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A Survey of Arsenic Level in Tube-Wells in Bam Province (Burkina Faso)

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Abstract

Groundwater is a main source of water supply for populations in Burkina Faso where there is a serious problem for drinking water access. However, water quality has not been always followed regularly. Recent studies showed that more than 50% of drillings in Yatenga province (north of Burkina Faso) have an arsenic concentration above the recommended WHO requirement. Preliminaries studies conducted in Bam (Center North of Burkina Faso) showed high arsenic level in certain localities. This work presents for the first time data on a large scale evaluation that had been performed in all the localities of Bam province in other to have a better assessment of contamination scale. A total of 707 drilling water samples have been selected randomly in 9 communes and analysed for the arsenic level using atomic absorption spectrometry with hydride generation. The results showed that 11% of drillings have an arsenic concentration above the recommended WHO requirements with Rouko commune having the highest rate of high arsenic level (22%).

Keywords

Arsenic, Groundwater, Contamination, Bam Province

1. Introduction

Surface water and shallow dug wells are widely used as sources of drinking water. But due to microorganism's contamination, groundwater is the preferred alternative [1] [2]. Consequently, borehole-drilling programs have been undertaken by various agencies including non-governmental organizations (NGOs) and state agencies in recent decades. Most villages have now boreholes (tube-wells) with hand pumps in majority. In the northern part of the country, the problem of water contamination by arsenic has been recently pointed out [3]. There are nu-

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merous toxic symptoms attributed to chronic arsenic exposure [4]-[6] such as specific dermatological effects [6]. A comprehensive review of arsenic toxicology has been published by Hughes *et al*. [7].

Arsenic contamination originates mainly from natural sources and mining activities tend to widespread it [8]. In Burkina Faso, studies have shown that the northern part of the country presents a geological profile of Au mineralisation zones in Birimian (lower proterozoic) volcano-sedimentary rocks along with arsenopyrite from which the contamination seems to originate [9]. We have recently introduced a study on the arsenic exposure in Yatenga province in North of Burkina Faso [3] due to tube-wells contamination by arsenic. Toxicological effects we noticed, such as gastrointestinal problems and skin diseases, in local population were in agreement with literature data on arsenic heath problem [2].

Bam province is located in south of Yatenga province and presents the same geological characteristics as in the northern part. Preliminary analyses of water quality have shown the presence of arsenic in tube-wells. This large scale study was undertaken in order to have an overview of the water quality in the province in terms of arsenic contamination.

2. Methodology

2.1. Sampling

The study was conducted in the province of Bam located in the central northern part of Burkina Faso. The province of Bam has 9 administrative communes (Bourzanga, Guibaré, Kongoussi, Nasséré, Rollo, Rouko, Sabcé, Tikaré and Zimtenga). It has an area of 4084 km^2 and includes 241 villages with a population of about 300,000. It is a gold mining area. All functional drillings in the communes of Guibaré and Sabcé (200) were subjected to a systematic sampling because previous analyses have shown high arsenic concentration. The choice of drillings to be sampled in other communes was done considering a stratified random sampling method taking into account the nature of the ground (risk area or undefined risk area). Two levels of stratification were retained. The first level consisted of drillings in the risky area based on previous finding and the second level represented all drillings in other parts of the province.

2.2. Water Collection

All the samples were taken in 33 mL polyethylene bottles previously treated with nitric acid (10% v/v) and rinsed with Milli-Q water. Water was pumped from wells for 10 to 15 min before sample collection, in order to flush out all retained water in the pipes. For the conservation, each sample was acidified with 6.6 mL hydrochloric acid (37%).

2.3. Sample Treatment and Analysis

The samples from Sabcé and Guibaré were analysed for arsenic but also for temperature, conductivity, pH, and turbidity. The samples from the other communes were only analysed for their arsenic content.

2.3.1. Determination of the pH

It was measured at sampling using a portable pH-meter (Hanna Instruments). The precision of the determination was ±0.02 unit of pH.

2.3.2. Determination of the Temperature and Conductivity

Conductivity is dependent on the ion concentrations, the nature of the ions, the temperature of the solution, the viscosity of the solution. The measurement of conductivity was realized on site using a multiparameter portable conductimeter (Hanna Instruments). The results were expressed in µsiemens per centimeter (µS/cm).

2.3.3. Determination of Turbidity

Turbidity was measured on the site using an optical turbidimeter and expressed in Nephelometric Turbidity Unit (NTU). The normal values should be less than 5.0 NTU.

2.3.4. Determination of Total Arsenic by Atomic Absorption Spectrometry (AAS)

All the samples were digested with a mixture of hydrogen chloride and nitric acid (3:1) in a microwave digester

(MARS XPRESS CEM, UK). Arsenic content in water was then determined by atomic absorption spectrophotometry using a hydride generation method (Varian AAS 240 FS USA). Milli-Q water acidified with hydrogen chloride was used as control. A commercial standard solution of arsenic was used for linearity (As III 1000 ppm Atomic Spectroscopy Standard Solution Fluka, Switzerland). The method used for the determination of total arsenic was based on the direct measurement of the specific absorbance generated by the thermal decomposition hydride arsenic. The reduction of arsenic (V) to arsenic (III) was done with potassium iodide (KI) and acid ascorbic solution and the generation of arsenic hydride (III), AsH_3 was done by reaction with sodium tetra hydroborate in hydrochloric acid medium.

3. Results and Discussions

3.1. Analytical Method

The selected analytical parameters are presented in **Table 1**. The determination of the concentration of each element was realised from the calibration curve using the specific absorbance of arsenic. The results are expressed in microgram per liter (µg/L) or ppb.

3.2. pH, Turbidity and Bacteria Contamination

The results of the field measurement of pH, turbidity and bacteria contamination in up to 200 drillings in Guibaré and Sabcé are presented in **Table 2**.

The control of the water pH is useful for the estimation of corrosion risk and scaling. In general, the corrosion of a metal becomes important at pH values lower than approximately 6.5 and incrustation of matters and scaling are especially important a pH values above 8.5. Thus the acceptable pH scale in drilling water is between 6.5 and 8.5. The water turbidity is due to the presence of the finely divided suspended matter (clay, silt, organic matters…). Turbidity does not represent a direct health risk but a high value can contribute to the decrease of the disinfection effectiveness and generate microbiological risks. The percentage of abnormal turbidity (8.0%) can

Table 1. Method development parameters in HGAAS.

Spectrophotometer parameters (Varian AAS 240 FS, USA)	
Wavelength	193.7
Exit slit	0.7 nm
Ultra-lamp intensity	10 mA
Signal measurement mode	pic high
Linearity	2.5 - 15.0 ppb (r^2 = 0.99)
Precision (n = 3)	5.6%
LOQ	2.5 ppb
LOD	0.5 ppb
$NaBH_4$ concentration	0.6 % (m/v) stabilised with NaOH (0.5%)
$NaBH_4$ flow rate	4 - 6 mL/min
HCl concentration	5 M
HCl flow rate	9 - 11 mL/min
Argon flow rate	40 - 60 mL/min

Table 2. Results of water pH, turbidity and bacteria concentration in 200 drillings in Guibaré and Sabcé.

	Sample size	% of water out of pH scale	% of water out of turbidity scale	% of bacteria contaminated waters
Guibaré	111	4.5%	7.2%	10.8%
Sabcé	89	5.6%	8.9%	5.6%
Guibaré and Sabcé	200	5.0%	8.0%	8.5%

be related to the bacteriological contamination (8.5%). The presence of organic particles contributes to the turbidity and may favour bacteria growth. Underground waters are normally protected from any risk of pollution and do not contain coliform bacteria.

3.3. Arsenic Concentration

The arsenic concentration was measured in 707 drillings all over the province of Bam. The data on **Table 3** show the presence of arsenic at different concentrations in drinking water from the drillings.

The proportion of drillings with high arsenic concentration compared to the WHO [10] standard value varied from 7.4% in Zimtenga till 22.6% in Rouko. Only the commune of Bourzanga in the all province had wells in compliance with acceptable arsenic concentrations. We found in previous study [3] that up to 50% of water from drillings in Yatenga province (next to Bam) was also contaminated. Population are exposed to arsenic contamination through the consumption of this underground water in some extent. The situation is similar to West Bengal in India where more than 50 % of groundwater from drilling had an arsenic concentration higher than the WHO standard of 10 ppb and 25% had arsenic concentration above 50 ppb [11]. Water from tubular wells can also be contaminated in the same area [11]. Cutaneous lesions were observed in all arsenic contaminations areas even if the arsenic concentration respects WHO requirements [3] [11]. Like in the province of Yatenga, the water contamination seemed to be of natural original since no human activity was found [12]. The presence of arsenic in water was therefore attributed to the volcano-birrimian nature of the soil in this area. This soil contains high arsenic level reflecting the oxidation/weathering of arsenopyrite [3]. Communes of Rouko and Sabcé have the highest frequency of contaminated drills (above 100 ppb). Indeed, most of the drills with arsenic concentration above 100 ppb were located in these two communes. The village of Bissa in the commune of Sabcé was the first village where the population displayed cutaneous signs prompting the search of the causes that led to the discovery of arsenic contamination. This village must dawned special attention, because more than 50% of the population had cutaneous signs due to the unique drill in the village which was tested for 380 ppb and 430 ppb of arsenic during two control campaigns.

4. Conclusion

High arsenic concentration in groundwater in the province of BAM in the northern part of Burkina Faso was reported in this large scale study. The results showed that 11.3% of water from the drillings had arsenic concentration above the recommended WHO requirement. The arsenic contamination level in some localities in this study prompted local authorities to close water accessibility which generated a dramatic situation. This study

Table 3. Results of arsenic concentration measurements of drillings in Bam province.

Commune	Sample size	Minimum (µg/L)	Maximum (µg/L)	% of contamination above 10 µg/L	Arsenic concentration (µg/L)				
					<0.5	0.5 - 10	10 - 50	50 - 100	≥100
Guibaré	111	<0.5*	34.3	10.8%	52	47	12	00	00
Sabcé	89	<0.5	631	16.8%	32	42	9	01	05
Kongoussi	151	<0.5	368	11.2%	80	54	13	02	02
Bourzanga	77	<0.5	0.64	0.0%	76	01	00	00	00
Nasséré	38	<0.5	24.2	10.5%	24	10	04	00	00
Rollo	45	<0.5	48.5	8.3%	35	06	04	00	00
Rouko	53	<0.5	228	22.6%	20	21	07	01	04
Tikaré	76	<0.5	25.7	14.4%	35	30	11	00	00
Zimtenga	67	<0.5	46.7	7.4%	32	30	05	00	00
Bam Province	707	<0.5	631	11.3%	386	241	65	04	11

*Not detectable (instrument detection limit: 0.5 µg/L); WHO standard is 10 µg/L (10 ppb).

showed for the first time that populations of the Bam province in Burkina Faso are highly exposed to arsenic contamination through groundwater and actions must be taken to alleviate the consequences. These results combined with our previous findings make the arsenic contamination of water an incoming serious health problem in the northern part of the country.

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