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CONTAMINATION OF ARSENIC IN DRINKING WATER IN AYEYARWADY DELTA REGION, MYANMAR

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ABSTRACT

In Myanmar an estimated 2.5 million people are at risk of arsenic poisoning from drinking water sources, especially ground water. The highest arsenic contamination is found in the delta region. Baseline investigations of the inhabitants' primary sources of drinking water through face-to-face interviews and the level of arsenic contamination in wells were conducted. This cross-sectional study included 904 households in seven villages in Thabaung Township, Ayeyarwady region, Myanmar. Arsenic content was measured by field kit arsenator. In rainy season (June-September), half of the households reported rain water as one of the primary sources of drinking water. Among 181 tube wells, 123 wells (68%) were contaminated with arsenic >50 µg/L. In total 404 (45%) of the households used contaminated wells as their primary source of drinking water, affecting 1704 (44%) individuals. A large proportion of the households in the Thabaung region are at risk of arsenic poisoning through drinking water from contaminated tube wells.

KEYWORDS: Arsenic, Ground water, Myanmar.

Recent global estimates indicate that 844 million people lack access to basic drinking water and 159 million people still collect drinking water directly from surface water sources that are subjected to contamination.[1] Consumption of unsafe drinking water is a significant health risk due to contamination with infectious agents, toxic chemicals, radiological substances, and metals, including arsenic. Arsenic is an element which dissolves easily in water and does not produce any odour or coloring of the water, thus posing a hidden threat to health in areas where water is not tested.[2] Long-term exposure to arsenic at elevated levels from drinking-water and food can cause cancer, neurological and skin problems.[3] In geological hotspots around the world, arsenic is naturally present at high levels in groundwater and soil due to weathering processes of rocks and minerals. Globally, arsenic in groundwater threatens the health of over 100 million people, especially in South and East Asia where high levels of arsenic in the ground water and high population density coincide.[4-6] Bangladesh and the West Bengal in India are known to be some of the most affected areas, and several studies have shown high levels of arsenic in wells associated with high prevalence of health issues in the population.[7,8] In the Red River Delta of Northern Vietnam and Cambodia high levels of inorganic arsenic concentrations in drinking water have also been reported.[9,10]

To date, there is limited information in Myanmar with regards to prevalence of contaminated drinking water sources in rural areas. However, a few studies indicate that arsenic contamination in drinking water sources is an important public health issue also in this country. As early as the year 2000, the water and sanitation program implemented by 'Save the Children-United Kingdom' revealed high levels of arsenic contamination of groundwater in rural parts of the Ayeyarwady delta region. It is estimated that 2.5 million of Myanmar's 51 million population are potentially at risk of arsenic poisoning from drinking water sources.[11] The highest arsenic contamination is found in river valleys and delta regions.[12] A few studies in selected areas have found levels of arsenic in groundwater above the WHO

permissible limit of 10ug/L in several locations in the Ayeyarwady delta region.[13-15]

These findings have led to basic public awareness and water treatment initiatives in some parts of the region.[16] However, in order to reduce wide-spread exposure to arsenic through ground water and provide safe and reliable water supply, installation of water treatment plants are necessary. A number of arsenic removal technologies are available to ensure safe drinking water for villages: 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. At present, previous work in Bangladesh has demonstrated the challenges in providing low-cost safe water interventions for those at risk.[7]

Before an introduction of a culturally acceptable, feasible and cost-effective arsenic mitigation program, we aimed to collect baseline information about different sources of drinking water, seasonal variations and arsenic awareness in the region, as well as scope feasibility of different water treatment interventions. Therefore, this study aimed to a) investigate the primary sources of drinking water in rural households in arsenic contaminated area of the Ayeyarwady delta region and b) measure the prevalence of arsenic contaminated wells and the level of arsenic contamination.

METHODS

Study design

This is a cross-sectional baseline study conducted in 2016 to inform regional implementation of a water safety intervention program.

Study area and study population

The study area covered Thabaung Township in Ayeyarwady region, Myanmar targeting rural households in arsenic contaminated areas (Figure 1 and 2). Seven out of 398 villages of Thabaung Township were selected based upon their hard-to-reach in nature. A total of 904 households in these villages were identified in these villages. All households in the selected villages agreed to participate and one eligible respondent of age 15-84 years (either head of the household or the assigned member) was selected by the household as a household representative.

Data collection method

In January 2016, nineteen trained interviewers administered structured interviews by using pre-tested and modified questionnaires. It consisted of 3 components: household information, household members' demographics and information about drinking water sources. The interviews were conducted in Myanmar language and each interview lasted for 7 to 10 minutes. Each household was assigned a unique ID number.

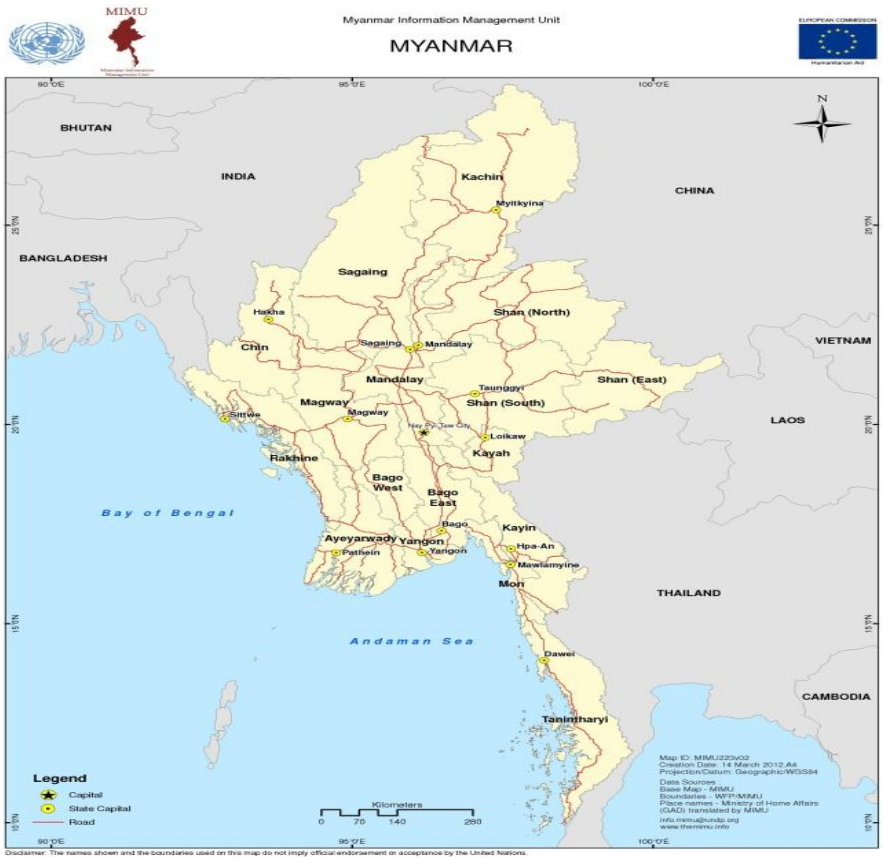

Figure (1): Map of Myanmar.[17]

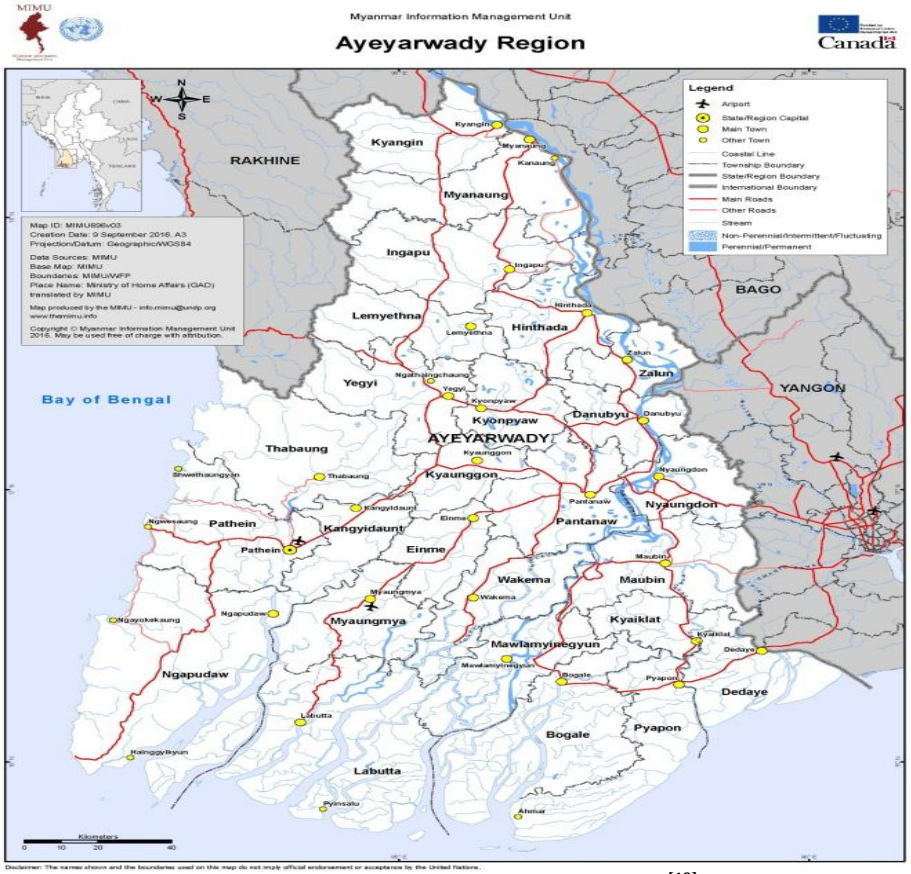

Figure (2): Map of Ayeyarwady Region.[18]

Water sampling method

In 2016 January, all tube wells from the seven villages of Thabaung Township were listed, coded with geo-location and assigned a unique ID number. Before collecting the water samples, all tube well owners provided their informed consent. Each tube well was first pumped 20 times with the handle. The collection bottles were rinsed with tube well water about three times, before the samples were collected in the bottle. Arsenic content was analyzed immediately using a Digital Arsenic Test Kit capable of analyzing arsenic levels between 2 and 100µg/L (Wagtech Palintest, Model WAG-WE1050 Arsenator System). The results were provided to the villagers directly after measurement.

Data management and statistical analysis

Data entry, data validation, range and consistency checks were done using EPI DATA version 3.2.[19] Data were analyzed using SPSS 16 for Windows.[20] For the data collected from the household survey, we calculated means with standard deviations for age, duration of stay in the village, number of household members, and proportions for sex, education level and type of drinking water source.

Ethical considerations

The research team sought permission from the regional, township and village authorities. Informed consent was taken from all participants. Privacy, confidentiality and anonymity issues were strictly observed during the household interviews. Ethical clearance certificate was granted by the Ethics Review Committee, Department of Medical Research, Ministry of Health and Sports, Myanmar. (Ethical Document No. Ethic/DMR/2015/123E/2017)

RESULTS

Study population characteristics

Table 1 presents the village characteristics. A total number of 904 households had a total of 3,846 household members. Htanzinhla village was the largest village with 257 households and the smallest was Shankwin village with 42 households. In total, there were 181 wells used by these households.

In this study, 67% of the total populations were 15-64 years old. 17% of the populations were under 15 years old and only 6% of the population was above 65 years old. The male to female ratio was 1:1.1. Regarding the education level of the household members interviewed, 43% of the population had finished primary school level (10 years). 15% were illiterate or had basic literacy. When exploring the occupation of heads of the household, 31% were farmers and 39% were manual laborers. Over 90% of the villagers were native to the region and 90% did not report any sickness during the study period.

Table 1: Characteristics of study villages, Thabaung Township, 2016.

Study villages	Characteristics of study villages		
	Number of households	Household members	Number of wells
Htanzinhla	257	1,063	41
Yaylegyi	188	743	41
Thayattaw	143	571	27
Latechaung	98	511	25
Dale-et	91	367	12
Konetangyi	85	394	18
Shankwin	42	197	17
Total	904	3,846	181

Drinking water

There were seasonal variations in primary source of drinking water. During hot and cool seasons, ground water was the primary source of drinking water more often than during the rainy season. In the rainy season, six out of ten used ground water compared to eight out of ten in the hot and cool seasons (table 2). Half of the villagers used conserved rainwater as one of their primary sources of drinking water in rainy season, although a majority still also used ground water, reportedly out of convenience and easy accessibility. One in four households used surface water (rivers and ponds) as primary source of drinking water during hot and cold season, while only one in six used surface water during rainy season.

Table 2: Seasonal variations by primary source of drinking water in study households in seven villages, Thabaung Township, 2016.

	Primary sources* of drinking water reported by study households (N=904)					
	Ground water			Surface water		Rain water
Well / Season	Private wells	Public wells	Brick-lined wells	River	Pond	Rain water conservation
Hot season (Feb-May)	444 (49%)	128 (14%)	147 (16%)	102 (11%)	132 (15%)	5 (1%)
Rainy season (Jun-Sep)	375 (41%)	76 (8%)	76 (8%)	52 (6%)	89 (10%)	492 (54%)
Cool season (Oct-Jan)	444 (49%)	135 (15%)	141 (16%)	97 (11%)	142 (16%)	5 (1%)
Any season	506 (56%)	144 (16%)	160 (18%)	117 (13%)	149 (16%)	492 (54%)

*Two primary sources possible, row percentages do not add up to 100%

Arsenic levels in ground water

Two thirds of the wells were contaminated by arsenic levels above 50µg/L. The highest proportion of contaminated wells (89%) was found in Konetangyi village and the lowest was reported from Dale-et village (42%). There was no association between tube well depth and arsenic level, except that the shallowest wells <20m all had very low arsenic levels (figure 3).

Table 3: Prevalence and use of arsenic contaminated tube wells in seven villages, Thabaung Township, 2016.

Villages	Tube Wells (N)	Tube wells with As>50µg/L N (%)	Use of contaminated wells (As >50µg/L) as primary source of drinking water (any season)	
			Households (%)	Individuals (%)
Htanzinhla	41	32 (78%)	174 (68%)	736 (69%)
Yaylegyi	41	18 (44%)	70 (37%)	280 (38%)
Thayattaw	27	21 (78%)	74 (52%)	307 (54%)
Latechaung	25	19 (76%)	9 (9%)	39 (8%)
Dale-et	12	5 (42%)	43 (47%)	167 (46%)
Konetangyi	18	16 (89%)	8 (9%)	42 (11%)
Shankwin	17	12 (71%)	26 (62%)	133 (68%)
Total	181	123 (68%)	404 (45%)	1704 (44%)

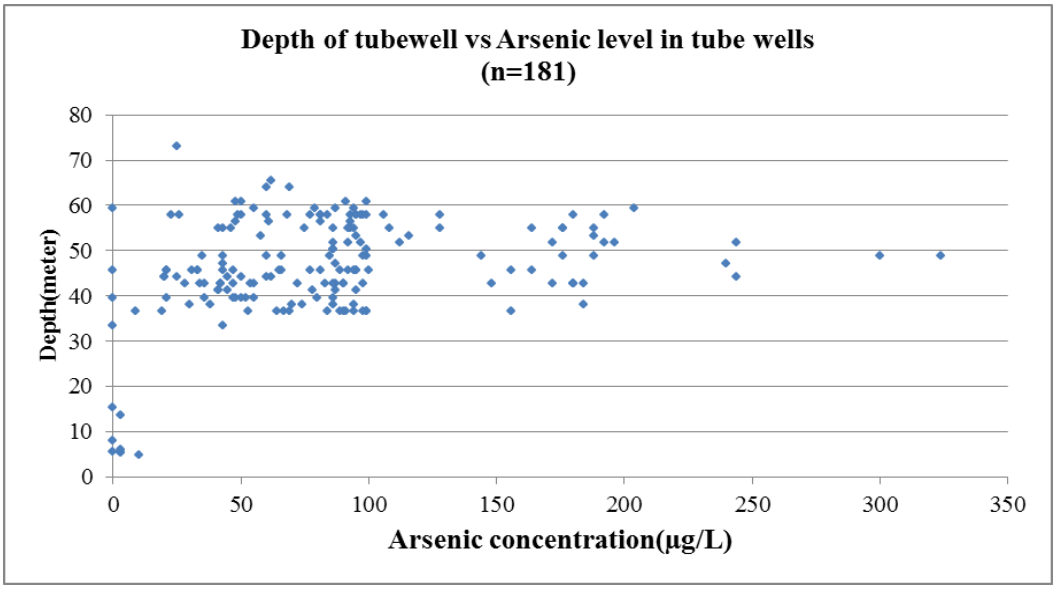

Figure 3: Depth of tubewell vs. Arsenic level in tube wells.

DISCUSSION

Main results

In this study of tube wells in the Ayeyarwady region, Myanmar we found that seven out of ten wells (68%) were contaminated with arsenic levels exceeding 50µg/L. In some villages as many as nine out of ten wells in use, were contaminated. In total 45% of the households (44% of the individuals) used a contaminated well as one of their primary sources of drinking water. Arsenic level was not associated to well depth, except for very shallow wells (<20m depth) where arsenic levels were very low.

Although half the population in this area drank rainwater during the rainy season, tube wells was the most commonly used source of drinking water irrespective of season. The study found that nearly 90% of households used public wells in summer and 53% of households used public wells in the rainy season. In this study, most of the respondents were farmers with seasonal odd jobs and they had difficulties to keep enough containers for drinking water storage in the hot season which may be one of the reasons of high use of public wells in summer.

LIMITATIONS

We studied all the wells in the selected township. We had a 100% participation rate among households and thus the numbers in this study are a correct representation of the actual conditions in these townships. We also used a validated method to assess arsenic levels in water from the wells. We used a standardized protocol for testing and equipment with high accuracy.

As we do not know the actual water consumption of the households and individuals from each source, this study can only give an indication of likely exposure based on reported water source use and water source contamination. Furthermore, as we only interviewed one member from each household the results for arsenic awareness may not be representative for the whole household.

Interpretation

Thabaung is located in Ayeyarwady delta region in which the groundwater arsenic level is known to be high. This study builds on a previous study by Tun *et al* in 2003 in Thabaung Township, which found that 37% of tube wells were contaminated with arsenic levels in excess of 50µg/L.[15] With comparable sampling strategies in both studies, we found almost double the proportion of wells that had high arsenic levels. Although this could imply that arsenic levels are getting worse over time, and urgent action needs to be taken, it also highlights the difficulties in estimating the size of the population at risk. As with our study, previous studies in the region have demonstrated wide variability in arsenic levels between wells.[13,15] even within the same geographical area. This provides a challenge in determining true prevalence in arsenic exposure risk in the population, as well as determining which non-sampled areas are most at risk, and more work needs to be done in establishing the factors that cause high arsenic levels in this region.

Our study highlighted the variability of drinking sources depending on season. This presents its own challenges when establishing safe water supplies in remote areas. In Myanmar, the hot season (summer) is usually linked to water shortages,[7] as ponds and rainwater are scarce. People in Myanmar usually use rainwater for drinking in the rainy season. When considering methods for arsenic free safe water such as rainwater harvesting, household arsenic removal filters and rural piped water supply, these variations must be taken into account.

Our study demonstrated that very shallow wells show lower levels of arsenic than deeper wells, which was also

found in the 2014 study by van Geen *et al*.[13] From this we conclude three possible ways of reducing arsenic exposure through drinking water; a) switching to non-contaminated wells in the same area, b) exploring options for shallower wells and c) installing water treatment plans based on local seasonal drinking water practices. This has to go in conjunction with awareness programs, with more information than just reporting back results to well-users. The latter has shown not to work in previous studies, as only a minority can correctly recall the status of their well despite testing.[13] By understanding the demographics and literacy levels of the local populations, our study provides a basis for developing effective arsenic awareness programs. Further work we conducted in this region looking at the health impact of potential arsenic exposure and impact of arsenic awareness programs in schools will be described in subsequent papers.

Generalization

This study was carried out in an area purposely selected because of previously known high levels of arsenic in ground water. Although levels were extremely high in some villages in the township, these levels are not uncommon in the Ayeyarwady area. However, even within this region there is high variability in arsenic levels, which limits generalization for the Ayeyarwady region as a whole or similar area bordering the Bay of Bengal. Water treatment programs should include methods to identify high-arsenic areas as well as increasing awareness and water safety.

Information collected from the household surveys is specific to the villages studied but are likely to be representative of many similarly remote villages in the region.

Implications

The safety and accessibility of drinking water are major concerns throughout the world, and arsenic contamination of drinking water sources is a public health issue in Myanmar. As demonstrated in this study, arsenic awareness and treatment programs are challenging due to low literacy levels and high seasonal variation in water sources. Myanmar's National Water Resources Committee (NWRC) has developed a National Water Policy since 2014 with a clear vision on sustainable water management.[21] This study adds useful information that can help guide steps towards this vision.

Conclusions

In the studied townships most of the households were at risk of arsenic poisoning through drinking water from contaminated tube wells. In the context of low socioeconomic status, community arsenic filtration system, advice and awareness programs might promote health of the people residing in that area.

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Authors contribution statement

All the authors reviewed the different versions of the manuscript and approved this final version.

Financial statement

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Competing interests

The authors declare no conflicts of interest.

Ethics approval

This study was conducted with the approval by the Ethics Review Committee, Department of Medical Research, Myanmar (Ethical Document No. Ethic/DMR/2015/123E/2017).

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