IOP Conference Series: Earth and Environmental Science

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To cite this article: Khin Phyu Phyu *et al* 2020 *IOP Conf. Ser.: Earth Environ. Sci.* **496** 012009

IOP Conf. Series: Earth and Environmental Science **496** (2020) 012009 doi:10.1088/1755-1315/496/1/012009

Assessment and treatment of arsenic contaminated tube well water from selected areas in Kyaunggon Township, Ayeyarwady Region, Myanmar

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Abstract. Arsenic contamination of tube well water has become the greatest health threat to the people. This cross-sectional analytic study aimed to find out the prevalence of arsenic contaminated wells in selected areas of Kyaunggon Township, to increase the arsenic awareness and to construct the low-cost arsenic reducing Gravel Sand Filter (GSF) for household use. The water samples were tested for arsenic and other parameters. About 66% (63/96) tube wells of depth between 12 to 183 meters had arsenic concentration more than 10 ppb and moreover 42 out of 63 tube wells had depth between 30 to 90 meters. Therefore, this depth range should be avoided for tube well construction in that area. About 67.7 % (65/96) had iron concentration more than 0.3 ppm, 74 % (71/96) had manganese concentration more than 0.4 ppm and 4.1 % (4/96) had phosphate concentration more than 4 ppm according to WHO drinking water quality guideline. These results were disseminated to basic health staff, teachers and students from respective areas. GSF was constructed and demonstrated to villagers. Widely using of this removal method in arsenic contaminated areas will partly contribute towards the safe water supply and promote the community health.

1. Introduction

Recent global estimates indicate that 2.1 billion people have lack of access to safe, readily available water at home and 159 million people still collect drinking water directly from surface water sources that are subjected to contamination [1]. Contamination of ground water with arsenic is a major environmental concern affecting the health of some 140 million people in over 50 countries worldwide [2]. Arsenic is naturally occurring metalloid, present in inorganic and organic forms [3]. Inorganic arsenic is highly toxic than organic forms. In natural water, arsenic takes most commonly inorganic forms arsenite (trivalent arsenic, As (III)) and arsenate (pentavalent arsenic, As (V)). Unsafe drinking water necessitates the significant risk to affect consumers' health. It is imperative to facilitate the assistance to key stakeholders for sustainable improvement in drinking water quality inclusive of capacity building, research, and promotion of best practices [4].

Long-term exposure to arsenic at elevated levels from drinking-water and food can cause cancer, skin and neurological problems. Globally, arsenic in groundwater threatens the health of over 100 million people especially in South and East Asia where there is a high population density at the unacceptable level of arsenic above the WHO limit of 10 μg/L for drinking water [5,6].

In the Red River Delta of Northern Vietnam, inorganic arsenic concentrations in the drinking water have been reported between 1 and 3,050 μg/L and averaged at 159 μg/L [7]. In Cambodia, one of the key indicators for the hazardous concentration of arsenic in groundwater included well depths greater than 16 m. As early as the year 2000, the water and sanitation programme implemented by 'Save the Children-United Kingdom' revealed the arsenic contamination of groundwater in rural parts of the Ayeyarwady delta region in Myanmar [8]. The estimated numbers of an arsenic-exposed population being about 2.5 million are potentially at risk of arsenic poisoning from drinking water sources. Since then public health interest, concern and action related to arsenic testing, communication, and mitigation in Myanmar has been increased [1]. In 2016, the previous recent study in Thabaung Township revealed that 123 wells (68%) were contaminated with arsenic, the concentrations of which being > 50 μg/L, with substantial variability between villages (42-89%). In total, 404 (44.6%) of the households used contaminated wells as their primary source of drinking water, affecting 1704(44.3%) individuals [9]. The occurrence of peripheral neuropathy was detected in arsenic exposed villagers who drink arsenic contaminated water above the WHO limit of 10 μg/L in drinking water [10]. Another study in Kyone Pyaw Township, Ayeyarwady Region reported the highest arsenic contamination in river valleys and delta [11]. The research team of this study performed the pilot study in 2018, in the area of previously arsenic contaminated wells (>500 μg/L) in 2 wards of Kyaunggon Township. It showed that arsenic concentration in drinking water sources ranged from 415 to 505 ppb in 6 shallow tube wells and 1 dug well.

The most important action to be taken in affected communities is the prevention of further exposure to arsenic by provision of a safe water supply. Remediation is the most viable solution whereas the global population affected by arsenic contaminated water remains high. A great number of arsenic removal technologies are available to ensure safe drinking water for villages at different levels: household level arsenic removal filters, community-level water treatment plants, in-situ arsenic treatment, arsenic-safe dug wells and ponds and piped water supply schemes. Bangladesh introduced low-cost safe water alternatives for 20 million people who were at risk of drinking water from arsenic-contaminated wells to provide arsenic-safe and pathogen-free water [12]. In 2017, community arsenic removal Gravel Sand Filters (GSF) was built in Kone Htan Gyi and Lae Ti Chaung villages, at Thabaung township, Ayeyarwady Region [9]. This method is low cost and has arsenic removal efficiencies of 95% and so it needs to accelerate wide scale use of this method in highly arsenic contaminated rural areas. The aim of the study was to establish low cost arsenic removal Gravel Sand Filter (GSF) by using locally available materials for community use in rural area of Kyaunggon Township, Ayeyarwady Region.

Specific objectives

- To investigate the arsenic level and water quality parameters in water sources
- To construct and demonstrate the safe water supply system (GSF) by arsenic filtration
- To reassess immediately the arsenic level of filtered water
- To advocate and disseminate the results to the local authority and public

Materials and Methods

Materials

- Field kit Arsenator
- pH meter
- PhotoFlex
- ICP-OES

2. Method

Cross sectional analytic study was applied.

2.1. Study area and study population

The study area covered 96 drinking water sources which were being used by half of the Kyaunggon Township population (80,000). Sixty nine out of 365 villages of this Township were randomly selected because these rural areas were arsenic contaminated with the inconsistent and scanty of water safety options. Firstly, 69 tube wells from schools including basic education primary school, middle school, high school from 69 villages and a total of 27 tube wells from Kyaunggon township hospital, rural health centers and sub centers from Kyaunggon township were coded with the separate ID number and located by GPS method. The informal communication was conducted to the representatives of the schools and health centers about the depth of these wells, how long they use, and the colour, smell, taste, and turbidity of water.

Sample size determination

Number of wells needed to be tested $n = \frac{z^2_{1-\alpha/2}(pq)}{d^2}$

$z_{(1-\alpha)} = 1.96$
$p = 50\%$
$q = 1-p$
$d = 0.1(10\%)$

$$n = \frac{(1.96)^2 \times 0.5 \times 0.5}{0.1^2}$$

$$= 96$$

A total of 96wells were tested.

2.2. Sampling procedures

The convenient sampling was used in this study. Before collecting the water samples, the permission letter was presented to Township Medical Officer and Township Educational Officer. After pumping of a tube well for 20 times, collection bottles were rinsed with tube well water about three times. Then, water samples were collected and arsenic content was immediately measured by using the field kit with Arsenator [Wagtech Digital Arsenator: digital read-out between 2 and 100µg/L]. The results were provided to these representatives by making the dissemination workshop.

The level of iron and manganese were measured by ICP-OES at Department of Medical Research. The remaining water quality parameters such as Phosphate, sulphate, chloride, fluoride, pH, electricity, turbidity, nitrite, nitrate and ammonium were measured by PhotoFlex.

2.3. Data analysis

Data was checked, cleaned, entered and analyzed by the research team by using Microsoft Excel 2010. The results were shown according to water quality parameters standards of WHO and Myanmar National Drinking water quality [13].

2.4. Ethical considerations

The research team asked permission from the Township General Administration Department, Township Education Department and Township Medical and Public Health Department. The technology of the home-based arsenic removal method was transferred to the local authority and public residing in the high arsenic area not merited to criteria for GSF system. For ethical clearance certificate, the proposal was submitted to the Institutional Review Board, Department of Medical Research, Ministry of Health and Sports with the IRB No. ERC/2019-86. Ethical clearance for the project (IRB No. ERC/2019-86)

IOP Conf. Series: Earth and Environmental Science **496** (2020) 012009 doi:10.1088/1755-1315/496/1/012009

was obtained from the Institutional Review Board, Department of Medical Research, Ministry of Health and Sports on August 2019.

3. Results

A total of 96 tube wells including 69 tube wells from primary schools, middle schools and high schools of 69 villages and 27 tube wells from township hospital, rural health centers and subcenters of Kyaunggon township were coded with separate ID numbers and located using GPS method as shown in Figure 1.

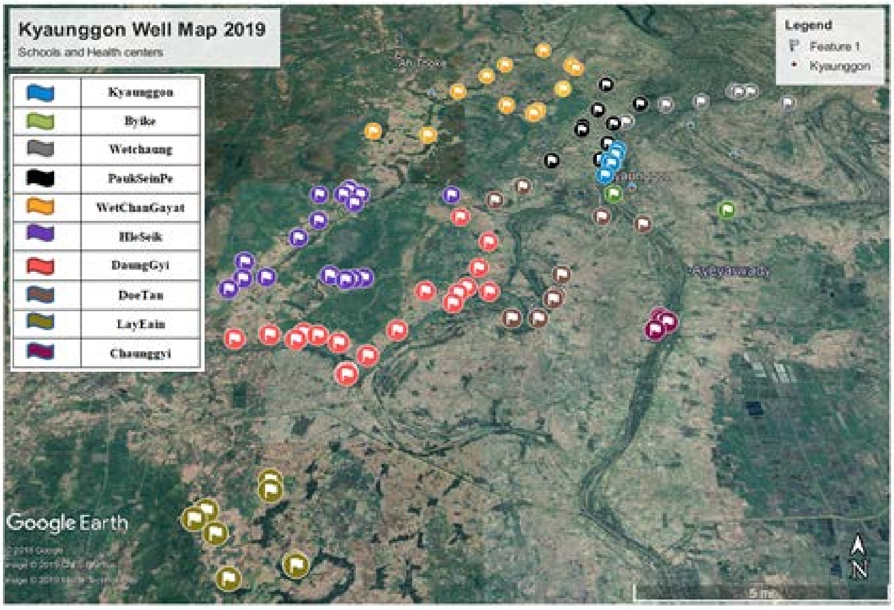

Figure 1. Kyaunggon Tube Well Map.

Among 96 tube wells, 16 tube wells had As concentration of more than 50 µg/L (63 to 384 µg/L). High concentrations of arsenic exceeding National Drinking Water Quality Standard (NDWQS) value were detected in drinking water from 17% of the tube wells. The highest As level was 7 times higher than NDWQS and found no regularity in distribution of arsenic. More than 70% of the tube wells in all villages provide water satisfying NDWQS. Depth of the all tube wells were 30 to 600 feet. High

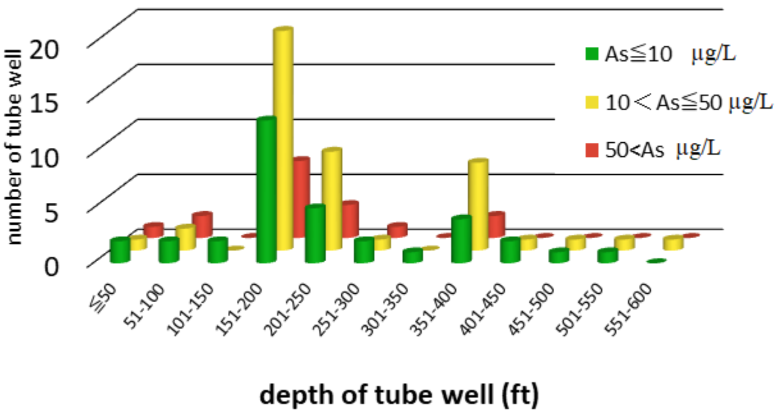

Figure 2. Relationship between arsenic concentration, number of tube wells and depth of tube wells (n=96).

arsenic level was found in tube wells with 150 to 250 feet depth, and 400 feet depth (figure 2). Arsenic concentration more than 50 µg/L was not detected in wells deeper than 400 feet. Concentration of arsenic in each village was shown in Table 1.

Table 1. Concentration of arsenic in each village of Kyaunggon Township.

Villages	Arsenic level (µg/L)		Number of tube well			
	min	Max	total	As≦10	10<As≦50	50<As
Byike	3	21	3	2	1	0
Kyaunggon	13	272	7	0	5	2
Wetchaung	0	93	8	2	5	1
HleSeik	0	188	17	7	7	3
Chaunggyi	0	13	4	1	3	0
WetChanGayat	0	87	12	6	4	2
DoeTan	0	384	9	5	2	2
LayEain	0	92	7	4	2	1
DaungGyi	0	268	20	4	12	4
PaukSeinPe	0	63	9	4	4	1
Total			96	35	45	16

High concentrations of iron, manganese and ammonia exceeding NDWQS values were detected in 67.7% (65/96), 74% (71/96) and 85.4%, (82/96) of the study tube wells respectively. Exceeding NDWQS levels were detected in 4% (4/96) for Phosphate and 2% (2/96) for electricity conductivity and the rest of other parameters were within the NDWQS values in tube well water. See Table 2.

Table 2. Results of water quality parameters (n=96).

Parameter	Range	% of sample over reference range	Reference (NDWQS)
Fe (ppm)	0.025-13.74	**67.7**	0.3
PO_4^{2-} (ppm)	0.2-13.75	**4**	<5
Mn (ppm)	0.018 – 3.678	**74.0**	0.4
NH_4^+ (ppm)	0.07- 73.5	**85.4**	0.5
NO_3^- (ppm)	<1	**-**	50
NO_2^- (ppm)	0.018 – 0.076	-	3
pH	6.0 – 7.4	**-**	6.5 – 8.5
EC (µs/cm)	202 – 1852	**2.0**	1400
Hardness (ppm)	30 – 356	-	500
F^- (ppm)	<0.05 – 1.47	-	1.5

The level of Arsenic and the results of all parameters were immediately informed to township medical officer, health staff, school headmaster, school teachers and local authority of Kyaunggon.

Construction and demonstration of low-cost arsenic removal Gravel Sand Filter (GSF)

In this GSF, Iron content in tube well water (11.3 ppm) was found enough to combine with arsenic. Therefore, co-precipitation of iron with arsenic method was able to use for arsenic removal from tube well water [14]. The model of filter system was built in Kyaunggon together with health staff and school teachers. After filtration, concentrations of arsenic and iron in filtered water were reduced from 173µg/L to 13µg/L (removal efficiency percentage - 92%) and 11.3mg/L to 0.07 mg/L respectively. Arsenic and iron levels were reduced from high concentration to within permissible level of NDWQS.

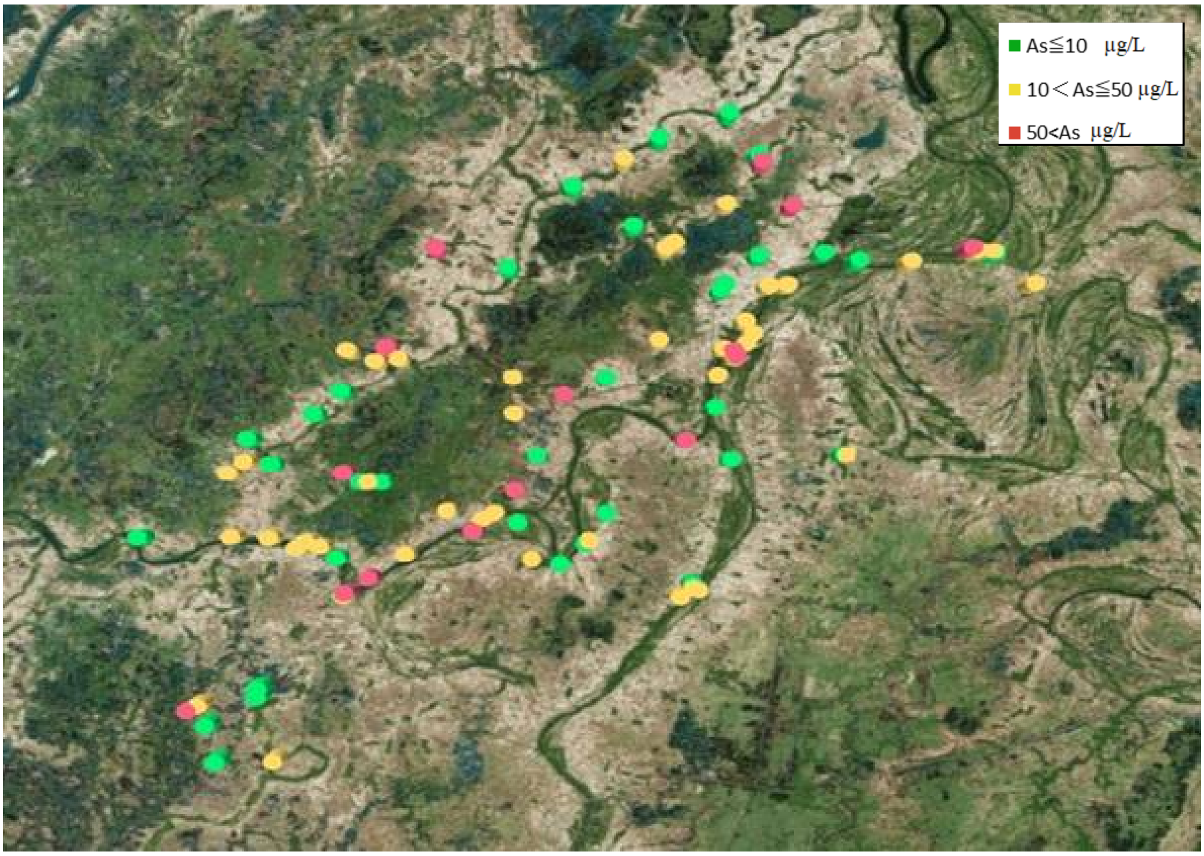

Figure 3. Risk map of study area in Kyaunggon Township.

4. Discussion

This study demonstrated the current situation of arsenic contamination of tube well water in selected areas of Kyaunggon township. According to the results, people should use safe water from near uncontaminated well and GSF water to reduce arsenic exposure of the people who live in this arsenic contaminated area. For making new tube well, the risk map should be used by selecting low risk location or depth of tube well more than 400 feet.

Awareness is one of the important factors in implementing arsenic mitigation process. In 2018study, it was found that as a result of dissemination and awareness, the knowledge about arsenic was increased from (14% to 78%) in Thabaung township [9]. It is suggested that the success of these interventions depends on effective community education and engagement.

For the long-term use of GSF, maintenance should be done by regular monitoring and evaluating of water composition as well as cleaning of GSF.

5. Implication

Since the wells with high arsenic concentration was known in this study area, the research findings should be applied to explore the risk identification of Arsenic contamination by producing risk map (Figure-3), and also to perform risk management by implementing GSF system as a remediation of arsenic contamination process in this rural area. Moreover, this GSF system is cost effective and affordable because it is made of locally available materials and can be constructed by villagers. Widespread use of this removal method in arsenic contaminated areas will partly contribute to safer water supply and for promoting the community health of the area.

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