF Installed Date | Quality of Iron nails | No. of KAF Households | Number of KAF Users |
|---|---|---|---|---|---|
| 4 | NRCS | 2003 | Well rusted | 1 | 7 |
| 5 | NRCS | 2004 | Well rusted | 1 | 9 |
| 6 | NRCS | 2004 | Well rusted | 1 | 3 |
| 7 | Filters for families | 2004 | Well rusted | 1 | 2 |
| 8 | Filters for families | 2005 | Well rusted | 1 | 5 |
| 9 | Filters for families | 2006 | Well rusted | 1 | 5 |
| 10 | Filters for families | 2005 | Well rusted | 1 | 4 |
| 11 | Filters for families | 2006 | Well rusted | 1 | 5 |
| 13 | Filters for families | 2007 | Well rusted | 1 | 2 |
| 14 | Filters for families | 2007 | Well rusted | 1 | 4 |
| 15 | Filters for families | 2007 | Well rusted | 1 | 3 |
| 17 | Filters for families | 2007 | Well rusted | 1 | 7 |
| 18 | Filters for families | 2007 | Well rusted | 1 | 2 |
| 19 | Filters for families | 2007 | Well rusted | 1 | 4 |
| 21 | Filters for families | 2007 | Well rusted | 1 | 5 |
| 22 | Filters for families | 2007 | Well rusted | 1 | 5 |
| 23 | Filters for families | 2007 | Well rusted | 1 | 4 |
| 24 | Filters for families | 2007 | Well rusted | 1 | 5 |
| 25 | Filters for families | 2007 | Well rusted | 1 | 7 |
| 26 | Filters for families | 2007 | Well rusted | 1 | 10 |
| 27 | Filters for families | 2007 | Well rusted | 1 | 7 |
| 28 | Filters for families | 2007 | Well rusted | 1 | 4 |
| 29 | Filters for families | 2007 | Well rusted | 1 | 4 |
| 31 | RWSSSP | 2004 | Well rusted | 1 | 4 |
| 32 | RWSSSP | 2004 | Well rusted | 1 | 7 |
| 33 | Filters for families | 2007 | Well rusted | 1 | 2 |
| 34 | Filters for families | 2007 | Well rusted | 1 | 3 |
| 35 | RWSSSP | 2004 | Well rusted | 1 | 3 |
| 36 | RWSSSP | 2004 | Well rusted | 1 | 7 |
| 37 | Filters for families | 2007 | Well rusted | 1 | 3 |
| 41 | DWSS | 2010 | Well rusted | 1 | 4 |
| 42 | DWSS | 2010 | Well rusted | 1 | 5 |
| 43 | DWSS | 2010 | Well rusted | 1 | 4 |
| 44 | DWSS | 2010 | Well rusted | 1 | 7 |
| 45 | DWSS | 2010 | Well rusted | 1 | 4 |
| 46 | DWSS | 2010 | Well rusted | 1 | 4 |
| 47 | DWSS | 2010 | Well rusted | 1 | 4 |
| 48 | DWSS | 2010 | Well rusted | 1 | 10 |
| 49 | DWSS | 2010 | Well rusted | 1 | 8 |
| 50 | NRCS | 2006 | Well rusted | 1 | 7 |
| 51 | NRCS | 2007 | Well rusted | 1 | 2 |
| 52 | NRCS | 2006 | Well rusted | 1 | 7 |
| 53 | NRCS | 2003 | Well rusted | | |
| 54 | NRCS | 2003 | Well rusted | 1 | 6 |
| 55 | NRCS | 2003 | Well rusted | 1 | 4 |
| 56 | NRCS | 2005 | Well rusted | 1 | 4 |
| 58 | Local entrepreneur (Raju Bishwo) | 2004 | Well rusted | 1 | 5 |
| 60 | RWSSSP | 2003 | Well rusted | 1 | 27 |
| 61 | DWSS | 2010 | Well rusted | 1 | 7 |
| 62 | DWSS | 2010 | Well rusted | 1 | 6 |

| Filter Number | KAF provided by | KAF Installed Date | Quality of Iron nails | No. of KAF Households | Number of KAF Users |
|---|---|---|---|---|---|
| 63 | DWSS | 2010 | Well rusted | 1 | 4 |
| 65 | DWSS | 2010 | Well rusted | 1 | 2 |
| 66 | DWSS | 2010 | Well rusted | 1 | 9 |
| 70 | Filters for families | 2007 | Well rusted | 1 | 4 |
| 71 | DWSS | 2010 | Well rusted | 1 | 5 |
| 72 | DWSS | 2010 | Well rusted | 1 | 8 |
| 73 | NRCS | 2007 | Well rusted | 1 | 5 |
| 74 | DWSS | 2010 | Well rusted | 1 | 6 |
| 76 | DWSS | 2010 | Well rusted | 1 | 4 |
| 79 | NRCS | 2003 | Well rusted | 1 | 6 |
| 80 | NRCS | 2003 | Well rusted | 1 | 8 |
| 81 | Filters for families | 2005 | Well rusted | 1 | 11 |
| 82 | Filters for families | 2005 | Well rusted | 1 | 11 |
| 83 | Filters for families | 2005 | Well rusted | 1 | 5 |
| 84 | Filters for families | 2005 | Well rusted | 1 | 9 |
| 85 | Filters for families | 2005 | Well rusted | 1 | 6 |
| 86 | Filters for families | 2005 | Well rusted | 1 | 4 |
| 87 | Filters for families | 2005 | Well rusted | 1 | 5 |
| 91 | Local Entrepreneur (Narayan Pandey) | 2003 | Well rusted | 1 | 8 |
| 92 | Filters for families | 2005 | Well rusted | 1 | 5 |
| 93 | Filters for families | 2005 | Well rusted | 1 | 11 |
| 94 | Filters for families | 2005 | Well rusted | 1 | 6 |
| 95 | NRCS | 2003 | Well rusted | 1 | 6 |
| 96 | Filters for families | 2005 | Well rusted | 1 | 8 |
| 97 | Filters for families | 2005 | Well rusted | 1 | 5 |
| 98 | Filters for families | 2005 | Well rusted | 1 | 4 |
| 99 | Filters for families | 2005 | Well rusted | 1 | 6 |
| 100 | Filters for families | 2005 | Well rusted | 1 | 9 |
| 101 | Filters for families | 2005 | Well rusted | 1 | 4 |
| 102 | Filters for families | 2005 | Well rusted | 1 | 5 |
| 103 | Filters for families | 2005 | Well rusted | 1 | 8 |
| 105 | Filters for families | 2004 | Well rusted | 1 | 8 |
| 106 | Filters for families | 2004 | Well rusted | 1 | 3 |
| 107 | Filters for families | 2006 | Well rusted | 1 | 12 |
| 108 | Filters for families | 2005 | Well rusted | 1 | 5 |
| 109 | Filters for families | 2005 | Well rusted | 1 | 10 |
| 112 | Filters for families | 2005 | Well rusted | 1 | 4 |
| 113 | Filters for families | 2005 | Well rusted | 1 | 6 |
| 114 | Filters for families | 2005 | Well rusted | 1 | 3 |
| 115 | Filters for families | 2005 | Well rusted | 1 | 6 |
| 116 | Filters for families | 2005 | Well rusted | 1 | 5 |
| 117 | Filters for families | 2005 | Well rusted | 1 | 6 |
| 118 | Filters for families | 2005 | Well rusted | 1 | 8 |
| 119 | Filters for families | 2005 | Well rusted | 1 | 4 |
| 120 | Filters for families | 2005 | Well rusted | 1 | 6 |
| 121 | Filters for families | 2005 | Well rusted | 1 | 5 |
| 122 | Filters for families | 2005 | Well rusted | 1 | 2 |
| 123 | Filters for families | 2005 | Well rusted | 1 | 8 |
| 124 | Filters for families | 2005 | Well rusted | 1 | 7 |
| 125 | Filters for families | 2005 | Well rusted | 1 | 4 |
| 126 | Filters for families | 2005 | Well rusted | 1 | 4 |

| Filter Number | Filter Water Per Day (L) | Filte use | Filter cleaning Frequency | Date of last cleaning |
|---|---|---|---|---|
| 4 | 45 | everyday | When water is insuffient/once in every 2-3 months | 20 days back |
| 5 | 30 | everyday | once in every two weeks | 5 days back |
| 6 | 20 | everyday | once in a month | a month back |
| 7 | 25 | everyday | once in every two weeks | two week back |
| 8 | 30 | everyday | when water is insufficient/once in every 2-3 months | two months back |
| 9 | 40 | everyday | once in every two weeks | 3 days back |
| 10 | 30 | everyday | once in a month | 20 days back |
| 11 | 30 | everyday | once in a month | a month back |
| 13 | 25 | everyday | once in month | 25 days back |
| 14 | over 50 litre | everyday | once in a month | a month back |
| 15 | 30 | everyday | once in a month | a month back |
| 17 | 40 | everyday | once in a month | 23 days back |
| 18 | 10 | everyday | once in a month | more than a month |
| 19 | 30 | everyday | once in a two weeks | 10 days back |
| 21 | over 50 litre | everyday | once in every 2-3 months | two months back |
| 22 | 30 | everyday | once in a month | a month back |
| 23 | 30 | everyday | once in every three month | two months back |
| 24 | 50 | everyday | once in two week | two weeks back |
| 25 | over 50 litre | everyday | once in a month | two weeks back |
| 26 | over 50 litre | everyday | once in a month | yesterday |
| 27 | 40 | everyday | once in a month | yesterday |
| 28 | 50 | everyday | once in a week | a week back |
| 29 | 20 | everyday | once in a month | yesterday |
| 31 | 20 | everyday | When water is insufficient/ 1-3 month | a month back |
| 32 | 30 | everyday | once in a month | 15 days back |
| 33 | 20 | everyday | When water is insufficient/once in every 2-3 months | three months back |
| 34 | 20 | everyday | once in every two month | a month back |
| 35 | 20 | everyday | when water is insufficient/once in every 2-3 months | two months back |
| 36 | 40 | everyday | once in two month | No idea |
| 37 | 20 | everyday | when water is insufficent | two months back |
| 41 | 20 | everyday | once in every 2-3 months | 25 days back |
| 42 | 25 | everyday | once in every 2-3 months | 3 months back |
| 43 | 35 | everyday | once in every two weeks | 10 days back |
| 44 | 30 | everyday | once in every 2-3 months | 2 months back |
| 45 | 25 | everyday | once a month | a month back |
| 46 | 30 | everyday | once in every 2-3 months | 45 days back |
| 47 | 10 | everyday | once in every 2-3 months | 3 months back |
| 48 | over 50 litre | | No idea | No idea |
| 49 | 50 | everyday | once in every 2-3 months | 3 months back |
| 50 | 35 | everyday | Never | Never |
| 51 | 25 | everyday | once in every two weeks | 12 days back |
| 52 | 50 | everyday | once in every 2-3 months | 1 day back |
| 53 | | | | |
| 54 | 40 | everyday | once in every 6 months | 6 months back |
| 55 | 35 | everyday | once in every 2-3 months | two months back |
| 56 | 40 | everyday | once in every two weeks | 7 days back |
| 58 | 25 | everyday | once in every 2-3 months | two months back |
| 60 | over 50 litre | everyday | once in a month | 15 days back |
| 61 | 20 | everyday | once in every 2-3 months | two months back |
| 62 | 30 | everyday | once in every 2-3 months | two months back |

| Filter Number | Filter Water Per Day (L) | Filte use | Filter cleaning Frequency | Date of last cleaning |
|---|---|---|---|---|
| 63 | 40 | everyday | once in every 2-3 months | 3 months back |
| 65 | 12 | everyday | Never | Never |
| 66 | over 50 litre | everyday | once in a month | a month back |
| 70 | 25 | everyday | once in every 4 month | two months back |
| 71 | 35 | everyday | Never | Never |
| 72 | over 50 litre | everyday | once in every 2-3 months | 20 days back |
| 73 | 40 | everyday | once in every 2-3 months | a month back |
| 74 | 40 | everyday | once in every 2-3 months | a month back |
| 76 | 40 | everyday | once in every 2-3 months | 15 days back |
| 79 | 50 | everyday | once in a month | 12 days back |
| 80 | 40 | everyday | once in a month | a month back |
| 81 | over 50 litre | everyday | once in every 2-3 months | 20 days back |
| 82 | over 50 litre | everyday | once in every 2-3 months | a month back |
| 83 | 40 | everyday | once in every 2-3 months | 40 days back |
| 84 | over 50 litre | everyday | once in every 2-3 months | 20 days back |
| 85 | 40 | everyday | once in every 2-3 months | 2 months back |
| 86 | 30 | everyday | once in every two weeks | 15 days back |
| 87 | 40 | everyday | once in a month | 15 days back |
| 91 | over 50 litre | everyday | once in a month | 15 days back |
| 92 | 40 | everyday | once in every 2-3 months | a month back |
| 93 | over 50 litre | everyday | once in a month | 5 days back |
| 94 | 50 | everyday | once in a month | 10 days back |
| 95 | 40 | everyday | once in a month | 25 days back |
| 96 | 50 | everyday | once in every 2-3 months | a month back |
| 97 | 30 | everyday | once in a month | 10 days back |
| 98 | 30 | everyday | once in a month | 10 days back |
| 99 | 50 | everyday | once in a month | 20 days back |
| 100 | 40 | everyday | once in every two weeks | 8 days back |
| 101 | 40 | everyday | once in every two weeks | 7 days back |
| 102 | 35 | everyday | once in every 2-3 months | 45 days back |
| 103 | 40 | everyday | once in a month | one month ago |
| 105 | 40 | everyday | once in every two weeks | a months back |
| 106 | 30 | everyday | once in a month | 15 days back |
| 107 | over 50 litre | everyday | once in every two weeks | 12 days back |
| 108 | 35 | everyday | once in a month | a month back |
| 109 | 30 | don't uses during cold season | once in every two weeks | 2 months back |
| 112 | 20 | everyday | once in every 2-3 months | a month back |
| 113 | 32 | everyday | once in every 7-8 months | 5 months back |
| 114 | 20 | everyday | once in every 2-3 months | 45 days back |
| 115 | over 50 litre | don't uses during cold season | once in every 2-3 months | 2 months back |
| 116 | 40 | everyday | once in every 2-3 months | 45 days back |
| 117 | 50 | everyday | once in every 4 month | 4 months back |
| 118 | over 50 litre | don't uses during cold season | once in every 4 month | 3 months back |
| 119 | 40 | don't uses during cold season | once in every 4 month | 4 months back |
| 120 | 30 | everyday | once in every 4 month | 4 months back |
| 121 | 40 | everyday | once in every 2-3 months | a month back |
| 122 | 30 | everyday | once in a month | a month back |
| 123 | 40 | everyday | once in every 2-3 months | a month back |
| 124 | over 50 litre | everyday | once in every 4 month | 4 months back |
| 125 | 40 | everyday | once in every 4 month | a day back |
| 126 | 36 | everyday | once in a month | a month back |

| Filter Number | Remarks |
|---|---|
| 4 | |
| 5 | Some floating materials above sand layer |
| 6 | |
| 7 | |
| 8 | |
| 9 | |
| 10 | |
| 11 | Filter was not in use from 10 days becoz filter water is cold. |
| 13 | |
| 14 | |
| 15 | |
| 17 | |
| 18 | Filter was not in use from past 15 days due to cold water from KAF |
| 19 | |
| 21 | |
| 22 | |
| 23 | |
| 24 | |
| 25 | Low sand level (~1 inch less) |
| 26 | |
| 27 | Low sand level (~1 inch less) |
| 28 | Using tubewell of filter no. 24 |
| 29 | |
| 31 | |
| 32 | |
| 33 | Low sand level (~1 inch less) |
| 34 | |
| 35 | |
| 36 | |
| 37 | |
| 41 | Low sand level (~1/2 inch less) |
| 42 | Arsenicosis symptom seen in HH member |
| 43 | Low sand level (~1/2 inch less) |
| 44 | Low sand level (~1/2 inch less) |
| 45 | Low sand level (~1/2 inch less) |
| 46 | Low sand level (~1/2 inch less) |
| 47 | Low sand level (~1/2 inch less) |
| 48 | Not in use since a month |
| 49 | |
| 50 | |
| 51 | |
| 52 | |
| 53 | Retest of filter no. 43 |
| 54 | |
| 55 | |
| 56 | |
| 58 | |
| 60 | Nails more than 5 kg |
| 61 | Large nail size |
| 62 | |

| Filter Number | Remarks |
|---|---|
| 63 | Large nail size |
| 65 | Large nail size |
| 66 | |
| 70 | |
| 71 | |
| 72 | |
| 73 | absence of resting water level |
| 74 | |
| 76 | |
| 79 | |
| 80 | |
| 81 | |
| 82 | |
| 83 | |
| 84 | |
| 85 | |
| 86 | |
| 87 | |
| 91 | |
| 92 | |
| 93 | |
| 94 | |
| 95 | |
| 96 | Fine sand mixed with coarse sand |
| 97 | Filter was not in use from past 15 days due to cold water from KAF |
| 98 | |
| 99 | |
| 100 | |
| 101 | |
| 102 | |
| 103 | |
| 105 | |
| 106 | |
| 107 | |
| 108 | |
| 109 | Filter was not in use from past 2 months due to cold water from KAF |
| 112 | |
| 113 | |
| 114 | filter was not in use from past 1 months due to cold water from KAF |
| 115 | |
| 116 | |
| 117 | |
| 118 | Filter was not in use from past 2 months due to cold water from KAF |
| 119 | |
| 120 | Filter was not in use from past 4 months due to cold water from KAF |
| 121 | |
| 122 | |
| 123 | |
| 124 | |
| 125 | |
| 126 | |

# **Appendix H:** Data of Samples Not Used in Present Study

| Filter # | H20 sourse | As (ppb) | Fe(II) (ppm) | Sil (ppm) | pH (1) | pH (2) | Hard (2) ppm | Alk (ppm) | Cl (ppm) | Flow (L/min) | Notes (1): |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | GW | 47 | 2.33 | 13.2 | 8 | 7.8 | 425 | 240+ | 0 | 0.91 | too low GW [As], <50ppb |
| 2 | GW | 39 | 2.98 | 17.7 | 8 | 7.2 | 425 | 240+ | 0 | | too low GW [As], <50ppb |
| 3 | GW | 92 | 0.47 | 14.7 | 8 | 7.8 | 250 | 180 | 0 | | Filter type 4 discarted |
| | filter | 8 | 0 | 11.9 | 7.5 | 7.2-7.8 | 120 | 120 | 0 | | |
| | after nails | | 0.84 | | | | | | | | |
| 16 | GW | 200-300 | 3.75 OR | 30.9 | 7.5 | 7.2 | 250-425 | 180 | 0 | >0.5 | flow too fast |
| 20 | GW | 100 | | | 7 | 7.2 | 425 | 180 | 0 | >0.5 | flow too fast |
| 30 | GW | <10 | 2.04 | 9.5 | 7 | 7.2 | 425 | 240 | 0 | | too low GW [As], <50ppb |
| 38 | GW | 0 UR | 1.28 | 16 | 7 | 6.8 | 425 | 290 | 0 | 0.14 | too low GW [As], <50ppb |
| 39 | GW | 0 UR | 1.78 | 13.5 | 7.5 | 6.8 | 425 | 280 | 0 | 0.30 | too low GW [As], <50ppb |
| 40 | GW | 13 | 4.24 | 18.5 | 7 | 6.8 | 425 | 280 | 0 | | too low GW [As], <50ppb |
| 57 | GW | 200-300 | 1.2 | 14.4 | 7.5 | 7.2-7.8 | 425 | 280 | 0 | 0.08 | flow too fast |
| 59 | GW | 41 | 1.28 | 12.3 | 7.5 | 7.2-7.8 | 425 | 280 | 0 | 0.30 | too low GW [As], <50ppb |
| 64 | GW | 56 | 2.92 | 14.1 | 6.5 | 6.8 | 425 | 240 | 0 | 0.48 | too low GW [As], <50ppb |
| 67 | GW | 39 | 3.66 | 22.5 | 7 | 7.2 | 425 | 240 | 0 | 0.48 | too low GW [As], <50ppb |
| 68 | GW | 48 | 4.04 | 15.1 | 7 | 7.2 | 425 | 240 | 0 | 0.30 | too low GW [As], <50ppb |
| 69 | GW | 42 | 5.32 | 17.4 | | | | | | 0.38 | too low GW [As], <50ppb |
| 75 | GW | 12 | | | 6.5 | 7.2 | 425 | 240 | 0 | 0.31 | too low GW [As], <50ppb |
| 77 | GW | 2 | 4.5 OR | 12.3 | 6.5 | 6.8 | 425 | 240 | 0 | 0.28 | too low GW [As], <50ppb |
| 78 | GW | 37 | | 14.6 | 7 | 7.2 | 250 | 240 | 0 | | too low GW [As], <50ppb |
| 88 | GW | 0 | | | | | | | | | too low GW [As], <50ppb |
| 89 | GW | 0 | | | | | | | | | too low GW [As], <50ppb |
| 90 | GW | 47 | | | | | | | | | too low GW [As], <50ppb |
| 104 | GW | 28 | 2.67 | 15.5 | 7.5 | 7.2-7.8 | 425 | 240 | 0 | 0.13 | too low GW [As], <50ppb |
| 110 | GW | 41 | | | 7.5 | 7.8-8.4 | 425 | 240 | 0 | | too low GW [As], <50ppb |
| 111 | GW | 19 | 3.56 OR | 25.2 | 7.5 | 7.8-8.4 | 425 | 240 | 0 | 0.23 | too low GW [As], <50ppb |

| Filter No. | Date | District | VDC | Ward No. | Tole | Type of KAF | Name of the Household owner |
|---|---|---|---|---|---|---|---|
| 1 | Jan. 9, 2011 | Nawalparasi | Tilakpur | 7 | Patkhauli | Concrete square | Netra Narayan Chaudhary |
| 2 | Jan. 9, 2011 | Nawalparasi | Tilakpur | 7 | Patkhauli | Concrete square | Amar Narayan Chaudhary |
| 3 | Jan. 9, 2011 | Nawalparasi | Tilakpur | 7 | Patkhauli | Plastic square | Baliram Chaudhary |
| 16 | Jan.11, 2011 | Nawalparasi | Pratappur | 1 | Khaireni/Tharu | Plastic square | Bishwonath Chaudhary |
| 19 | Jan.11, 2011 | Nawalparasi | Pratappur | 1 | Khaireni/Tharu | Gem 505 | Govinda Chaudhary |
| 30 | Low Arsenic | | | | | | |
| 38 | Jan. 14, 2011 | Nawalparasi | Swathi | 8 | Swathi | Gem 505 | Sima Chaudhary |
| 39 | Jan. 14, 2011 | Nawalparasi | Swathi | 8 | Swathi | Gem 505 | |
| 40 | Jan. 14, 2011 | Nawalparasi | Swathi | 8 | Swathi | Gem 505 | |
| 57 | Jan. 16, 2011 | Nawalparasi | Bhutaha | | | | |
| 59 | Jan. 16, 2011 | Nawalparasi | Bhutaha | | | | |
| 64 | Jan. 17, 2011 | Nawalparasi | Tilakpur | 7 | Pathkhouli | Gem 505 | Dinesh Chaudhary |
| 67 | Jan. 17, 2011 | Nawalparasi | Sunwal | 3 | Naduwa | Gem 505 | Nawodurga Primary School |
| 68 | Jan. 17, 2011 | Nawalparasi | Sunwal | 3 | Naduwa | Gem 505 | Nawodurga Primary School |
| 69 | Jan. 17, 2011 | | | | | | |
| 75 | Jan. 18, 2011 | Nawalparasi | Makar | 8 | Laghuna | Gem 505 | Krishna Pageni |
| 77 | Jan. 18, 2011 | Nawalparasi | Makar | 8 | Laghuna | Gem 505 | Ram Prasad Mishra |
| 78 | Jan. 18, 2011 | Nawalparasi | Makar | 8 | Laghuna | Gem 505 | Uday Bdr. Lamichane |
| 88 | Jan. 20, 2011 | Rupandehi | Rudrapur | 4 | Gargare | Concrete square | Buddhadeep English Boarding School |
| 89 | Jan. 20, 2011 | Rupandehi | Rudrapur | 4 | Gargare | Concrete square | Buddhadeep English Boarding School |
| 90 | Jan. 20, 2011 | Rupandehi | Rudrapur | 4 | Bargadhawa | Concrete square | Dinanath Acharya |
| 104 | Jan. 22, 2011 | Nawalparasi | Ramgram Municipality | 13 | Shiwangadh | Gem 505 | Sukhed Ansari |
| 110 | Jan. 22, 2011 | Nawalparasi | Ramgram Municipality | 13 | Paratikar | Gem 505 | Hari Harijan |
| 111 | Jan. 23, 2011 | Nawalparasi | Ramgram Municipality | 13 | Paratikar | Gem 505 | Laxman Harijan |

| Filter No. | KAF provided by | Installed Date | Quality of Iron nails | No. of Households | Number of Users |
|---|---|---|---|---|---|
| 1 | Local entrepreneur (Raju Bishwo) | 2007 | Well rusted | 1 | 6 |
| 2 | Local entrepreneur (Raju Bishwo) | 2007 | Well rusted | 1 | 2 |
| 3 | NRCS | 2003 | Well rusted | 1 | 6 |
| 16 | Filters for families | 2003 | Well rusted | 1 | 7 |
| 19 | Filters for families | 2007 | Well rusted | 1 | 4 |
| 30 | | | | | |
| 38 | DWSS | 2010 | Well rusted | 1 | 4 |
| 39 | DWSS | 2010 | Well rusted | 1 | |
| 40 | DWSS | 2010 | Well rusted | 1 | |
| 57 | | | | | |
| 59 | | | | 1 | |
| 64 | DWSS | 2010 | Well rusted | 1 | 2 |
| 67 | Filters for families | 2007 | Well rusted | 1 | 120 students |
| 68 | Filters for families | 2007 | Well rusted | 1 | 120 students |
| 69 | No arsenic | | Well rusted | | |
| 75 | DWSS | 2010 | Well rusted | 1 | 4 |
| 77 | DWSS | 2010 | Well rusted | 1 | 3 |
| 78 | DWSS | 2010 | Well rusted | 1 | 8 |
| 88 | Local Entrepreneur (Narayan Pandey) | 2007 | Well rusted | 1 | total 42 teachers and 900 student |
| 89 | Local Entrepreneur (Narayan Pandey) | 2007 | Well rusted | 1 | total 42 teachers and 900 student |
| 90 | Local Entrepreneur (Narayan Pandey) | 2003 | Well rusted | 1 | 5 |
| 104 | Filters for families | 2005 | Well rusted | 1 | 6 |
| 110 | Filters for families | 2005 | Well rusted | 1 | 5 |
| 111 | Filters for families | 2005 | Well rusted | 1 | 4 |

| Filter No. | filter water per day(in. lit) | Filte use | Filter cleaning Frequency | Date of last cleaning |
|---|---|---|---|---|
| 1 | 30 | everyday | When water is insufficient once in every 2-3 months | a month back |
| 2 | 10 | everyday | when flow rate drops/once in every 2-3 months | 15 days back |
| 3 | 45 | everyday | once in a month | a month back |
| 16 | 40 | everyday | once in every 4 month | 2 months back |
| 19 | 30 | everyday | once in a two weeks | 10 days back |
| 30 | | | | |
| 38 | 20 | everyday | once in every two weeks | 10 days back |
| 39 | | | | |
| 40 | | | | |
| 57 | | | | |
| 59 | | | | |
| 64 | 40 | everyday | Never | Never |
| 67 | over 50 litre | not use during vacation | once in every 2-3 months | 45 days back |
| 68 | over 50 litre | not use during vacation | once in every 2-3 months | 45 days back |
| 69 | | | | |
| 75 | 30 | everyday | once in every 2-3 months | 20 days back |
| 77 | 30 | everyday | once in every 2-3 months | 10 days back |
| 78 | over 50 litre | everyday | once in every 2-3 months | a month back |
| 88 | over 50 litre | everyday | once in every 2-3 months | 20 days back |
| 89 | over 50 litre | everyday | once in every 2-3 months | 20 days back |
| 90 | 40 | everyday | once in every 2-3 months | 45 days back |
| 104 | 30 | everyday | once in every 2-3 months | 3 months back |
| 110 | 20 | everyday | once in a month | 15 days back |
| 111 | 20 | everyday | once in every 2-3 months | 2 months back |

| Filter No. | Remarks |
|---|---|
| 1 | Arsenic concentration below 50 ppb |
| 2 | Arsenic concentration below 50 ppb |
| 3 | |
| 16 | |
| 19 | |
| 30 | Low arsenic |
| 38 | Low As concentration in GW |
| 39 | Low As concentration in GW |
| 40 | Low As concentration in GW |
| 57 | |
| 59 | Low Arsenic in GW |
| 64 | |
| 67 | |
| 68 | |
| 69 | Low Arsenic in GW |
| 75 | |
| 77 | |
| 78 | |
| 88 | |
| 89 | |
| 90 | |
| 104 | |
| 110 | |
| 111 | |