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Health safety assessment of drinking water for some hand-pumps based on analysis of heavy metals with public health concern

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Abstract: Six house-hold Abyssinian pumps distributed in different villages of Mansoura (Mans-I, Mans-II and Mans-III) and Talkha (Talk-I, Talk-II and Talk-III) cities, Egypt, were selected for regular seasonal water quality assessment during 2017. Water samples were collected within the mid-periods of four seasons namely, winter, spring, summer and autumn. The selected metals include Sodium (Na, an alkali metal), Barium (Ba, an alkaline earth metal), lead (Pb), Aluminium (Al) (two post transition metals), Manganese (Mn), Cadmium (Cd), Chromium (Cr), copper (Cu), iron (Fe), zinc (Zn), molybdenum (Mo) (seven transitional metals), antimony (Sb), arsenic (As) (two metalloids) and Se (non-metalloid) Metal analysis was carried out by Inductively Coupled Plasma-Mass Spectrometry (ICPMS). The selected elements maintained both health hazardous and aesthetic water quality effects, and all have been assigned drinking water guidelines by World Health Organization (WHO) [1]. The results indicated that, concentration levels of all elements displayed remarkable local and seasonal variations. Based on the WHO drinking water guidelines of heavy metals, all water samples collected only from Mans-I pump were health safe with acceptable guidelines of drinking water. However, water samples collected from the other five pumps showed remarkably high levels mostly exceeding the guidelines of acceptable drinking water quality. Concisely, all water samples collected from Mans-I pump were health safe with acceptable drinking water guidelines while samples collected from other pumps can impose great human health risks if used for drinking.

keywords: Drinking water, Water Quality, heavy metals, Abyssinian pumps, tube-well aquifer.

1. Introduction

It has become evident that water scarcity and declining access to the drinking water of acceptable and healthy safe quality represent acute global problems prevailing in arid and semi-arid countries, including Egypt [1].

Water quality is a term used to characterize the physicochemical and biological properties for its suitability for a specific use or purpose [2].

Heavy metals are persistent in the environment and impose a potential threat to human health. Heavy industries, smelters, battery manufacturing, and mining pursuits are the major suppliers of excessive heavy metal pollution of the environment [3].

Heavy metal pollution has resulted in many problems for human health and aquatic ecosystems as well [4]. Industry and sewage pollution represent the most potential source of a variety of toxic heavy metals [5].

According to their potential hazard, the heavy metals Pb, Hg, As and Cd were considered by the U.S. Agency for Toxic Substances and Disease Registry [6] as the most toxic metals greatly hazardous to human health [7]. Accumulative research findings have already confirmed that excessive exposure and/or intake of these metals cause serious human diseases and health disorder including, but not limited to, kidney failure, bone damage liver dysfunction, cancers, neurobehavioral effects, and other deleterious health effects on fetuses, infants, children, and adults (e.g). [1, 6, 8-12]. Accordingly, it is a must to set drinking water guidelines to health-hazardous metals to certify whether or not a drinking water source is safe to human health [1].

It has become evident that groundwater is a vital supply of drinking water supply worldwide. In Egypt, the annual groundwater supply is about 20.65 billion m^3 $year^-$ and thus contributing by about 28% of available water resources in Egypt [13, 14]. This indicates the vital importance of groundwater for different multipurpose uses of water in Egypt. Comprehensive data on water availability and demands in Egypt are available from the Ministry of Water Resources and Irrigation (MWRI).

Abdel-Shafy and Kamel [15] reviewed the groundwater in Egypt with special emphasis on resources, location, amount, contamination, protection and renewal. They reported that the quality of potable groundwater in the Nile Delta had been threatened by chemicals, particularly toxic heavy metals, and microbiological pollution through various complicated routes. Domestic wastewater from septic tanks represents a significant source of toxic heavy metals and pathogenic bacteria [16, 17].

In Egypt, the hand pumps prevail in rural areas as a source of multiuse underground water [18]. In general, the depth of tube-well pumps varied between 20 and 92 meters, with water being found between 4 and 15 meters from the ground surface, particularly at the Nile Delta [19, 20].

It is true that many Egyptians end up with drinking untreated underground water provided by hand (Abyssinian) pumps. Accordingly, hand pumps households, have a substantial chance of drawing polluted and health unsafe water [20].

Based on facts mentioned in the preceding paragraphs, it is a must to carry out regular water quality monitory of hand pump waters to assess its health safety and hazard to the ultimate consumers, including man.. The present study aimed at seasonal monitoring of concentration of certain health hazardous elements (e.g. Pb, Cd, Sb, As) in addition to certain atheistic water quality deteriorating elements (Mn and Fe). The results of metal analyses will be compared with global and national standards for drinking water guidelines in order to ascertain whether or not the underground pump water is suitable for drinking purposes.

2. Materials and methods

The study area

Figure 1, shows the map of Egypt (A), where the geographical location and the area of Dakahlia Governorate are represented by a black block, from which an arrow points to the administrative map of Dakahlia Governorate (B). An orbit encircles Mansoura and Talkha, the cities (Merkez) from which water samples were collected from six households' Abyssinian pumps distributed in different villages. A Google earth map (C) illustrates the topographic locations of different sampling sites from which well (ground) water samples were seasonally collected.

Sampling stations

A total of six household Abyssinian pumps were selected for regular seasonal water sampling, three are located in different villages of Mansoura (Mans-I, Mans-II and Mans-III) Merkez (city) and three (Talk-I, Talk-II and Talk-III) located in different villages of Talkha city. Table 1, lists a host of a full descriptive data including the village name, the sampling site code, its coordinates, and its vertical straight-line distance (km) from the eastern (Damietta) branch of the River Nile. Important information about water uses from each sampling site in addition to other important additional remarks are also included in Table 1. In all cases the water was pumped from the underground aquifers at depths ranged between 20 and 30 meters as the owners of pumps indicated.

Meteorology of the study area

The climate of the study area is more or less dry and consists of four distinct seasons: summer, autumn, winter, and spring. Winter extends from 20th of December to the 21st of

March. It is, relatively, the coldest season in Egypt with minimum day length and sunshine. The season also experiences some showers which are irregularly distributed during its period. The spring starts from 21st of March and lasts till the 20th of June. During spring, air temperature, humidity, day length and the duration of bright do increase to reach maximum levels in summer. Summer commences from 21st June and continues till the 20th of September. It is characterized by high atmospheric temperature, relative humidity, bright sunshine and longer days. The autumn season starts from 21st September till 20th of December. In this period the air temperature, duration of bright and day length decrease, also the sky gets cloudy sometimes.

Sampling program

The sampling procedure followed the standard method 1060 B [21]. During 2017, two representative water samples were collected from each house hold Abyssinian pumps at the middle period of four-season including winter (one sample was collected in 22nd January and other samples was collected in 22nd February), spring (22nd April and 22nd May), summer (22nd July and 22nd August) and autumn (22nd October and 22nd November.

Before sampling, the water pump was operated for three minutes to pump out water in order to wash out any contaminants from the pump mouth and to ensure that the collected water sample represent the underground well water. In general, samples collection and handling followed the standard method 9060 [21].

Samples for chemical analysis water were collected in large (4L volume) wide-mouth High-Density Polyethylene (HDPE) plastic bottles of food-grade quality.

Metals analysis

Simultaneous multi-element determination of the trace metals Na, Ba, Pb, Al, Mn, Cd, Cr, Cu, Fe, Zn, Mo, Sb, As, and Se were done by Inductively Coupled Plasma-Mass Spectrometry (ICPMS) according to their specific method (325-B), described in [21]. Analyses of heavy metals were carried out at Egyptian Atomic Authority (EAEA) laboratories, Cairo, Egypt.

Drinking water guidelines

Mean concentrations of different heavy metal were matched against the Egyptian Guidelines of Drinking water (Decree of Minister of Health No. 458/2007) to assess whether or not the value copes with drinking water quality standards. It is relevant to indicate that Egyptian Drinking water guidelines are, more or less, as similar as those set by World Health organization [22].

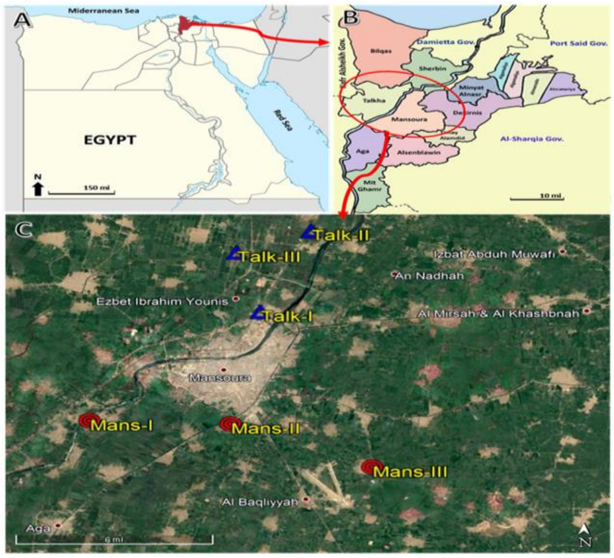

Figure 1: Location map showing the sampling stations. A) Map of Egypt, B) Administrative map of Dalkahlia Governorate, and C) Google earth map showing the different sampling stations of Mansoura (Mans-I, II, & III) represented by red circle (●) and Talkha (Talk-I, II, & III) represented by blue triangle (▲)

Statistical Analysis

Summary statistics including mean values and standard deviations were carried out using Microsoft Office Excel 2007

Tables1a-d, lists mean seasonal variations of concentrations of 14 elements including, 11 metals (Na, Ba, Pb, Al, Mn, Cd, Cr, Cu, Fe, Zn, and Mo), two metalloids (Sb and As) and a single non-metal (Se). The selected metals, metalloids and non-metal maintain both aesthetic and public health concerns of drinking water quality

Table 2 simplifies the metal analyses data in a more understandable oriented manner using explanatory symbols. It lists acceptable (√) and non-acceptable (X) drinking water guidelines of all metals, metalloids and the non-metal analyzed during the whole period of study

Concisely, mean concentration levels of the metals Al, Cr, Cu, and Zn, of water samples collected from all pumps cope perfectly with the drinking water guidelines

Table 1: Site description including native names of sampling sites, their codes, coordinates and distances to Damietta (eastern) branch of the River Nile

Native village and site name	Sampling site code	Coordinates	Distance [a] (Km) to Damietta branch of the River Nile	Supplementary notes and remarks
Kafr Ash Shinhab, Mansoura	Mans-I	31° 0'29.30"N, 31°18'33.90"E	0.05	This station (Abyssinian pump) is located at the western edge of Kafr Ash Shinhab village which is bordered by the eastern branch (Damietta) of the River Nile. The distance between the pump and Damietta branch is about 50 meters. Water is mainly used for drinking of humans and animals and other domestic purposes. Water is pumped from 30 meter deep
Minyat Sandub, Mansoura	Mans-II	31° 0'22.00"N, 31°22'55.40"E	9.801	This household pump is located in a densely populated area. The water maintains a multiuse nature. Water may be used for drinking in case of temporarily municipal water is cut-off. Water is pumped from 20 meter deep
Tilbanah, Mansoura	Mans-III	30°58'42.80"N, 31°27'17.00"E	10.059	This pump is surrounded with a densely populated area. It is situated at only 30 meters from a domestic and agricultural wastewater drain The water is of a multiuse nature but mainly used for laundry and drinking water for household animals. Water may be used for drinking in case of temporarily municipal water is cut-off. Water is pumped from25 meter deep
Mit Antar, Talkha	Talk-I	31° 4'41.30"N, 31°23'51.30"E	1.884	This household pump is located at the western edge of Mit Antar village. It is located at only 20, meters from an industrial wastewater drain The water is mainly used for garden irrigating, drinking water for household animals and cooling water for small-scale plastic grinding installations. Water may also be used for drinking during municipal water is cut-off. Water is pumped from 25 meter deep
Kafr at Tawilah, Talkha	Talk-II	31° 7'50.40"N, 31°25'27.20"E	2.136	This household pump is located in a densely populated area. The water is pumped by an electric motor pump. The water is mainly used for cooling system of a refrigerator for storing vegetables and potato tubers. Water is also used for drinking of household and farm animal but seldom for humans as the owner confirmed. Water is pumped from 30 meter deep
Al Manyal, Talkha	Talk-III	31° 6'59.90"N, 31°23'7.50"E	7.968	This is a public pump located in a sparsely populated area. The water is mainly used for cement brick industry and for drinking of farm animals. From the same well a tube is extending to a public bakery to prepare bread dough. Water is pumped from 30 meter deep

[a]Vertical line distance

Sodium concentrations exceeded the drinking water guideline (200 mg L^{-1}) only in summer (Talk-III, Table 1c) and autumn (Talk-II and Talk-III, Table 10d). It must be highlighted that the mean concentration levels of all metals, metalloids, and no-metal of all water samples collected from Mans-1 were consistent with drinking water guidelines.

Depending on the collection season and site, the elements Pb, Cd, Cr, Cu, Zn, Mo, Sb, As and Se were sometimes undetectable. Out of 24 pump water samples collected during the study period, the non-metal Selenium (Se) was undetectable in 20 samples (Table 2). According to drinking water guidelines, the upper limits of Se concentration were unacceptable only for water samples collected from Mans-II in summer and Autumn (Table 2)

Arsenic (As) was undetectable in 17 water samples. The smallest (0.014 mg L^{-1}) and the maximum (0.06 mg L^{-1}) concentration of arsenic were recorded in summer for water samples collected from Mans-II and Mans-III, respectively (Table 1c). As seen from Table 2, the upper concentration levels of arsenic were unacceptable as drinking water of water samples collected from Mans-II (in spring and autumn), Mans-III (in summer) and Talk-I (in spring and summer).

Cadmium (Cd) was undetectable in 17 water samples (Table 2). The detectable concentrations of Cd ranged between 0.001 mg L^{-1} (Talk-I, spring, Table 1b) and 0.014 mg L^{-1} (Talk-II, autumn, Table 1d), According to the drinking water guidelines (0.003 mg L^{-1}), water samples collected from Talk-II (during spring, summer and autumn), and from Talk-III (during spring and summer) were unacceptable.

Antimony (Sb) concentrations fluctuated within a wide range from 0.002 mg L^{-1}(Mans-III, summer, Table 1c) and 0.730 mg L-1 (Talk-I, summer, Table 1c) and was undetectable in 14 water samples (Table2). As shown in Table 2, the upper concentrations levels of this metalloid exceeded the drinking water guidelines (0.02 mg L^{-1}) of water samples collected from the pumps Mans-II (in spring and Autumn), Mans-III (spring), Talk-1(spring, summer, and Autumn) and Talk-III (spring and summer)

Molybdenum (Mo) was undetectable in 7 water samples collected during this study (Table 2). The detectable concentrations ranged between 0,006 mg L^{-1} (Mans-II, spring, Table 1b) and 0.415 mg $L-^{1}$ (Talk-II, autumn, Table 1d). Only the water samples collected from Talk-II pump (during spring, summer and autumn) and from Talk-III (during spring and summer) remarkably exceeded the drinking water guideline (0.07 mg L^{-1})

Lead (Pb) was only not detected in all water samples collected during winter (Table 1a) but detected in all water samples collected in spring, summer and Autumn with concentrations fluctuated between 0.008 mg L^{-1} (Mans-I, spring, Table 1b) and 0.196 mg L^{-1} (Mans-II, Autumn, Table 1d). Water samples collected during spring, summer and Autumn from stations Mans-II, Mans-III, Talk-I, Talk-II and Talk-III were unacceptable as source of during water, as Pb levels exceeded the drinking water guideline (0.01 mg L^{-1}) with varying degrees (Table 1 b-d, Table 2)

The alkaline earth metal Barium (Ba) was detected in all water samples collected during this study (Tables 1a-d) with the lowest concentration of 0.005 mg L^{-1}(Mans-II, summer, Table 1c) and the highest one of 1.347 mg L^{-1} (Talk-II, winter, Table 1a). All water samples collected from Talk-II pump were unacceptable as their upper concentrations levels (1.156 - 1.347 mg L^{-1}) largely exceeded the drinking water guideline of Ba (0.7 mg L^{-1})

Similarly, manganese (Mn) was detected in all pump water samples (Table 1 a-d). Mn levels were acceptable for all pumps except Talk-II as concentrations of winter (0.6mg L^{-1}), spring (0.6 mg L^{-1}), summer (0.574 mg L^{-1}) and autumn (0.655 mg L^{-1}) exceeded the drinking water guideline (0.4mg L^{-1})

Iron (F) concentrations displayed great local and seasonal variation between 0.051 mg L^{-1} (Mans-II winter, Table 1a) and 3.351 mg L^{-1} (Talk-II, autumn, Table 1d). According to drinking water guideline (0.03 mg L^{-1}) all water samples collected from pumps Mans-I, Mans-II, and Mans-III are acceptable while those collected from Talk-I and Talk-II pumps in all seasons were unacceptable. In addition, water samples collected from Talk-III pump were unacceptable only in spring and summer (Table 2)

3. Results and Discussion

According to the World Health Organization, up to 50% of developed countries' population suffers from health issues associated with lack of safe drinking water [2].

In Egypt, nearly 56% of rural inhabitants are deprived of their right to a regular supply of municipal clean drinking water, and thereby they are exposed to detrimental health disorders such as renal failure, cancer, and high child mortality [18, 23]. For lack of other options, many Egyptians end up with drinking untreated underground water provided by hand (Abyssinian) pumps. Accordingly, hand pump households have a substantial chance of drawing polluted water [20]

Accordingly, regular water quality monitoring and assessment of household Abyssinian pumps deserve ultimate importance for human health safety and welfare. This was the major objective of the present study to achieve

The present study paid considerable attention to record local and seasonal variations of 14 elements with mandatory drinking water guidelines [1]. Comprehensive data about the mean seasonal concentrations of Na, Ba, Pb, Al, Mn, Cd, Cr, Cu, Fe, Zn, Mo, Sb, As and Se of different pump water samples are listed in

Table 1. The data are comprehensive and may maintain an overwhelming aspect, yet they represent potential documentary information recorded for the first time for the groundwater of the study area. The detectable concentrations of Al, Cr, Cu, and Zn were agreeable with the drinking water guidelines for all pump water samples. For an easy understanding, acceptable (√) and non-acceptable (X) drinking water guidelines of all elements are listed in Table 2 A detailed description of local and seasonal variations of these elements, with special reference to their acceptable and unacceptable drinking water guidelines were fairly described before in the section of results. Nevertheless, in a brief, the mean concentration levels of all metals, metalloids and no-metal of water samples collected only from Mans-1, which is located in a relatively sparsely populated area close to the Damietta branch of the River Nile, were agreeable with drinking water guidelines (Table 2), and thus highlighting health safe water qualities. However, other elements exhibited remarkable variations regarding their acceptable and unacceptable levels for drinking water. These variations were largely dependent on the element, the water sample and the season of the collection (Table 2). It seems a must to highlight that, except for antimony (Sb), arsenic (As) and selenium (Se), the other 11 elements were detected in water samples collected from Talk-II pump at different seasons (Table 2) with a total of 37 records; out of them 21concentration levels were unaccepted for drinking water quality. These findings lead to a conclusion that based on metals and their mean concentrations, water samples collected from Mans-I and Talk-II pumps maintained the best and the worst drinking water qualities, respectively.

Metal	Drinking water Guideline	Symbol	Group	Sampling Stations														
				Mans-I		Mans-II		Mans-III		Talk-I		Talk-II		Talk-III				
				Mean	± SD	Mean	± SD	Mean	± SD	Mean	± SD	Mean	± SD	Mean	± SD	MIN	MAX	Average
Sodium	200	Na	Alkali metals	55.735	0.867	51.809	1.425	109.68	4.524	157.88	7.124	152.97	3.603	164.81	5.884	51.809	164.806	115.48
Barium	0.07	Ba	Alkaline earth metals	0.1	0.0	0.0	0.0	0.1	0.0	0.1	0.0	1.3	0.0	0.0	0.0	0.0	1.3	0.3
Lead	0.01	Pb	Post transition metals	0.008	0.002	0.132	0.006	0.074	0.012	0.121	0.012	0.078	0.007	0.066	0.018	0.008	0.132	0.080
Aluminium	0.2	Al	Post transition metals	0.015	0.000	0.059	0.005	0.023	0.001	0.021	0.004	0.026	0.002	0.038	0.002	0.015	0.059	0.030
Manganese	0.4	Mn	Transition metals	0.209	0.001	0.048	0.001	0.089	0.003	0.281	0.001	0.610	0.001	0.219	0.000	0.048	0.610	0.243
Cadmium	0.003	Cd	Transition metals	ND		ND		ND		0.001	0.000	0.009	0.001	0.005	0.001	0.001	0.009	0.005
Chromium	0.05	Cr	Transition metals	0.003		0.005	0.000	0.002	0.000	0.004	0.000	0.026	0.006	0.022	0.003	0.002	0.026	0.010
Copper	2.0	Cu	Transition metals	0.010	0.002	0.001	0.000	0.008	0.002	0.009	0.001	0.009	0.005	0.020	0.004	0.001	0.020	0.010
Iron	0.3	Fe	Transition metals	0.272	0.011	0.094	0.003	0.134	0.008	0.687	0.011	2.614	0.012	0.339	0.011	0.094	2.614	0.690
Zinc	3.0	Zn	Transition metals	0.021	0.004	0.071	0.001	0.020	0.001	0.017	0.000	0.006	0.001	0.014	0.002	0.006	0.071	0.025
Molybdenum	0.07	Mo	Transition metals	0.022	0.002	0.006	0.002	0.022	0.002	0.037	0.001	0.244	0.006	0.177	0.012	0.006	0.244	0.085
Antimony	0.02	Sb	Metalloid	ND		0.032	0.004	0.031	0.003	0.278	0.005	ND		0.037	0.001	0.031	0.278	0.095
Arsenic	0.01	As	Metalloid	ND		0.019	0.000	0.007	0.000	0.022	0.001	ND		ND		0.007	0.022	0.016
Selenium	0.01	Se	Non-metal	ND		0.013	0.007	ND		ND		ND		0.003	0.000	0.003	0.013	0.008

Table 1c: Summer season 2017. Data represent mean values of two readings (each of three measurement) of water samples collected in July 22, and Aug. 22, 2017.

Metal	Drinking water Guideline	Symbol	Group	Sampling Stations														
				Mans-I		Mans-II		Mans-III		Talk-I		Talk-II		Talk-III				
				Mean	± SD	Mean	± SD	Mean	± SD	Mean	± SD	Mean	± SD	Mean	± SD	MIN	MAX	Average
Sodium	200	Na	Alkali metals	57.324	0.4796	98.963	1.9045	109.93	5.2667	178.81	5.1344	197.39	3.5499	204.84	0.9029	57.324	204.844	141.2097
Barium	0.7	Ba	Alkaline earth metals	0.1	0.0012	0.0	0.0001	0.0	0.0003	0.1	0.0005	1.2	0.0155	0.0	0.0003	0.0	1.2	0.2
Lead	0.01	Pb	Post transition metals	0.011	0.0081	0.174	0.0024	0.044	0.001	0.158	0.0062	0.104	0.008	0.015	0.0427	0.011	0.174	0.084
Aluminium	0.2	Al	Post transition metals	ND		0.030	0.0031	0.029	0.0044	0.032	0.0109	ND		0.020	0.0056	0.020	0.032	0.028
Manganese	0.4	Mn	Transition metals	0.229	0.002	0.055	0.001	0.086	0.002	0.252	0.0004	0.574	0.001	0.216	0.0001	0.055	0.574	0.235
Cadmium	0.003	Cd	Transition metals	ND		ND		ND		0.002	0.0006	0.012	0.0014	0.012	0.0028	0.002	0.012	0.009
Chromium	0.05	Cr	Transition metals	ND		ND		ND		0.005	0.0001	0.026	0.007	0.034	0.0015	0.005	0.034	0.021
Copper	2.0	Cu	Transition metals	ND		ND		ND		0.022	0.0019	ND		ND		0.022	0.022	0.022
Iron	0.3	Fe	Transition metals	0.330	0.0114	0.0963	0.0051	0.105	0.0148	0.718	0.0065	2.794	0.011	0.774	0.0141	0.105	2.794	0.944
Zinc	3.0	Zn	Transition metals	0.013	0.0041	0.181	0.0025	0.023	0.0008	0.030	0.0007	ND		0.014	0.0035	0.013	0.181	0.052
Molybdenum	0.07	Mo	Transition metals	0.036	0.0037	ND		0.037	0.005	0.058	0.0008	0.389	0.0095	0.260	0.0242	0.036	0.389	0.156
Antimony	0.02	Sb	Metalloid	ND		ND		0.002	0.0004	0.730	0.022	ND		0.110	0.0032	0.002	0.730	0.281
Arsenic	0.01	As	Metalloid	ND		ND		0.014	0.0006	0.060	0.0025	ND		ND		0.014	0.060	0.037
Selenium	0.01	Se	Non-metal	ND		0.038	0.0209	ND		ND		ND		ND		0.038	0.038	0.038

Table 2: Seasonal variations of acceptable (√) and non-acceptable (X) drinking water guidelines of different 14 metals with aesthetic and public health concerns of water samples collected from six Abyssinian pumps distributed in different villages of Mansoura and Talkha cities during 2017.

											Sampling stations and seasons														
		Mans-I				Mans-II				Mans-III				Talk-I				Talk-II				Talk-III			
Metal	Symbol	W	Sp	Su	A	W	Sp	Su	A	W	Sp	Su	A	W	Sp	Su	A	W	Sp	Su	A	W	Sp	Su	A
Sodium	Na	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	X	√	√	X	X
Barium	Ba	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	X	X	X	X	√	√	√	√
Lead	Pb	ND	√	√	√	ND	X	X	X	ND	X	X	X	ND	X	X	X	ND	X	X	X	ND	X	X	X
Aluminium	Al	√	√	ND	ND	√	√	√	√	√	√	√	ND	√	√	√	ND	√	√	ND	√	√	√	√	ND
Manganese	Mn	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	X	X	X	X	√	√	√	√
Cadmium	Cd	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	√	√	ND	ND	X	X	X	ND	X	X	ND
Chromium	Cr	√	√	ND	ND	√	√	ND	√	√	√	ND	ND	√	√	√	ND	√	√	√	√	√	√	√	√
Copper	Cu	√	√	ND	√	√	√	ND	√	√	√	ND	√	√	√	√	ND	√	√	ND	√	√	√	ND	√
Iron	Fe	√	√	√	√	√	√	√	√	√	√	√	√	X	X	X	X	X	X	X	X	√	X	X	√
Zinc	Zn	ND	√	√	√	ND	√	√	√	ND	√	√	√	ND	√	√	√	ND	√	ND	√	ND	√	√	√
Molybdenum	Mo	ND	√	√	√	ND	√	ND	√	ND	√	√	√	ND	√	√	√	ND	X	X	X	ND	X	X	X
Antimony	Sb	ND	ND	ND	ND	ND	X	ND	X	ND	X	√	X	ND	X	X	X	ND	ND	ND	ND	ND	X	X	ND
Arsenic	As	ND	ND	ND	ND	ND	X	ND	X	√	√	X	ND	ND	X	X	ND	ND	ND	ND	ND	ND	ND	ND	ND
Selenium	Se	ND	ND	ND	ND	ND	X	X	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	√	√	ND	ND
W= Winter		Sp= Spring			Su = Summer			A= Autumn			ND= Non detectable														

Comprehensive and extensive ecological and health-related information about heavy metals in drinking waters, and any other quality parameter [1], can be accessed at https://www.who.int/water_sanitation_health/publications/drinking-water-quality-guidelines-4-including-1st-addendum/en/. Moreover, for each drinking water quality parameter a specific background-document was prepared by skilful experts with sound scientific merits and potential fundamental research outputs. These background documents are the pillars for developing World Health Organization guidelines for drinking water. The hazardous effects of metals on living organisms, including humans, are fairly described. Therefore, re-mentioning of these effects in detail in this paper seems totally unnecessary as already accurate and detailed pertinent information can easily be accessed online. However, it may be complimentary to give concise and precise, reminding hints about the health relevance of each metal analyzed in pump underground waters during this study. The information was obtained from [1] as the collective mother reference.

Normally, sodium is important to human life. Acute effects and death were documented after accidental sodium chloride overdoses. Acute symptoms may include nausea, vomiting, seizures, muscle twitching, weakness, and cerebral and pulmonary edema. Therefore, no health-based guideline value is proposed, but sodium can affect drinking water taste at rates above 200 mg L^{-1}[1, 18].

Based on [1] barium guideline (0.7 mg L^{-1}) of all water samples obtained only from, Talk-II pump was inappropriate as drinking water. At high concentrations, barium induces vasoconstriction by direct stimulation of the arterial muscle, peristalsis due to violent stimulation of smooth muscles and seizures and paralysis following central nervous system stimulation. Depending on the dosage and solubility of barium salt, death can occur in a few hours or days. The acute oral toxic dose is 3-4 grams [24]. Laboratory animals proved that barium induces nephropathy. In relatively low concentrations, barium retains possible blood pressure results.

Corresponding to [1] guideline for drinking water (0.01 mg L^{-1}), detectable lead (Pb) concentrations were only appropriate for water samples obtained from Mans-I pump and absolutely unacceptable for all other water samples (Table 2). Based on the dosage and exposure duration, lead has been shown to be associated with a broad range of effects, including multiple neurological and behavioral effects, mortality (mainly from cardiovascular diseases), impaired renal function, hypertension, impaired fertility, adverse pregnancy outcomes, delayed sexual maturation, impaired dental health and possible carcinogenic effects [1].

For drinking purposes, manganese (Mn) concentrations were totally unacceptable for all water samples collected from Talk-II pump (Table 2). Manganese is a vital element for humans and other animals. The existence of manganese in drinking-water is objectionable to consumers if being dumped in water mains and causes water discoloration. Manganese is well-known to cause neurological effects at very high levels in drinking-water

Cadmium (Cd) concentrations exceeded the [1] guideline (0.003 mg L^{-1}) during spring, summer, and Autumn for water samples collected from Talk-II and Talk-III (Table 2). The kidney appears to be the most sensitive organ to Cd toxicity. This affects the resorption function of proximal tubules, the first symptom being an increase in low-molecular-weight protein urinary excretion, known as tubular proteinuria. More extreme kidney cadmium damage can also include glomeruli, indicated by increased inulin clearance. Many potential symptoms include aminoaciduria, glucosuria, phosphaturia. Chronic cadmium exposure induces osteomalacia with different osteoporosis rates. Cadmium is considered to be carcinogenic [25].

Iron (Fe) recorded unacceptable drinking water qualities for almost all water samples collected from Talk-I, Talk-II, and Talk-III pumps (Table 2). Iron is a crucial element in human nutrition. At concentration levels above 0.3 mg L^{-1}, iron can adversely affect taste and appearance of drinking water. No health-based guideline value for iron is proposed [1].

Water samples collected in spring, summer and Autumn from pumps Talk-II and Talk-II recorded mean concentrations of molybdenum (Mo) above the drinking water guideline (0.07 mg L^{-1}), Molybdenum is an essential micronutrient for both animals and humans. No data are available to indicate uts carcinogenicity. However, some studies indicated that a relatively high intake of molybdenum (10–15 mg day^{-1}) might cause a gout-like disease characterized by joint pains of the legs and hands [1].

Depending on the season of collection, the concentrations levels of antimony (Sb) in samples collected from pumps Mans-II. Mans-III and Talk-III were unacceptable for drinking water (Table 2). Water-soluble antimony salts have a significant rubbing effect on the gastrointestinal mucosa, causing prolonged vomiting. Many symptoms include cramps, diarrhea, and cardiac toxicity. Some evidence was reported for the carcinogenicity of water-soluble antimony compounds. WHO at [1] advises a recommendation of 0.02 mg L^{-1} Sb for drinking water.

Out of 24 samples, arsenic (As) recorded unacceptable levels for 5 water samples collected in different seasons from the pumps Mans-II, Mans-III and Talk-I (Table 2). In water, arsenic is mostly present as a pentavalent arsenate with a relatively higher abundance in anoxic groundwater. The gastrointestinal tract absorbs both penta valent and trivalent soluble arsenic compounds quickly and extensively.

Highly toxic to humans and acute arsenic poisoning associated with drinking underground well water containing 1.2 mg L^{-1} As has been documented. Studies have shown that elevated levels of arsenic from drinking-water are causally linked to cancer. The drinking water standard is 0.01 mg L-1 [1].

The non-metal selenium recorded unacceptable concentration levels (above the 0.01 mg L^{-1} guideline) only for 2 water samples collected from the pump Mans-II in spring and summer (Table 2). Selenium is an essential human element, with a recommended daily intake of about 1μg kg^{-1} adult body weight. Long-term toxicity in rats characterizes growth instability and liver pathology. In humans, long-term selenium exposure toxic effects are expressed in the skin, hair and liver.

Numerous studies have been performed on the toxicity of individual metals to living environments (e.g., [26]). To protect human health from the adverse effects of heavy metals, especially in drinking water, international health organizations set standards using individual metals. Such safety requirements are based on the premise that there is minimal contact between metal or chemical species and, even if interactions occur, the degree does not surpass applicable safety factors. However, this conclusion became controversial as [27] found that exposure to sub-chronic concentrations of eight different metals (As, Cd, Pb, Hg, Cr, Ni, Mn, and Fe) in drinking water impaired male rats' overall health. In their research, they found that the functional and structural integrity of male rats' kidneys, liver, and brain was altered at 10-100 times the mode concentrations of individual metals. Therefore, bioassays are critical methods for reliable and integrated drinking water toxicity assessment

Discussion

The mean concentration levels of health-hazardous heavy metals including Pb, Cd, As, Sb, and Ba exceeded the drinking water guidelines indicating serious health risks for the

ultimate consumers including humans. One outstanding observation was that all water samples only collected from the pump Mans-I, contained relatively low concentrations of toxic trace metals that were totally health safe. This pump is located in a sparsely populated area at only 50 meters from the bank of the eastern (Damietta) branch of the River Nile. In contrast, water samples collected from pumps located in densely populated areas showed remarkable high concentration of toxic heavy metals maintaining potential risk to human health if being used for drinking. Accordingly, this research study may alert for considering the underground water, pumped from areas closely adjacent to the banks of the Nile system, as health safe alternative source of drinking water for rural areas in Egypt

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