JBAAR
Journal of Bioscience and Applied Research
WWW.JBAAR.ORG

Heavy Metal Analysis in Some Water Types from Egypt and Saudi Arabia, and Future Aspirations of Water Resources Management

Ahmed M. El-Naggar
Zoology Department, Faculty of Sciences, Mansoura University, Egypt
(Corresponding author e-mail. ahmedelnaggaro38@yahoo.com)

Abstract

A comparative evaluation of the heavy metals Arsenic, Lead, Cadmium, Chromium, Copper and Zinc in versatile water resources in Egypt and Saudi Arabia was conducted during the summer of 2015. All the studied water brands contained markedly scarce amounts of Arsenic, which was under the limit of detection. Chromium was also found to be under the limit of detection in Baraka, Nestle Pure Life, Hayat, Aman Siwa and Siwa from the water market at Mansoura (Egypt). Similar finding was recorded for Cadmium in Aman Siwa and Lead in Hayat, Aman Siwa and Siwa water brands. The highest levels of Cadmium, Chromium, Copper, Lead and Zinc were recorded in Baraka, Aquafina, Dasani, Safi and Aquafina water brands, respectively. However, the lowest amounts of these metals were detected in Siwa, Safi, Safi, Nestle Pure Life and Aman Siwa, respectively. Ablution water showed undesirable amounts of Zinc (0.25 ppm). Street coolers recorded relatively low amounts of Chromium (0.09 ppm) and Zinc (0.10 ppm). Zamzam water was free of Cadmium, Lead and Zinc, however it recorded low amounts of Copper (0.004 ppm) and undesirable levels of Chromium (0.13 ppm). The level of Chromium detected in the purified River Nile's water was 0.125 in the tap water and 0.110 ppm in vending machines. On the other hand, the amounts of Zinc were 0.085 and 0.546 ppm in the two water brands, respectively. The heavy metal analysis provided insight into the quality of water sources under investigation. The study discussed the effects of heavy metals on the human health and their effects on the community health in the long term. The study reviewed future aspirations for the management of water resources in Egypt and Saudi Arabia.

***Keywords**:* Arsenic, Lead, Cadmium, Chromium, Copper, Zinc, Egypt, Saudi Arabia, Water Resources Management.

1 Introduction

During recent years, the Middle East and North Africa suffered from chronic water scarcity (Hakan and Anders, 2006; Michel *et al*., 2012; Ganter, 2015). Countries facing the challenge of severe water shortages such as Saudi Arabia, Jordan and Yemen rely either on groundwater-supplied community water systems or private household water wells. However, long-term extra mining (over drafting) of the groundwater could lead to sharp water depletion and deterioration, particularly if the replenishment rate of the aquifer is slower than the pumping rate (Al-Saud *et al*., 2011). The precious fossil groundwater occupies the microscopic perforations between the rock molecules/particles that accommodate relatively more or less proportion of the chemical, biological and radiological properties of these ancient geologic formations. Dick *et al*. (2010) estimated that more than one third of the world only drinks their local water supply after pretreatment of the initial purification of the water. Untreated water can lead to a wide range of health problems and randomness, for example Diarrhea, Cholera and Dysentery (Dick *et al*., 2010).

A heavy metal has a specific density of more than 5 gm/cm^3 (Fernandez-Luqueno *et al*.,2013). The fundamental source of heavy metals in the human body is the underground rocks. These elements are ingested with food items and water, inhaled with air or adsorbed via the skin contacts (Morais, 2012). Most metals are accumulated in the bones (Reilly, 2008). Metals aid in the cell growth, help facilitate biochemical reactions and ease the transmission of signals. Metals do not provide energy, however they help release energy inside the body (Morais, 2012). Heavy metal poisoning is a health problem caused by ingestion from the air, water and/or food (Sarkar, 2002). The critical point is the bioaccumulation of these toxic elements within the human body at rates higher than their degradation through the catabolic processes. According to Jones and Miller (2008), long-term ingestion of the heavy metals could lead to physical, muscular and neurological abnormalities. Moreover, heavy metals in water and food could cause *Diabetes mellitus*, gangrene, cardiac asthma and hypertension (e.g. Alissa and Ferns, 2011). Furthermore, heavy metal pollution of water plays an important role in the infection of aquatic animals with an array of potential pathogens (e.g. Abdel-Gaber *et al*., 2015; Abdel-Ghaffar *et al*., 2016).

The present study aimed at conducting a comparative evaluation of the heavy metals Arsenic, Lead, Cadmium, Chromium, Copper and Zinc in versatile and multipurpose resources of water, which are pivotal for millions of people in Egypt and KSA; and to compare these levels with the standards set by national and international organizations. The present study aimed also at raising the awareness of the society about water security issues and reviewing alternative strategies for the provision of water in future in relation to the thorny issue of the Renaissance Dam.

2 Materials and Methods

Three samples of each water brand were randomly selected during summer months (2015) and subjected to the heavy metals analysis. The Saudi water brands were: Zamzam water (commercial, bottled brand), household purified groundwater from the Saq Aquifer, bottled groundwater (Al-Ghazal), water received from the street coolers and the ablution water from three popular mosques of Al-Qurayyat, northwest KSA. The Egyptian water brands included tap water from the municipal water system at Mansoura, which is used in drinking, household and cleaning purposes, and purified tap water received from the dispensing machines at Mansoura University. Six heavy metals were analyzed in each water brand, namely Arsenic, Lead, Cadmium, Chromium, Copper and Zinc, with the aid of RAYLEIGH WFX-1308 Atomic Absorption Spectrophotometer (Figures 1 and 2) at the Biotechnology Unit, Mansoura University, Egypt. The standard levels adopted by some national and international organizations are documented in Table (1).

Each water sample was collected in 500 ml polythene bottle, kept in refrigerant at 4°C until analyzed within 48 hours. Ultra-pure chemicals and reagents (Mono-Element calibration standards) were used for the preparation of the calibration standard solutions. Air-Acetylene mixture was used at the burner head. The wavelengths at which the studied heavy metals were detected were: Arsenic (193.7 nm), Lead (217 nm), Cadmium (228.8 nm), Chromium (357.9 nm), Copper (324.8 nm) and Zinc (213.9 nm). The limits of quantification of the abovementioned metals were 0.005 ppm for Copper and Zinc, 0.002 ppm for Chromium and 0.001 ppm for Lead, Cadmium and Arsenic. The limit of quantification points to the lowest concentration of the element that could be detected with a confidence level up to 95% or the lowest concentration of the element that produces absorbency twice the value recorded by the blank. The environment of the laboratory accommodating the atomic absorption spectrophotometer was kept free of dust as well as other contaminants. Moreover, the glass and plastic wares were washed three times in deionized water and soaked in 20% of nitric acid for 24 hrs. Then, the soaked wares were rinsed in deionized water and terminally dried before use.

Water samples showing precipitations or cloudy appearance were subjected to digestion as follows: a particular volume of the water sample (from 1 to 5 ml) was placed in Griffin beaker (total volume= 250 ml); then, 3 ml of conc. HNO_3 were added gently into the beaker, which was covered by a watch glass and heated gradually on a hot plate up to the completion of the digestion process; the beaker and its content was allowed to cool at room temperature and then an additional 3 ml of conc. HNO_3 were added gently into the beaker, which was covered with a watch glass; heating was continued until the digestion was completed, indicated by a light coloured formed digestate; then, the evaporation was continued until the mixture was mostly dried. Following drying, 5 ml of HCl and H_2O solution (1:1) were added and heating was continued to dissolve the digestate. At this time, deionized water was added and the mixture was filtered to remove undissolved particles which can block the atomizer. The volume of the solution was adjusted to 20 ml and introduced into the Atomic Absorption Spectrophotometer.

One-Way ANOVA test on SPSS package (version 20) was used to compare the means of the heavy metals among the studied water types. Following the analysis of variance (One-Way ANOVA), Post Hoc Test (Tukey HSD) was selected for further data analysis, to determine which groups in the water samples differ. The probability values $P \leq 0.05$, 0.01 and 0.001 were employed to indicate significant, highly significant and very highly significant differences, respectively. Moreover, Levene's statistic on the SPSS package was used to test for the homogeneity of variances.

4 Results

The levels of the studied heavy metals Arsenic, Lead, Cadmium, Chromium, Copper and Zinc in a variety of water types from Egypt and KSA are shown in Table 2. It should be mentioned that Arsenic was under the limits of detection in all the studied water brands. Similarly, the heavy metals Cadmium, Lead and Zinc were below the estimation level in Zamzam water. Relatively low amounts of Copper were detected in Zamzam water (0.004 ppm), however higher amount of Chromium (0.13 ppm) was measured in the same water brand (Table 2).

Measurements of the RAYLEIGH WFX-1308 Atomic Absorption Spectrophotometer revealed that all the heavy metals selected for the present study were under the limits of detection in Hilwa water (Table 2). Similar findings were documented for the purified groundwater water available in Al-Qurayyat, KSA. Heavy metals analyses of the water derived from the street coolers in Al-Qurayyat revealed that this essential water resource contained scarce amounts of Arsenic, Cadmium, Copper and Lead, however it incorporated low amounts of Chromium (0.09 ppm) and Zinc (0.10 ppm). It could be noticed from Table 2 that the ablution water is generally safe and valid for washing and sanitary affairs. This water contained scarce amounts of Cadmium, Chromium, Copper and Lead, however it was loaded with undesirable amounts of Zinc (0.25 ppm).

Concerning the municipal and bottled water abundant at Mansoura, WFX-1308 Atomic Absorption Spectrophotometer revealed that the levels of the studied heavy metals exceeded the standard levels shown in Table 1. It is obvious that each water brand contained toxic levels of two or more of the studied heavy metals. The highest amounts of Cadmium, Chromium, Lead and Zinc were detected in Baraka, municipal, Safi and Aquafina water brands. The municipal water also exhibited the highest level of Copper (Table 2). On the other hand, the water derived from the dispensing machines at Mansoura University Campus contained undesirable amounts of the heavy metals Zinc and Chromium, however it was poor in its Arsenic, Cadmium, Copper and Lead content which came below the limits of detection.

Comparison of the mean values of the estimated levels of the heavy metals (One-Way ANOVA test) indicated that these differences were highly significant (F= 5.652, P≤ 0.01; Sum of Squares= 0.852 and 0.334 between and within groups, respectively; Mean Squares= 0.118 and 0.021 between and within groups, respectively). Tukey HSD test detected significant differences between Safi and three water brands, namely Hayat, Siwa and Aman Siwa. Moreover, the variation between the mean values of Lead between Hayat and Safi was also significant according to Tukey HSD. In contrast, the output of the statistical analysis (One-Way ANOVA test) revealed that differences in the mean values of the heavy metal Zinc were non-significant (F= 1.901, P> 0.05; Sum of Squares= 11.967 and 14.391 between and within groups, respectively; Mean Squares= 1.710 and 0.899 between and within groups, respectively). Similar non-significant difference was recorded for the mean values of Copper among the studied water brands from the Egyptian market (One-Way ANOVA: F= 0.793, P> 0.05; Sum of Squares= 5.551 and 31.865 between and within groups, respectively; Mean Squares= 0.793 and 1.992 between and within groups, respectively).

Regarding the levels of the studied heavy metals in the bottled water brands widely spread in Mansoura, Chromium was found to be under the detection level in Baraka, Nestle Pure Life, Hayat, Aman Siwa and Siwa (Table 2). Similar trend was recorded for Cadmium in Aman Siwa and for Lead in Hayat, Aman Siwa and Siwa (Table 2). The highest levels of Cadmium, Chromium, Copper, Lead and Zinc were attained by Baraka, Aquafina, Dasani, Safi and Aquafina water brands, respectively (Table 2). In contrast, the lowest levels of the abovementioned metals were exhibited by Siwa, Safi, Safi, Nestle Pure Life and Aman Siwa, respectively (Table 2).

The output of One-Way ANOVA test revealed very highly significant difference (F= 861.587, P≤ 0.001; Sum of Squares= 0.407 and 0.001 between and within groups, respectively; Mean Squares= 0.058 and 0.000 between and within groups, respectively) in the mean values of Chromium among these water brands. Tukey HSD test showed significant differences between Aquafina and any of the other bottled water brands (P≤ 0.001) as well as between Dasani and any of the remainder bottled water brands (P≤ 0.001). One-Way ANOVA test showed also that differences in the mean levels of Cadmium were very highly significant (F= 14.237, P≤ 0.001; Sum of Squares= 3.112 and 0.500 between and within groups, respectively; Mean Squares= 0.445 and 0.031 between and within groups, respectively). Tukey HSD test revealed significant differences between Aquafina and Aman Siwa as well as between Aquafina and Baraka water brands. Tukey HSD test showed also significant differences between Safi and Dasani as well as between Safi and each of the following water brands: Nestle Pure Life, Hayat, Siwa and Aman Siwa. Significant differences were also recognized between Dasani and Baraka, as well as between Nestle Pure Life and Baraka. Moreover, Tukey HSD test detected significant differences between Baraka and either Aman Siwa or Siwa bottled water brands.

The thorny topic of the Renaissance Dam:

Earlier in the last century (1929), Britain had signed the Nile Basin Initiative on the behalf of Egypt. Thirty year later, Egypt had signed the 1959 agreement with the countries of the Nile Basin (Ashok, 2002; Peichert, 2003; Di Nunzio, 2013; Salman, 2013). This initiative aimed at allocating water resources among countries that hold land along the course of the Nile River. The initiative included that the riparian countries are intended to develop the river in a cooperative manner, participate fundamental socioeconomic advantages, and establish peace and security in the basin (Peichert, 2003). Moreover, the initiative stressed that the establishment of any projects on the Nile Basin is prohibited, but only accepted after the agreement of the countries downstream (Sudan and Egypt). Unfortunately, in recent years, some upstream countries, namely Ethiopia, Kenya, Uganda, Rwanda and Tanzania signed a cooperative framework agreement in 2011 to explore more water from the River Nile. However, this agreement was strongly rejected from the downstream countries (Egypt and Sudan).

The year 2015 showed the signing of the declaration of principles in Khartoum by Egypt, Sudan and Ethiopia. This event reopened the complicated conflict over the sharing of Nile water and highlighted once more the thorny topic of the Renaissance Dam, which is being rapidly constructed by Ethiopia to generate electric power for socioeconomic and developmental purposes. The declaration aimed to establish the main principles that would protect the rights of downstream countries, their share of water is anticipated to be threatened by the completion of the Ethiopian dam. This could pose a disaster for the coming generations in the downstream states. Some people considered this declaration as a positive step towards the achievement of the Egyptian water security; however others showed that the declaration is not obligatory to any side, but just a general framework for the future connections between the parties.

Figure 1. The main parts of RAYLEIGH WFX-1308 Atomic Absorption Spectrophotometer. These are the fuel source unit (air and acetylene), the monochrometer and the cathode lamp operating unit.

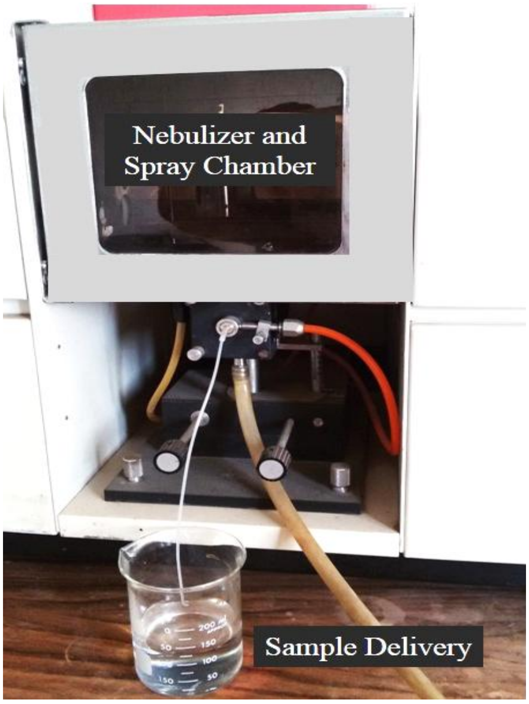

Figure 2. The most effective unit of RAYLEIGH WFX-1308 Atomic Absorption Spectrophotometer. This unit comprises the nebulizer and spray chamber where the atoms of the heavy metal is excited to emit a characteristic electromagnetic spectrum.

Table 1. Standard levels of Arsenic, Cadmium, Chromium, Copper, Lead and Zinc in drinking water as established by World Health Organization (WHO), Environmental Protection Agency (EPA), Food and Drug Administration (FDA), International Bottled Water Association (IBWA), European Commission (EU) and Saudi Standards, Metrology and Quality Organization (SASO)

	Heavy Metal (ppm)					
	Arsenic	Cadmium	Chromium	Copper	Lead	Zinc
WHO (2008)	0.01	0.003	0.05	2.00	0.01	–
EPA (2013)	0.01	0.005	0.10	1.30	0.015	5.00
FDA (2008)	0.01	0.005	0.10	1.00	0.005	5.00
IBWA (2008)	0.01	0.005	0.005	1.00	0.005	5.00
EU (1998)	0.01	0.005	0.05	2.00	0.01	–
SASO (2009)	0.05	-	0.05	1.00	0.05	5.00

4 Discussion

Waterborne diseases cause more than 5 million deaths every year (UNESCO, 2007). Heavy metals are highly toxic to the human health and biological systems and can lead to adverse impacts, even at low concentrations (Marcoveechio *et al*., 2007). In recent years, considerable research has documented the contamination of drinking water in KSA with heavy metals (e.g. Sadiq and Hussain, 2008; Alshikh, 2011; Assubaie, 2015). Similarly, some studies showed that the drinking water based on the public water systems is contaminated with heavy metals (for example, Bakirdere *et al*., 2013; Mohod and Dhote, 2013). In contrast, Alshikh (2011) analyzed heavy metals and organic pollutants of the ground water sampled from Jazan City, southwest of Saudi Arabia and found that the water is safe and potable without any prior purification. Similar findings were reported by Mohammed and Osman (1998), AlFraij *et al*. (1999), Saleh *et al*. (2001) and El-Harouny *et al*. (2009).

Obtained data indicated that the household tap water at Mansoura had 0.10, 1.07, 2.96, 0.25 and 0.82 ppm of Cadmium, Chromium, Copper, Lead and Zinc, respectively. Accordingly, consumers who drink three liters of water per day will receive 0.3, 3.21, 8.88, 0.75 and 2.46 mg of these metals respectively. The water derived from the vending machines at Mansoura University Campus contained 0.112 ppm of Chromium and 0.524 ppm of Zinc, however other metals were under the limit of detection. Thus, individuals who drink three liters per day will accumulate 0.34 and 1.57 mg of Chromium and Zinc, respectively. Comparatively high levels of the heavy metal were determined in bottled water at Mansoura. A consumer ingesting three liters of Aquafina water will receive about 1.53, 1.20, 3.30, 0.66 and 4.68 ppm of Cadmium, Chromium, Copper, Lead and Zinc, respectively. Moreover, ingesting three liters of Dasani water adds about 1.11, 0.30, 5.16, 1.17 and 2.19 ppm of the abovementioned metals, respectively. It should be mentioned that the daily requirement of water likely increases as the summer heat gets intense.

In the present study, Zamzam water was found to accommodate undesirable amounts of Chromium. However, other heavy metals in this blessed water were under the detection limit. Naeem *et al*. (1983) conducted an analysis of the heavy metals in the holy Zamzam water and encountered only trace amounts of Copper and Chromium. Shomar (2012) studied 30 properties in 30 Zamzam water samples collected from Makkah and some European markets and found that the level of As (27 ppm) was three times higher than the standards set by WHO. Arsenic is assorted as a carcinogen (Abernathy *et al*., 2012), however, some forms of this metal are beneficial as medications (Dhubhghaill and Sadler, 2005).

Table 2. The levels of the heavy metals Cadmium, Chromium, Copper, Lead and Zinc (Mean ± SD) in versatile water types from Egypt and Saudi Arabia. ND, Not detected.

	Heavy Metal (ppm)				
	Cadmium	Chromium	Copper	Lead	Zinc
Zamzam water	ND	0.13 ± 0.02	0.004 ± 0.003	ND	ND
Ablution water	ND	ND	ND	ND	0.25 ± 0.13
Hilwa	ND	ND	ND	ND	ND
Street Coolers (Al-Qurayyat)	ND	0.09 ± 0.02	ND	ND	0.10 ± 0.02
Purified groundwater (Al-Qurayyat)	ND	ND	ND	ND	ND
Municipal water (Mansoura)	0.10 ± 0.01	1.07 ± 0.14	2.96 ± 1.63	0.25 ± 0.12	0.82 ± 0.69
Vending Machine (Mansoura University)	ND	0.110 ± 0.15	ND	ND	0.546 ± 0.23
Aquafina	0.51 ± 0.33	0.40 ± 0.01	1.10 ± 1.57	0.22 ± 0.09	1.56 ± 1.29
Baraka	1.02 ± 0.21	ND	1.40 ± 0.76	0.32 ± 0.15	0.21 ± 0.02
Nestle Pure Life	0.13 ± 0.01	ND	1.05 ± 1.61	0.15 ± 0.01	0.38 ± 0.60
Dasani	0.37 ± 0.25	0.10 ± 0.02	1.72 ± 2.11	0.39 ± 0.33	0.73 ± 1.18
Hayat	0.28 ± 0.18	ND	1.49 ± 2.25	ND	0.27 ± 0.44
Safi	0.93 ± 0.04	0.03 ± 0.01	0.25 ± 0.12	0.52 ± 0.17	0.24 ± 0.32
Aman Siwa	ND	ND	0.40 ± 0.33	ND	0.06 ± 0.04
Siwa	0.07 ± 0.02	ND	1.11 ± 0.80	ND	1.50 ± 1.51

Chromium is involved in the metabolism of glucose as it facilitates the action of insulin. It is vital in the protein and lipid synthesis. Some chromium compounds such as chromium picolinate (chromium + amino acid metabolite) stimulates weight loss and increases slim muscle tissue. According to Balch and Balch (1997), low plasma chromium levels can be an early alarm of coronary heart disease. Symptoms of a chromium deficiency include: exhaustion, nervousness and glucose intolerance in diabetic patients, poor metabolism of amino acids, raised plasma free fatty acids, neuropathy, and increased risk of arteriosclerosis (Balch and Balch, 1997). Because chromium can influence insulin requirements, diabetic patients should first refer to a physician or health care professional before taking additional chromium doses, particularly chromium picolinate (Abraham *et al.*, 1992).

Individuals with low blood sugar may experience symptoms of hypoglycemia if an excess of chromium is taken (Abraham *et al*., 1992). Nielsen (2000) advised pregnant women and nursing mothers not to ingest chromium at doses greater than the Estimated Safe and Adequate Daily Dietary Intake (ESADDI).

ICPS (2001) stressed that Arsenic is not an essential element for human. Lethal doses in human range from 1.5 mg/kg body weight for diarsenic trioxide to 500 mg/kg body weight for dimethyl arsenic acid (Buchet and Lauwerys, 1982). WHO (2012) reported that the early clinical symptoms of acute arsenic intoxication include abdominal pain, vomiting, diarrhea, muscular pain and weakness, with flushing of the skin. Murphy *et al*. (1981) showed that these clinical symptoms are often followed by numbness and tingling of the extremities, muscular cramping. Heavy metals analysis by RAYLEIGH WFX-1308 Atomic Absorption Spectrophotometer showed that Arsenic was scarce and attained absorbency attitude far below the absorbency recorded for the standard solutions derived from the Mono-element Arsenic stock. Apart from this measurement, one should consider the tendency of Arsenic for bioaccumulation in the human body over long periods of exposure.

Zinc is a highly important nutrient and plays a major role in the proper development of the brain and reproductive organs, learning and memorization, particularly in children (Dunne, 1990; Balch and Balch, 1997). This metal is a cofactor for over more than 300 enzymes employed in the digestion and metabolism of carbohydrate digestion, and phosphorous metabolism (Dunne, 1990; Medical Economics Company, 2001). The highest concentrations of zinc have been found in bone, muscle, prostate, liver, and kidneys (Wastney *et al*., 1986). Less than 10% of the total zinc in the human body is freely exchanged with plasma (Miller *et al*., 1994) and most of this is from the slow exchange of zinc located in bone and muscle. In blood, zinc is found in plasma, erythrocytes, leukocytes, and platelets (EPA, 2005). Zinc may help prevent spots and govern the activity of oil glands and assists in the synthesis of protein and formation of collagen, stimulates a vigorous immune system, participates in wound healing and helps facilitate improved vision, smell and taste (Balch and Balch, 1997). Zinc is one of the constituent elements of insulin (Dunne, 1990; Balch and Balch, 1997). It prevents the establishment of the free radicals and increases the absorption of vitamin A (Balch and Balch, 1997). The thymus gland, which is full of zinc allocates and sustains T-lymphocytes or white blood cells to defend the body against bacteria and viruses as well as cancer cells. Moreover, the thymus is necessary for the cell division and protein synthesis, and produces a zinc-dependent hormone, namely FTS, which is significant in the immune responses (Lukaski, 2006).

Imbalances in daily zinc uptake can lead to many health problems (Rink, 2011). Because the human body has no specific zinc storage arrangement, daily ingestion of a sufficient amount of zinc is of great importance (Rink and Gabriel, 2000). Zinc deficiency can lead to slow growth rates, immunity impairment, prolonged healing of wounds, reduced sense of smell and taste, fragile and thin nails, poor night vision, poor memory and skin sores (Rink, 2011).

Copper is a glorious metal and plays a remarkable role in achieving a broad spectrum of metabolic processes. The absorption, storage, and metabolism of iron is facilitated by copper. This metal may be regarded as an antioxidant (Osredkar and Sustar, 2011). The total amount of copper in the human body ranges between 50 and 120 mg. Copper is accumulated in the brain, heart and kidney, however it is mainly accumulated in the liver to accomplish the energy and detoxification processes (Osredkar and Sustar, 2011). According to Medeiros and Percival (2006), the human blood contains 120 mg/dl for women and 109 mg/dl for men. Balch and Balch (1997) found that individuals consuming 20 % of their daily calories from fructose showed diminished levels of an important copper-dependent enzyme, namely red blood cell superoxide dismutase, a free radical scavenger protecting the red blood cell from antioxidants.

Copper is an important nutrient and plays a remarkable role in the maintenance of the metabolic processes. However, high levels of Copper can cause adverse impacts and even toxicity (Elizabeth and Ward, 2003; Brewer, 2010). Copper functions in balance with zinc and vitamin C to form elastin, an essential protein supporting the elastic cartilages. Moreover, it participates in the healing process, production of energy and colouration of the hair and skin, helps maintain the cardiovascular system and the myelin, which envelopes the neurons and supports signal transmission between the brain and various body organs, and aids in the production and regulation of the neurotransmitters in the brain (Osredkar and Sustar, 2011). Signs of copper deficiency include: general weakness, anemia, osteoporosis, hair loss, diarrhea, paleness, skin lesions, poor respiratory function (Balch and Balch, 1997). Overdoses of copper can cause troubles in the stomach and vomiting. High intakes of dietary iron or zinc can reduce copper absorption (Watts, 1988). Dunne (1990) reported that vitamin C supplementation lowered copper.

The Saq Aquifer is mostly an isolated ecosystem, hardly influenced by the industrial, agricultural and urban surface and subsurface water discharges (Brooks, 2007). Al-Qurayyat as well as the northwestern districts of Saudi Arabia relies merely on the Saq Aquifer in providing safe and potable water for drinking, sufficient clean water for large-scale agriculture and sanitation. The Saq Aquifer is a fossil deep ground water source (20000 - 30000 years old). It is 320 km long, extending over 1200 km in the northern region of KSA and continues under the southern region of Jordan. It is regarded as a Cambro-Ordovician Formation, which is composed primarily of Nubian sandstones and being locked among huge masses of impermeable rocks (Vengosh *et al*., 2009). Such geological buildup seems to minimize the recharging rates of the aquifer through the rainfall and other refilling sources as well. This geological fact could account for the markedly scarce amounts of the heavy metals in the groundwater at Al-Qurayyat and neighboring districts that showed an intensive agricultural practices over the last few decades. However the industrial field has not been developed yet in such amazing and highly important geopolitical area in which nearly 300000 Egyptians are now living.

Competition over water among people and nations creates a climate of conflict that cripples human welfare and ecosystem operations (Awulachew *et al*., 2012). To neutralize such competition, countries holding lands along the course of the River Nile require new advances and successful strategies in integrated water resources management and sustainable development in order to ensure food security and human comfort in such amazing geopolitical region of the world (Awulachew *et al*., 2012). In addition to the application of more effective control measures to the protection of the available water resources, the adoption of alternative strategies of providing water to meet the growing needs of the ever increasing population has become a priority for the Egyptian government. Apart from the thorny issue and the long-term, arduous negotiations about the Renaissance Dam and its adverse impacts on the Egyptian share of water, the groundwater represents a safe haven to meet the future water needs of the Egyptian society and a precautionary measure against the possible procrastination of the Ethiopian side in this complicated issue. Relying on the satellite image data in mapping the drainage and geological formations in Egypt, accompanied by the administration of the knowledge with the aid of a geographic information system (GIS) methodology, Wilseman and El-Baz (2007) introduced the evidence for the groundwater wealth of Egypt. The Disi aquifer is a precious deep sandstone, 320 kilometers long, aquifer that is located underneath the boundary between Saudi Arabia and Jordan. This aquifer meets the basic needs of Jordan and the north region of Saudi Arabia. However, the growing needs for clean water in such an arid environment make it more likely for conflict to emerge at any time (Jasem *et al*., 2011).

According to ElNashar (2014), the Nile River is the main freshwater source in Egypt, providing 50 billion cubic meters every year (97% of the renewable water supplies). Annually, a total of 55.5 billion m^3 is allocated for Egypt according to the terms of the Nile Water Agreement signed in 1959. The annual average per capita share of water in Egypt was 800 m^3 in 2004, however it is expected to drop markedly to 600 m^3 by the year 2025 (ElNashar, 2014). Egypt has a composite of the groundwater aquifers, which accommodate tremendous amounts of the freshwater (El-Baz and Himida, 1998; Hefny and Shata, 2004). The four major groundwater systems in Egypt are the renewable Nile Aquifer, Moghra Aquifer and Coastal Aquifer, as well as the non-renewable Nubian Sandstone Aquifer (ElNashar, 2014).

ElNashar (2014) found that the fossil groundwater is hosted in deep aquifers as non-renewable water resources. Also, non-conventional resources include agricultural drainage water reuse, sea water desalination, municipal wastewater reuse, rain harvesting, and brackish water desalination. Fossil water exploitation is estimated at a rate of 1.65 Billion m^3/yr mainly concentrated at the oases of the Western Desert. The municipal wastewater reuse capacity is currently of the order of 2.9 billion m^3/yr, while the agricultural drainage reuse is projected around 9.7 billion m^3/yr in the Nile Valley and delta (ElNashar, 2014). The author added that groundwater stored in the aquifer system of the River Nile and desert boundaries is continuously replenished from the river by ooze from canals and percolation from cultivated lands and estimated the annual groundwater mining in Egypt at the average of 4.6 billion m^3. Moreover, and additional amount (0.5 billion m^3) of water is pumped from the desert aquifers and the coastal regions. Rough estimations made by ElNashar (2014) indicated that the groundwater mining is expected to reach up to 11.4 billion m^3 within the next few years.

Sea water desalination is a promising strategy to make use of the infinite amounts of water resident in the Mediterranean Sea and the Red Sea. This strategy is successfully implemented in Saudi Arabia as well as other Arab Gulf countries. However, because of its high economic cost, desalination is not a priority in Egypt at the present time. Saudi Arabia is the largest producer of the desalinated water, with a total annual production of one billion and six million cubic meters (18% of the world production) (US/SA Business Council, 2015). The authorities involved in the development of the water sector must accept the desalination as an effective strategy to meet the water needs of the ever growing population and to compensate for the expected water shortages as a result of the Renaissance Dam and other dams which will be built in South Sudan Republic over the next decade. The output of desalination could meet all the basic needs of the Egyptian community and support the water-demand management in the present century. In this respect, issuing attractive laws for business men and investors is of great importance.

5 References

Abdel-Gaber, R.; Abdel-Ghaffar, F.; Bashtar, A. R.; Morsy, K.; Saleh, R. (2016). Interaction between the intestinal parasite *Polyonchobothrium clarias* (Cestode: Ptychobothriidae) from the African sharptooth catfish *Clarias gariepinus* and heavy metal pollutants in an aquatic environment in Egypt. Journal of Helminthology, 8: 1-11.

Abdel-Ghaffar, F.; Abdel-Gaber, R.; Bashtar, A. R.; Morsy, K.; Mehlhorn, H.; Al Quraishy, S. and Saleh, R. (2015). *Hysterothylacium aduncum* (Nematoda, Anisakidae) with a new host record from the common sole *Solea solea* (Soleidae) and its role as a biological indicator of pollution. Parasitol. Res.; 114(2): 513-22.

Abernathy, C. O.; Calderon, R. L. and Chappell, W. R. (2012). Arsenic: exposures and health effects. Chapman and Hall.

Abraham, A.; Brooks, B. and Eylath, U. (1992). The effects of chromium supplementation on serum glucose and lipids in patients with and without non-insulin dependent diabetes. Metabolism, 41: 768–771.

Al Fraij, K.M.; El Aleem, K.A. and Al Ajmy, H. (1999). Comparative study of potable and mineral waters available in the State of Kuwait. Desalination, 123(2): 253–264.

Alissa, E. M. and Ferns, G. A. (2011). Review Article: Heavy Metal Poisoning and Cardiovascular Disease. Journal of Toxicology, Volume 2011 (21 pp.).

Al-Saud, M.; Teutsch, G.; Schüth, C. and Rausch, R. (2011). Challenges for an Integrated Groundwater Management in the Kingdom of Saudi Arabia. International Journal of Water Resources and Arid Environments 1(1): 65-70.

Alshikh, A. (2011). Analysis of Heavy Metals and Organic Pollutants of Ground Water Samples of South Saudi. Life Science Journal, 8(4): 438–441.

Al-Othman, A. M.; Al-Othman, Z. A.; El-Desoky, G. E.; Aboul-Soud, M. A. M.; Habila, M. A. and Giesy, J. P. (2013). Lead in drinking water and human blood in Riyadh City, Saudi Arabia. Arabian Journal of Geosciences, 6: 3103–3109.

Al-Turki, A. I. (2009). Evaluation of Well Water Quality in Hael Region of Central of Saudi Arabia. Thirteenth International Water Technology Conference, IWTC 13 2009, Hurghada, Egypt, 1121–1132.

Ashok, S. (2002). 'The Nile Basin Initiative: Too Many Cooks, Too Little Broth', SAIS Review, Washington, 22(3), p. 293.

Assubaie, F. N. (2015). Assessment of the levels of some heavy metals in water in Alahsa Oasis farms, Saudi Arabia, with analysis by atomic absorption spectrophotometry. Arabian Journal of Chemistry, 8(2): 240–245.

Awulachew, S. B.; Smakhtin, V.; Molden, D. and Peden, D. (2012). The Nile River Basin: Water, Agriculture, Governance and Livelihoods. Routledge, Taylor and Francis Group, London and New York.

Bakırdere, S.; Yaroğlu, T.; Tırık, N.; Demiröz, M.; Fidan, K. A.; Maruldalı, O. and Karaca, A. (2013). Determination of As, Cd, and Pb in Tap Water and Bottled Water Samples by Using Optimized GFAAS System with Pd-Mg and Ni as Matrix Modifiers. Journal of Spectroscopy. 2013, Article ID 824817, 7 pages.

Balch, J. F. and Balch, P. A. (1997). In Prescription for Nutritional Healing (pp. 24). New York, NY: Avery Publishing.

Brewer, G. J. (2010). Copper toxicity in the general population. Clinical Neurophysiology 121 (4): 459–60.

Brooks, D. P. (2007). Integrated Water Resources Management and Security in the Middle East. Freshwater in the Middle East and North Africa: Source of Conflict/Base for cooperation.

Buchet, J. P. and Lauwerys, R. R. (1982). Evaluation of exposure to inorganic arsenic. Cahiers de médecine du travail, 19: 15.

Dhubhghaill, O. M. and Sadler, P. J. (2005). The structure and reactivity of arsenic compounds: Biological activity and drug design. Bioinorganic Chemistry, Volume 78 of the series Structure and Bonding pp 129-190.

Di Nunzio, J. (2013). Conflict on the Nile: The future of transboundary water disputes over the world's longest river. Future Directions International Pty Ltd, Australia.

Dunne, L. J. (1990). In Nutrition Almanac (3rd ed., pp.71-72). New York, NY: McGraw-Hill Publishing Company.

El-Baz, F. and Himida, I. (1998). Recommendations for the strategy of groundwater exploration in the deserts of Egypt. In: Ground Water Potential of the Sinai Peninsula, Egypt; El-Baz, F., Kusky, T., Himida, I., Mogheeth, A., Eds.; Ministry of Agriculture and Land Reclamation: Cairo, Egypt, 1998; pp. 217-219.

El-Harouny, M.; El-Dakroory, S.; Attalla, S.; Hasan, N. and Hegazy, R (2009). Chemical Quality of Tap Water versus Bottled Water: Evaluation of Some Heavy Metals and Elements Content of Drinking Water in Dakhlia Governorate – Egypt. The Internet Journal of Nutrition and Wellness, 9(2): 1–15.

Elizabeth, M. and Ward, M. S. (2003). A Review: The Impact of Copper on Human Health. International Copper Associations Ltd. 19 Pages.

ElNashar, W. Y. (2014). Groundwater Management in Egypt. IOSR Journal of Mechanical and Civil Engineering, 11(4): 69-78.

EOS (2005). The Egyptian Organization for Standardization and Quality Control. Decree No. 1589/2005 for standards of natural purified drinking bottled water.

EPA (2005). Toxicological Review of Zinc and Compounds. 83 Pages. Water.epa.gov.

EPA (2013). Drinking Water Contaminants: Standards and Regulations. Water.epa.gov.

Fernández-Luqueño, F.; López-Valdez, F.; Gamero-Melo, P.; LunaSuárez, S.; Aguilera-González, E. N.; Martínez, A. I.; GarcíaGuillermo, M. S.; Hernández-Martínez, G.; Herrera-Mendoza, R.; ÁlvarezGarza, M. A. and Pérez-Velázquez, I. R. (2013). Heavy metal pollution in drinking water - a global risk for human health: A review. African Journal of Environmental Science and Technology, 7(7): 567–584.

Ganter, C. (2015). Water crises are a top global risk. Environment and Resource Security: Water. World Economic Forum (Agenda).

Hakan, T. and Anders, J. (2006). Water Scarcity Challenges in the Middle East and North Africa (MENA). Human Development Report 2006: Water for Human Development. Stockholm International Water Institute.

Hefny, K. and Shata, A. (2004). Underground water in Egypt. Ministry of Water Supplies and Irrigation, Cairo, Egypt.

International Bottled Water Association (2008). Bottled water code of practice. Alexandria, VA: IBWA. http://bottledwater.org/public/modelmain.htm.

Jasem, A.; Shammout, M.; AlRousan, D. and AlRaggad, M. (2011). The Fate of Disi Aquifer as Strategic Groundwater Reserve for Shared Countries (Jordan and Saudi Arabia), Journal of Water Resource and Protection, 3(10): 711-714.

Jones, D. C. and Miller, G. W. (2008). The effects of environmental neurotoxicants on the dopaminergic system: A possible role in drug addiction. Biochemical Pharmacology, 76: 569–581.

Khdary, N.H.M. and Gassim, A.E.H. (2014). The Distribution and Accretion of Some Heavy Metals in Makkah Wells. Journal of Water Resource and Protection, 6: 998–1010.

Khater, A. E. M.; Al–Jaloud, A. and El-Taher, A. (2014). Quality Level of Bottled Drinking Water Consumed in Saudi Arabia. Journal of Environmental Science and Technology, 7: 90–106.

Lukaski, H. C. (2006). Low dietary zinc decreases erythrocyte carbonic anyhydrase activities and impairs cardiorespiratory function in men during exercise. American Journal of Clinical Nutrition, 81(5): 1045–1051.

Marcovecchio, J. E.; Botte, S. E. and Freije, R. H. (2007). Heavy Metals, Major Metals, Trace Elements. In: Handbook of Water Analysis. L.M. Nollet, (Ed.). 2nd Ed. London: CRC Press; 275–311.

Medeiros, D. and Percival, S. (2006). Copper. Retrieved from: http://www.jn.nutrition.org/nutinfo/content/copp.shtml.

Michel, D.; Pandya, A.; Hasnain, S. I.; Sticklor, R. and Panuganti S. (2012). Water Challenges and Cooperative Response in the Middle East and North Africa. The Brookings Project on U.S. Relations with the Islamic World 2012 U.S. –Islamic World Forum Papers.

Miller, L. V.; Hambidge, K. M. and Naake, V. L. (1994). Size of the zinc pools that exchange rapidly with plasma zinc in humans: alternative techniques for measuring and relation to dietary zinc intake. Journal of Nutrition, 124: 268–276.

Mohamed, M. A. and Osman, M. A. (1998): "Lead and cadmium in Nile river water and finished drinking water in Greater Cairo, Egypt". Environment International, 24: 767 –772.

Mohod, C. V. and Dhote, J. (2013). Review of Heavy Metals In Drinking Water And Their Effect. International Journal of Innovative Research in Science, Engineering and Technology, 2(7): 2992–2996.

Morais, S.; Costa, F. G. and Pereira, M. L. (2012). Heavy Metals and Human Health, Environmental Health - Emerging Issues and Practice, Prof. Jacques Oosthuizen (Ed.), InTech, DOI: 10.5772/29869.

Murphy, M. J.; Lyon, L. W. and Taylor, J. W. (1981). Subacute arsenic neuropathy: clinical and electrophysiological observations. Journal of Neurology, Neurosurgery and Psychiatry, 44: 896–900.

Nielsen, F. (2000). Importance of making dietary recommendations for elements designated as nutritionally beneficial, pharmacologically beneficial, or conditionally essential. The Journal of Trace Elements in Experimental Medicine, 13: 113–129.

Naeem, N.; Alsanussi, H.; Almohandis, A. (1983). Multielemental and hydrochemical study of holy Zamzam water. Journal of the New England Water Works Association, 97(2): 159–169.

Osredkar, J. and Sustar, N. (2011). Copper and Zinc, Biological Role and Significance of Copper/Zinc Imbalance. Journal of Clinical Toxicology, S3: 001.

Peichert, H. (2003). The Nile Basin Initiative: a Catalyst for Cooperation. In: Brauch, H.G., Liotta, P.H., Marquina, A., Rogers, P. F., Selim, M. E. S. (Eds.), Security and Environment in the Mediterranean: Conceptualising Security and Environmental Conflicts.

Pier, S. M. (1975). The role of heavy metals in human health. Tex. Rep. Biol. Med., 33(1): 85-106.

Reilly, C. (2008). The Nutritional Trace Metals. Wiley-Blackwell. 356 pages.

Rink, L. (2011). Zinc in Human Health. 596 pages. IOS Press.

Rink, L. and Gabriel, P. (2000). Zinc and the immune system. Proc. Nutr. Soc., 59:541-52.

Sadiq, M. and Hussain, G. (2008). Drinking Water Quality in Saudi Arabia - An Overview. Arabian Journal For Science and Engineering, 22: 153–164.

Saleh, M. A.; Ewane, E.; Jones, J. and Wilson, B.L. (2001). Chemical evaluation of commercial bottled drinking water from Egypt. Journal of Food Composition and Analysis, 14(2): 127–152.

Salman M. A. S. (2013): The Nile Basin Cooperative Framework Agreement: a peacefully unfolding African spring? Water International, 38(1): 17-29.

Sarkar, B. (2002). Heavy Metals In The Environment. CRC Press. 712 pages.

SASO (2009). Bottled and Unbottled Drinking Water. Standard No. 409.

Shomar, B. (2012). Zamzam water: Concentration of trace elements and other characteristics. Chemosphere, 86(6): 600-605.

UNESCO (2007). Water Portal newsletter. No. 161: Water-related Diseases. www.unesco.org/water/news/newsletter/161.shtml.

US/SA Business Council (2015). The Water Sector in the Kingdom of Saudi Arabia U.S. - Saudi Arabian Business Council. www.us-sabc.org.

U.S. Environmental Protection Agency (US EPA). National primary drinking water regulations. 2011. http://www.epa.gov /safewater/mcl.html

U.S. Food and Drug Administration (FDA). 21 CRF part 165: Beverages: Bottled water. 2008, http://www.cfsan.fda.gov /~Ird/fr050609.html.

Vengosh, A.; Hirschfeld, D.; Vinson, D.; Dwyer, G.; Raanan, H.; Rimawi, O.; Al-Zoubi, A.; Akkawi, E.; Marie, A.; Haquin, G.; Zaarur, S.; Ganor, J. (2009). High Naturally Occurring Radioactivity in Fossil Groundwater from the Middle East. Environmental Science and Technology, 43(6): 1769–1775.

Wastney, M. E.; Aamodt, R. L. and Rumble, W. F. (1986). Kinetic analysis of zinc metabolism and its regulation in normal humans. American Journal of Physiology, 251: R398–R408.

Watts, D. L. (1988). The Nutritional Relationships of Zinc. Journal of Orthomolecular Medicine, 3(2): 63–67.

Wiseman, J. and El-Baz, F. (2007). Remote Sensing in Archaeology. Interdisciplinary Contributions to Archaeology. Springer, New York, 553p.

World Health Organization (2008). Guidelines for Drinking Quality. 3rd Edn. Geneva. Switzerland.

WHO (2012). Arsenic in drinking-water. Background document for development of WHO guidelines for drinking-water quality. 24 pages.