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Arsenic in Drinking Water Resources in Six Cities Located in the Western Coastal Strip of Libya

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ABSTRACT

Water used for drinking and food preparation is the most dangerous source of long-term human exposure to arsenic. The study aimed to identify arsenic level in samples of domestic groundwater, public water supply, bottled water, and water from purification shops in five locations along the coastal strip of Libya. The efficiency of removing arsenic in water by reverse osmosis (RO) unit in two water bottling plants was also investigated. Arsenic was analyzed using inductively coupled plasma optical emission spectrometry (ICP-OES). Results show that arsenic in domestic groundwater, public water supply systems, bottled water, and water from purifying shops range respectively: 6.06-70.48, 2.66-22.76, 1.20-11.20, 2.022-9.55 ug/L. The results revealed that 83% of groundwater samples and 5% of bottled water samples exceeded 10ug/l the maximum permissible level in drinking water by Libyan standards. Meanwhile, water samples from purifying shops are below 10ug/l. Public water supply samples from two sites contained arsenic > 10ug/l. The RO unit is able to reduce arsenic in water by 75%, which means that arsenic in unpurified water should not exceed 35 ug/l. The study highly recommends that households who rely on domestic groundwater should install household RO units to be saved from the health risk of chronic arsenic exposure.

Keywords: Arsenic, Bottled water, Groundwater, Libya, Public supply system

INTRODUCTION

Arsenic is one of the known toxic elements and is classified under the group of elements known as a metalloid. The inorganic form of arsenic is more toxic than the organic form. The International Agency for Research on Cancer listed arsenic and its compounds as carcinogenic to humans under the first group, which means the existence of proof and validation of its carcinogenic action on humans (IARC,1987). Arsenic is naturally existing in the earth, s crust, soil, and natural

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rocks. Meanwhile, Arsenic and its chemical compounds have many uses in the agricultural and industrial fields, besides being a by-product of copper smelting, mining, and coal combustion. Drinking water is the main source of human exposure to arsenic, as long-term exposure to low concentrations of arsenic poses a threat to human health.

Saint- Jacques *et al*. (2014), reviewed the results of epidemiological studies on the association of arsenic exposure from drinking water and bladder and urinary tract cancer. He concluded that the existence of arsenic in drinking water is linked to an increased risk of bladder and kidney cancer. Wasserman *et al*. (2007), showed that chronic exposure to > 50 ug / l of arsenic in drinking water is linked with increased risks of lung, bladder, skin, blood vessels, and respiratory diseases and increased mortality. Also, an adverse association was reported between drinking water arsenic and cognitive function in 10-year-old children living in Bangladesh (Wasserman *et al*., 2004).

Arsenic enters the water supply either from the accumulation of natural sediments in the ground and consequently naturally reaches groundwater and/ or from industrial and agricultural pollution, especially the use of pesticides in agricultural practices. Water used for drinking and food preparations is deemed the most dangerous cause of human long-term exposure to arsenic in many regions of the world, such as Asia and South America, which suffer from the presence of a high concentration of arsenic in drinking water. An estimated 200 million people worldwide are exposed to arsenic concentrations in drinking water that exceed the recommended limit of 10ug/l as set out in the guidelines of the World Health Organization (WHO). The majority of this exposed population lives in Southern Asian countries such as Bangladesh, Cambodia, India, Nepal, and Vietnam (WHO, 2012). In addition, elevated levels of arsenic have been found in several countries in Latin America, such as Argentina, Bolivia, Chile, and Mexico. Recent estimates suggest that at least 4.5 million people in Latin America are exposed to arsenic levels higher than 50 ug/l – the Bangladesh threshold (McClintock *et al*.,2012). George *et al*. (2014) reported a high level of arsenic in 86% of water samples collected from 151 water sources in 12 regions in Peru, where the concentration was > 10 ug /l and the range was 0.1 – 93.1 ug /l. They showed those results pose a threat to public health. Kodes *et al*. (2013) pointed out that groundwater supplies in 13 European countries are in noncompliance with European Union drinking water standards 10 ug As/l, where substantial arsenic groundwater arsenic hazardous has been identified.

Based on what was revealed by earlier studies about the health hazards from exposure to arsenic in drinking water, and the lack of studies on the level of arsenic in drinking water sources in Libya, this study aimed to identify the level of arsenic in drinking water sources used in some cities on the western coastal strip of Libya extending from Misrata in the east to Zwara in the West, where the study included municipal water supply system based on different water sources as well as household groundwater wells, bottled water, and water from purification shops. The study also investigated the efficiency of the reverse osmosis unit used in two bottled water plants in reducing the arsenic level in the water.

Material and methods

Study region

The study targeted 6 cities (Misrata, Zletin, Khoms, Tripoli, Sabratha, and Zwara) located in the coastal area of Libya. These Cities were selected because they are heavily populated areas, their diversity of drinking water resources, and diversity of agricultural and industrial activities.

Samples collection

Drinking water samples were collected from each study area. The collected water samples represented 4 sources including, household wells, public water system supply, bottled water plants, and water samples from shops that purify water for sale. Table 1 shows the sampling plan and the parameters of each sampling.

Table 1: Numbers of water samples withdrawn from each source in the study area

Source / Location	Groundwater	Public water supply system	Bottled water	Water purifying shops	Total
Zawara	8	8	4	-	20
Sabratha	8	-	8	8	24
Tripoli	8	8	8	8	32
Khoms	8	8	8	8	32
Zletin	8	8	4	8	28
Misrata	8	8	8	8	32
Total	48	40	40	40	168

Two water samples were withdrawn from each source. Water sampling was repeated 4 times for each source at an interval of one hour between the sampling. A total of 168 samples were collected. The samples were collected in Food grade PE bottles that were previously rinsed with 10% nitric acid solution and dried. Two extra water samples were taken from two bottled water plants in Khoms City (before and after purification) to investigate the efficiency of the reverse osmosis (RO) technique used in those two plants to reduce arsenic concentration from the unpurified water

Arsenic determination

All glassware used in the analysis was previously washed with deionized water and immersed overnight in a 10% nitric acid solution. Then washed with deionized water and dried in the oven at 100 ^{0}C. The water samples were analyzed using inductively coupled plasma optical emission spectrometry (ICP-OES) according to the method described by Martin (2003). In brief, 1.5 ml of 70% nitric acid analytical grade was added to 1 liter of water sample to reduce the pH to 2. Then 100 ml of the acidified water sample was transferred to a 200 ml beaker, and 3 ml of 70% analytical grade nitric acid was added. The mixture was heated at 80 ^{0}C to digest the sample. The digestion process continued until the volume was reduced to about 10 ml. The heated samples were left to cool before filtration into 100 volumetric flasks. The beaker was rinsed with deionized water many times to ensure the complete transfer of the sample to the volumetric flask. Later the volume was completed to the mark (100 ml) using deionized water. A blank was subjected to the same sample digestion procedure. Then the blank and the digested samples were read using ICP-OES (Ultima 2 C series) following the steps described in the operation manual of the instrument.

Accuracy of the method

The accuracy of the method used was checked by determining the recovery of known amounts of arsenic added to water samples as shown in Table 2 followed by digestion and determination as described previously. The percent (%) recovery was calculated according to the formula:

$$\% \text{ recovery} = Cs/(C0 + Ca)\ X100$$

Where: CS = the actual arsenic recovered in the water sample

C_0 = The original arsenic in water before the addition of arsenic

C_a = amount of arsenic added to the water sample

Table 2: Results of % recovery of arsenic (ug/l) in water samples from different sources used in the study

Water sources	Arsenic conc. before addition	Arsenic conc. added	Expected total arsenic conc. After addition	Actual arsenic conc. found	% recovery of arsenic	% Recovery ± stdv
Groundwater	11.46	10.0	21.46	20.88	97.29	97.76±0.35
	11.46	25.0	36.46	35.78	98.13	
	11.46	50.0	61.46	60.14	97.85	
	11.46	75.0	86.46	84.54	97.77	
Public water supply system	6.59	10.0	16.59	15.42	92.94	95.81±2.00
	6.59	25.0	31.59	30.47	96.45	
	6.59	50.0	56.59	55.30	97.72	
	6.59	75.0	81.59	78.45	96.15	
Bottled water	4.23	10.0	14.23	14.16	99.51	98.14±1.40
	4.23	25.0	29.23	28.25	96.64	
	4.23	50.0	54.23	52.76	99.13	
	4.23	75.0	79.23	78.20	97.28	

The obtained results of arsenic in water samples were subjected to descriptive statistical analysis including mean, standard deviation, minimum and maximum values, Correlation coefficient, and one-way ANOVA using statistical package for social science (SPSS) version 17.

Results and Discussion

% recovery of arsenic.

The average percent recovery of arsenic in water samples from the four sources by the method used ranged between 95.34 ± 2.81 to 98.14 ± 1.40 with an overall mean average of 96.76 ± 2.10 (table 2). These results comply with the recommendation of Martin (2003) that the % recovery of arsenic by this method should be between 85 – 120%.

Arsenic in water from household wells.

Table (3) shows the results of arsenic concentration in water samples collected from household wells in the study area. The results revealed that arsenic concentration (ug/l) of the groundwater samples collected from Zwara, Sabratha, Tripoli, Khoms, Zliten, and Misrata ranged between 9.41-75.60, 10.35-12.11, 10.56-15.52, 13.19-36.80, 19.85-24.38, 6.06-20.48 respectively meanwhile the average concentration of arsenic of those samples for that areas was respectively 41.74 ± 34.47, 11.13 ± 0.68, 12.87 ± 1.97, 22.34 ± 10.34, 22.35 ± 1.46, 20.45 ± 1.40.

Table 3: Arsenic level (ug/l) in groundwater samples of the studied locations

Location	Well depth	Min. value	Max.value	Mean± Std.	Grand mean
Zawara:					
Zawara center	20	70.48	75.60	73.96 ± 2.40	41.74^{a}±34.47
Near beach	10	9.41	9.66	± 0.11 9.54	
Sabratha:					
Sabratha city	23	11.40	12.11	11.74 ± 0.29	11.13^{c}±0.68
Aldebashia	46	10.35	10.69	10.52 ± 0.16	
Tripoli:					
Salaheddin	60	10.56	11.46	11.0± 0.38	12.87^{c}±1.97
Alhudba	56	13.25	15.52	14.65 ± 0.69	

Khoms: Suk alkames Seleen	 20 175	 27.02 13.19	 36.80 13.25	 31.48±5.18 13.21±0.020	 22.34^{b}±10.34
Zletin: Azdwa north Alquaellat	 36 52	 22.90 19.85	 24.38 22.35	 23.50±0.65 21.22±1.0	 22.35^{b}±1.46
Misrata: Aldafnia Zawet almahjob	 30 52	 12.58 6.06	 20.48 13.19	 17.20±3.50 8.44±3.23	 20.45^{b}±1.40

Means with the same letter superscript are not significantly different at P <0.0

The results also showed that water samples from Zwara contained the highest concentration of arsenic. Statistical analysis of the results (Table 3) revealed significant differences (P >0.05) between arsenic concentration in Zwara groundwater samples and arsenic concentration in groundwater samples of the other study area. While non-significant differences (P < 0.05) were reported for arsenic in water samples among Khoms, Zliten, and Misrata. The arsenic content in water samples of Sabratha and Tripoli is not significantly different (P < 0.05). No strong statistical correlation was found (r = 0.27) between arsenic in water and the depth of wells. Even though the average range of arsenic concentration in groundwater samples of this study is within the range of arsenic concentration of groundwater samples reported in other studies in the USA 10-100 ug/l ((Lewis, 1999), Pakistan 10-100 ug/l (Baig *et al*., 2009), and China 10-2000 ug/l (Brown &Ross, 2002). However, 83% of the groundwater samples investigated in this study have arsenic contents exceeding the maximum limit of 10 ug/l adopted in the Libyan standard 82: 2015 for drinking water. This finding agrees with the results reported by George *et al*., (2014) where 86% of water samples out of 151 water sources in Peru were found to contain arsenic > 10 ug/l, and with Etorki *et al*.(2013) who reported that 37% of the groundwater samples collected from two locations (Al-Sawani and AL- Kerimiah) south of Tripoli city Libya contained arsenic > 10 ug/l with a range between 13.66 and 37.63 ug/l. and they indicated that the locations of the wells from which the water samples were collected are located within or close to an industrial activity which might contribute to the high level of arsenic reported in their study.

During the last few years' water supply from the manmade river to the public water supply system in Libya faced instability which forced most of the populations in the study area to depend on private wells as the sole source of water for their daily needs including drinking and cooking. These private wells are not regulated under drinking water treatment standards. The findings of this study reflect the health risk of continuous exposure to arsenic levels> 10 ug/l in water. from private wells for drinking and cooking food. It was not possible to determine the chemical form of arsenic in this study due to the limitation of the facility available in the laboratory to achieve this task, however, It is known that the inorganic form of arsenic is more toxic than the organic form, and the toxicological and physiological behavior of arsenic is known to depend on their oxidation state and chemical form. In natural waters, arsenic exists predominantly in inorganic form, as trivalent arsenite, As(III), and pentavalent arsenate, As(V), while organic forms of arsenic are rarely quantitatively important (Bissen & Frimmel, 2003). Actual valence states of arsenic depend on the redox environment in the water system. Pentavalent arsenic is more prevalent in surface water while trivalent arsenic is more likely to occur in anaerobic groundwater (Satnider, 2008).

According to previous research, the removal of arsenic As (III) by reverse osmosis treatment is 50 to 80%. and more than 98% of arsenate As (V) is removed

(Hou, 2017). Therefore, installing a small reverse osmosis unit is highly recommended in these situations because it is simpler than the conventional drinking water treatment process in small-scale situations and capable of reducing arsenic in water by up to 80% as pointed out by Walker *et al*., (2008) and Durate *et al*., (2009). This means that the household reverses osmosis unit is suitable only for water that contains arsenic not more than 40 ug/l. Another choice for reducing the health risk from exposure to water > 10ug/l is depending on rainwater harvesting and/or vendor-supplied water. The choice between installing a household reverse osmosis unit and harvesting rainwater or vendor-supplied water depends on the cost-effective impact. Chambertain and Sabatini (2014) pointed out that in Cambodia harvesting rainwater and/or vendor-supplied water are the cheapest with a worth value ranging from 2 to 10 Dollars per cubic meter per year of water delivered compared to household reverse osmosis units.

Public water supply system

Arsenic concentration in public water supply systems is shown in Table (4). The results indicated that the range of arsenic concentration in water samples from desalinated seawater public supply systems ranged between 3.32 and 7.88 ug/l in Zwara and 4.04—4.93 ug/l in Zliten. While for water samples collected from manmade river public water supply systems, the ranges were 6.59 – 22.47, 17.30 – 18.45, and 4.18 – 22.75 in Tripoli, khoms and Misrata respectively. Whereas the ranges for arsenic in water samples from local groundwater public supply systems were 2.66 – 3.82 and 22.61 – 24.38 ug/L for Khoms and Zletin, respectively.

Results of statistical analysis revealed non-significant differences (P <0.05) between the mean arsenic concentration of public water samples among Tripoli, Zliten, and Misrata where the mean concentration for those study areas was 13.66, 13.95, and 13.00 ug/l respectively. However, the mean arsenic concentration in the public water supply system of Zwara is significantly different (P>0.05) from the arsenic concentration found in public water systems of the other studied area (table 4). The mean concentrations of arsenic in the public water supply system samples of Zwara are 5.60 ± 1.85 and Khoms 10.63 ± 8.00 are within the range of arsenic concentration 1.93 – 9.85 reported in public water supply systems in France (Bortoleto &Cadore, 2005).

Table 4: Arsenic level (ug/l) in public water supply systems in the studied locations

Location	Water source	Min. value	Max.value	Mean± Std.	Grand mean
Zawara:					
Zawara center	Desalinated	3.32	7.88	5.57±2.38	5.60^{c}±1.85
Near beach	Desalinated	4.17	7.21	5.60±1.38	
Tripoli:					
Salaheddin	Manmade river	6.59	7.86	7.0±0.58	13.66^{a}±7.32
Alhudba		16.75	22.47	20.3±2.51	
Khoms:					
Suk alkames	Manmade river	17.30	18.45	18.14±0.56	10.63^{b}±8.00
Seleen	Well depth 150 meter	2.66	3.82	3.13±0.50	
Zletin:					
Azdwa north	Desalinated	4.04	4.93	4.64±0.40	13.95^{a}±9.97
Alquaellat	Well depth 150 meter	22.61	24.38	23.26±0.85	
Misrata:					
Aldafnia	Manmade river	21.05	22.75	21.61±0.77	13.0^{a}±9.13
Zawet almahjob		4.18	5.20	4.56±0.44	

Means with the same letter superscript are not significantly different at P <0.05

The variation in arsenic concentration of man-made river public water supply systems found in Tripoli, Khoms, and Misrata in this study (table 4) could be related to external contamination of the pipe system either due to aging or to contamination of the reservoir that feeds this system where the contamination reported. This needs further study to investigate the cause of the high concentration of arsenic in those parts of the public water supply system compared with the other system where the concentration was lower even though both systems are fed from the primary source of water. The differences in the arsenic concentration found in public water supply systems that rely on water from wells with a depth of 150 meters in Khoms 3.13 ± 0.50 and Zletin 23.26 ± 0.85 (table 4) could be related to the differences in the Geological composition of rocks and mineral precipitation in both areas.

Bottled water

The results presented in Table (5) showed that the bottled water sample from Zliten had the highest amount of arsenic with a range between 8.08 – 11.20 ug/l and a grand mean average of 9.12 ± 1.40 in comparison with the other studied area. The lowest arsenic concentration was found in bottled water from Misrata 2.59 ug/l. Whereas the arsenic concentration range in bottled water samples of the other studied area was between 4.00 – 6.25 ug/l. A significant difference ($P > 0.05$) was observed between the mean arsenic concentration in bottled water from Zletin and other bottled water from Zwara, Sabratha, Tripoli, Khoms, and Misrata. While non-significant difference ($P < 0.05$) was obtained between mean arsenic concentration in bottled water from Tripoli, Khoms, and Misrata (table 5).

It appears from the results stated in table (5) that the average arsenic concentration in all bottled water samples in this study did not exceed the maximum limit of 10 ug/l adopted in the Libyan standard 82/2015 for drinking water and WHO guideline (WHO,2012) for arsenic

In drinking water. These results agree with the results of Bakiradere *et al*., (2013) who found that arsenic in bottled water in the West part of Turkey is below the detection limit of 2 ng/ml

Table 5: Arsenic level (ug/l) in bottled water samples from plants in the studied Locations

Location	Well depth Meters	Min. value	Max. value	Mean± Std.	Grand mean
Zawara: Plant (A)	70	4.71	7.05	6.25±1.00	6.25^{b}±1.00
Sabratha: Plant (B)	43	1.64	6.44	2.92±2.40	2.57^{d}±1.68
Plant (C)	40	2.23	4.31	3.16±0.87	
Tripoli: Plant (D)	250	2.72	5.47	4.22±1.34	4.27^{c}±0.88
Plant (E)	130	4.18	4.50	4.31±0.14	
Khoms: Plant (F)	51	1.20	4.15	2.80±1.46	4.0^{c}±1.64
Plant (G)	51	4.81	5.75	5.23±0.45	
Zletin: Plant (H)	32	8.08	11.20	9.12±1.40	9.12^{a}±1.40
Misrata: Plant (I)	130	6.56	7.16	6.85±0.26	4.32^{c}±2.70
Plant (J)	56	1.71	1.99	1.80±0.13	

Means with the same letter superscript are not significantly different at $P < 0.05$

while nine samples contained detectable levels of arsenic between 8.51—11.59 ug/l. The finding from this study revealed that bottled water samples do not fall under the toxic and alert categories regarding arsenic.

Water from purifying shops

Arsenic concentration in water samples collected from water purifying shops in the study area ranged between 2.22-7.24, 5.56-9.55, 5.27-6.57, 1.39-5.78, 4.73-6.82 ug/l for Sabratha, Tripoli, Khoms, Zliten, and Misrata, respectively (table 6). The mean arsenic concentration of 7.20 ug/l reported in water from purifying shops in Tripoli are significantly different ($P > 0.05$) from the mean arsenic concentration found in water samples from purifying shops in the other study area, meanwhile, non-significant differences ($P < 0.05$) were observed for arsenic concentration in water samples from purifying shops in Sabratha, Khoms, and Misrata with average concentration 4.83, 5.81, and 5.70 ug/l respectively (table 6).

It appears from these results that water samples collected from purifying shops in Zliten had the lowest arsenic concentration with an average of 3.26 ug/l compared with the other study area. This may be because of the interest and commitment of the owners of those shops to periodically change the filters of the water treatment unit according to the recommended maintenance schedule, or maybe to the variations in water sources used by those shops., The results of arsenic in water from the other study area are close at a range between 4.83 and 7.20 ug/l (table 6). All the observed arsenic concentrations in water samples of the study area are below 10ug/l arsenic, which is the level adopted in the Libyan standard for drinking water 83/2015.

Table 6: Arsenic level (ug/l) in water samples withdrawn from water purifying shops In the study area.

Location	Water source	Min. value	Max. value	Mean± Std.	Grand mean
Sabratha:					
Shop (A)	Well (36 M)[1]	3.40	6.57	4.60±1.47	$4.38^{b}\pm1.86$
Shop (B)	Well (45 M)	2.22	7.24	5.00±2.40	
Tripoli:					
Shop (C)	Manmade R[2]	6.28	6.59	6.40±0.14	$7.20^{a}\pm1.41$
Shop (D)	Well (36 M)	5.56	9.55	8.00±1.71	
Khoms:					
Shop (E)	Manmade R	5.30	6.57	5.64±0.60	$5.81^{b}\pm0.50$
Shop (F)	Well (20 M)	5.27	6.30	5.76±0.48	
Zletin:					
Shop (G)	Well (20 M)	1.39	2.46	1.94±0.50	$3.26^{c}\pm1.64$
Shop (H)	Well (45 M)	3.11	5.78	4.60±1.63	
Misrata:					
Shop (I)	Manmade R	5.77	6.82	6.27±0.45	$5.70^{b}\pm0.73$
Shop (J)	Manmade R	4.73	5.58	5.14±0.42	

Means with the same superscript letter are not significantly different at $P < 0.05$.

[1]number between brackets indicates Well depth in meters.

[2]Manmade river public supply system.

The efficiency of the reverse osmosis unit

The percentage reduction in arsenic concentration in water after passing through reverse osmosis techniques in two bottled water plants (E & F) in Khoms are 75.70 and 74.50 % respectively (Table 7). These findings are in agreement with Duarte *et al*., (2009) who indicated that reverse osmosis can remove 80 to 90% of arsenic from water, and the percent removal of arsenic depends on water pH and the chemical state of arsenic whether it is present in arsenite or arsenate.

Based on these results a scenario was developed to determine the maximum arsenic level in water that should be treated by reverse osmosis to obtain treated water with a safe level of arsenic according to the Libyan standard 82/2015 for drinking water. It was found from this scenario (fig 1) that the level of arsenic in untreated water should not exceed 35 ug/l.

Table 7: Efficiency of reverse osmosis unit used in two bottled water plants in Reducing arsenic levels in water.

Water source	Well depth (Meters)	Arsenic in untreated water (ug/l)	Arsenic after RO treatment (ug/l)	% reduction in Arsenic by RO treatment
Plant (E)	60	11.48	2.79	75.70
Plant (F)	51	20.51	5.23	74.50

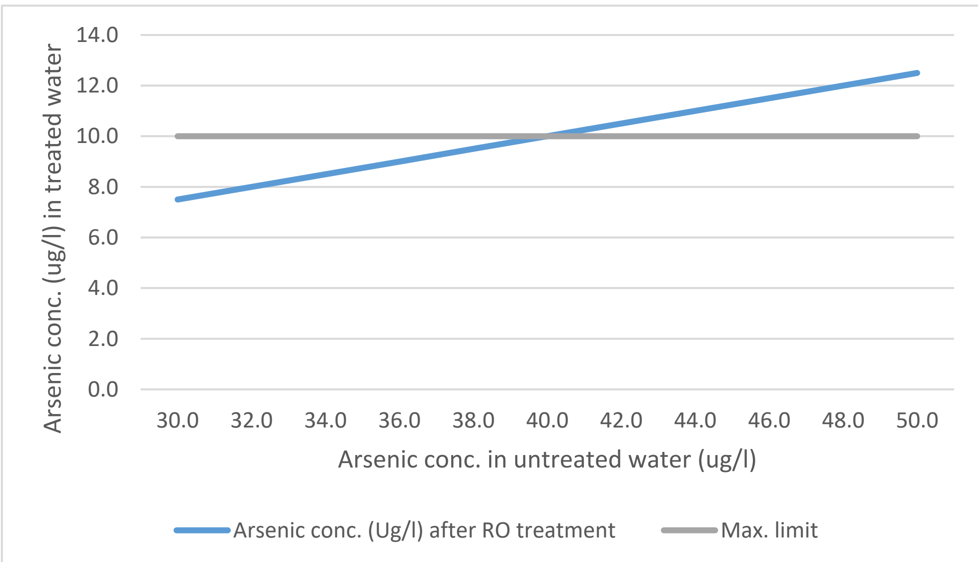

Figure 1: Arsenic concentration (ug/l) that must not be exceeded in the water source for the purpose of treatment in the water bottling plant

Conclusion

The results obtained in this study showed an elevated level of arsenic >10 ug/l in water from household wells. Considering the health risk from continuous exposure to arsenic > 10ug/l in drinking water, there is an urgent need to reduce the arsenic level in water from private wells by installing small household water treatment units in homes and water purification units in public institutes such as schools and hospitals that rely on groundwater sources. Bottled water plants and purifying shops should monitor the arsenic level in their unpurified water sources to be less than 35 ug/l to guarantee treated water with arsenic of less than 10ug/l.

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الزرنيخ في مصادر مياه الشرب في ست مدن تقع في الشريط الساحلي الغربي لليبيا

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ملخص

تعتبر المياه المستخدمة للشرب وإعداد الطعام أخطر مصدر لتعرض الإنسان للزرنيخ على المدى الطويل. هدفت الدراسة إلى تحديد مستوى الزرنيخ في عينات المياه الجوفية المنزلية، وشبكات المياه العامة، والمياه المعبأة، والمياه من محلات التنقية في خمسة مواقع على طول الشريط الساحلي لليبيا. كما تم دراسة كفاءة وحدة التناضح العكسي (RO) في إزالة الزرنيخ من الماء في مصنعين لتعبئة المياه. تراوح عنصر الزرنيخ في عينات المياه الجوفية المنزلية وشبكات المياه العامة والمياه المعبأة والمياه من محلات التنقية على التوالي: 6.06-70.48، 2.66-22.76، 1.20-11.20، 2.022-9.55 ميكروغرام / لتر. أظهرت النتائج أن 83٪ من المياه الجوفية المنزلية و5% من عينات المياه المعبأة تجاوز عنصر الزرنيخ بها 10 ميكروغرام / لتر, وهو الحد الأقصى المسموح به في مياه الشرب بالمواصفات الليبية. ، بينما كان مسوى الزرنيخ في عينات المياه من محلات التنقية أقل من 10 ميكروغرام / لتر. احتوت عينات شبكات المياه العامة من موقعين على الزرنيخ> 10 ميكروغرام / لتر. وحدة التناضح العكسي قادرة على تقليل الزرنيخ في الماء بنسبة 75٪، مما يعني أن الزرنيخ في المياه غير النقية يجب ألا يتجاوز 35 ميكروغرام / لتر. توصي الدراسة بشدة بضرورة قيام الأسر التي تعتمد على المياه الجوفية المنزلية بتركيب وحدات التناضح العكسي المنزلية لإنقاذها من المخاطر الصحية للتعرض المزمن للزرنيخ.

الكلمات الدالة: الزرنيخ، المياه المعبأة، المياه الجوفية، ليبيا، نظام الامداد العامة.