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EVALUATION OF DRINKING WATER QUALITY IN SOME URBAN AREAS IN NORTH SINAI, EGYPT

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ABSTRACT: This study was conducted to evaluate the quality of drinking water supplied by eight water stations *i.e.,* 1st East Qantara, 2nd Baluza, 3rd Rummaneh, 4th Rabaa, 5th Bir El-Abed, 6th Talol, 7th Al-Arish and 8th Al-Risa stations in the coastal strip of North Sinai Governorate, Egypt. The samples were taken monthly from December 2018 to June 2019. The study included the bacteriological assays *i.e.,* presumptive, confirmed and completed tests as well as performed a bacterial count of *Escherichea coli* bacteria using Most Probable Number (MPN) and some physiochemical parameters (pH, Electrical conductivity, chlorides, bicarbonate, sulfate, calcium, magnesium, sodium, potassium and iron ions contents. The bacteriological results (quantitative and qualitative tests) indicated that Baluza, Rabaa, Rummaneh, Bir El-Abed, Talol and Al-Risa drinking water stations were the most contaminated with *E. coli* and found to be non-potable. While, the East Qantara and Al-Arish drinking water stations being the least contaminated. If the contamination level is high the Government should demand for proper chlorination, but this process needs the hands of an expert chemist, as extra chlorination is harmful to human health. The pH and EC of most of the eight water stations under the study within the limits of World Health Organization and Egyptian standards for drinking water quality, except for the sample of the Rummaneh station in January, while the Rabaa station recorded the highest pH values in June. The water sample of the Rabaa station recorded the lowest EC values during December, while a water sample of Balouza station recorded the highest values during May. All cations (Ca^+, Mg^+, Na^+ and K^+) and anions (HCO_3^-, Cl^- and $SO4^{--}$) for all eight stations under study were within the permissible limits. The physicochemical tests of most of the eight water stations under the study were within the limits of the naturalization approved by the World Health Organization except Al-Arish station has exceeded the iron ion values of the WHO. Therefore, it should be recommended that the main water stations should be isolated from the weather, periodic maintenance and disinfection of water tanks to overcome the increase in iron concentration. The main water lines, which were made of iron harmful to human health, should be changed to be replaced by pressurized polyethylene pipes recommended by the World Health Organization and US. EPA.

Key words: Drinking water, water supply, physiochemical parameters and bacteriological assays.

INTRODUCTION

Water is one of the most important determinants of development. It affects the type of economic activity, its size, and its status. The importance of water and its role on the development aspects of Egypt has increased with the increasing need for it due to the large population increase and the noticeable rise in the standard of living and the urban, agricultural and industrial expansion (**Mahdii *et al.,* 2016**). Egypt's challenges of managing its limited fresh water resources in sustainable ways and providing sufficient amounts of water to its population that is for human consumption pose real problems to the daily lives of people in rural, Egypt. Some of Egypt's remote rural areas like North Sinai Governorate still lack a reliable, safe drinking water source. Although some drinking water quality studies found a compliance

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with national and WHO standards in urban areas **(Mohamed and Osman, 1998; Saleh *et al.,* 2001)**. The major limitations for development of Sinai Peninsula are the available water resources **(Abdel-Shafy *et al.,* 2010)**. Therefore, additional water should be secured, *e.g.,* the reuse of agriculture drainage water and/or adequate treated wastewater **(El-Degwi *et al.,* 2003; Abdel-Shafy *et al.,* 2013)**.

Despite the importance of water for humans, there are many problems that lead to water pollution, which leads to a defect in the ecosystem in one way or another, which reduces its ability to perform its natural role, but become harmful when used **(Al-Saadi, 2002)**. Other authors **El-Bahnasy *et al.* (2014) and Mandour (2012)** identified problems with drinking water contamination in rural areas due to heavy metals pollution, high levels of ammonia, iron and manganese, as well as chemical and biological contamination that exceed Egyptian standards. One of the reasons for the unreliability of health standards is a lack of disinfectants, such as chlorine, as well as issues with correct dosing and automatic monitoring of exact concentrations in the water. Contamination of drinking water sources both by biological or chemical contaminants has been a quite common scenario in an over-crowded country like Egypt. Both ground water and surface water may get microbiologically contamination by a variety of means including agricultural runoff, sanitation difficulties, accumulation of minerals, *etc.* **(Geldreich, 1990; Grabow *et al.,* 1996; WHO, 2008).** Fecal coliform group used as an indicator of fecal contamination in water, presence of coliforms in treated drinking water may be due to ineffective or poor application of water treatment techniques **(Acharjee *et al.,* 2013; Ahmed *et al.,* 2013)** or deterioration of the infrastructure of the water system (**Aenab and Singh, 2012).** Rapid detection of coliforms in drinking water is therefore necessary which can easily be carried out by Most Probable Number (MPN) method, a qualitative test to detect coliform and thereby to determine simply the potability or safety of water **(WHO, 2011)**. Also, water may contain toxic metals which can cause acute or chronic poisoning and should be eliminated from drinking water, if possible. Several metal ions such as sodium, calcium and magnesium are essential to sustain biological life. Iron is an essential mineral, but when it gets into our drinking water, it needs to be removed **(WHO, 2008)**. While a low level of iron isn't harmful in and of itself, iron in drinking water is classified as a secondary contaminant according to the **EPA (2006)**. This is because iron often carries with it bacteria that feed off the iron to survive. These small organisms can be harmful when digested **(Tayyeb *et al.,* 2004)**. In addition, if iron levels are too high, serious health effects can develop, including iron overload. Iron overload is caused by a mutation in the gene that digests iron. Iron overload can lead to hemochromatosis, which can lead to liver, heart and pancreatic damage, as well as diabetes. Early symptoms include fatigue, weight loss, and joint pain. Excessive iron is never recommended for digestion; it can lead to stomach problems, nausea, vomiting, and other issues **(El-Harouny *et al.,* 2009; WHO, 2011)**.

In areas where no attention is paid to water treatment programs due to difficult access, or that these areas do not contain wastewater treatment plants. To ensure water safety, water samples, bacteriological analyzes, and chlorine testing are taken **(Aenab and Singh, 2012)**. The United Nations Environment Program (UNEP) are interested in water-borne diseases and control. This leads to great attention to microbial contamination in water, especially public health studies. The World Health Organization reports that 80% of human diseases related to water pollution with microbial pathogens **(WHO, 2011).** Hence, an understanding of microbiological quality and safety of drinking water has been become important **(Roy *et al.,* 2013)**. Therefore, water quality control is very important in many parts of the world **(WHO, 2011).** Determination of physical and chemical parameters is also very important to evaluate water quality **(Dissmeyer, 2000).** The aim of this study to evaluate the drinking water quality in the coastal strip of North Sinai, Egypt according to the World Health Organization **WHO (2017)** and Egyptian standards of water quality **(ES, 2007)** guidelines.

MATERIALS AND METHODS

Study Area and Sampling

This study was conducted at the Environmental Protection Laboratory and the

Microbiology Laboratory at the Faculty of Environmental Agricultural Sciences, Arish University. The aim was to evaluate the drinking water quality for eight water stations obtained from different locations in Sinai Peninsula, Egypt namely East Qantara, Baluza, Rummaneh, Rabaa, Bir El-Abed, Talol, Al-Arish and Al-Risa stations (Fig. 1). The drinking water (DW) samples were collected for testing from different areas of eight stations monthly from December 2018 to June 2019, to ensure the quality of water in these areas and their eligibility to drink according to the World Health Organization **WHO (2017)** and Egyptian standards of water quality **(ES, 2007)**.

The DW samples have been collected in sterile sampling brown bottles and immediately stored in a chilled insulation containers preferably at 4°C in order to prevent the overgrowth of bacteria which may result in false bacterial counts **(APHA, 2005).**

Microbiological Assays

Microbiological assays had been done directly after collection from eight water stations in sterilized glass bottles.

Qualitative analysis through MPN method

Presumptive test

The presumptive test aimed to detect the Gram negative coliform bacteria in the water samples. For this task, 120 series of test tubes containing 10 ml of lactose fermentation broth were needed for each sample. DW samples (10, 1 and 0.1 ml) were added sequentially in 5 test tubes containing 10 ml lactose fermentation broth. Each tube was incorporated with a Derhum tube indicating gas formation after lactose fermentation by coliform bacteria after 24 or 48 hr., **(Cappuccino and Sherman, 1996; APHA, 2005 and Ahmed *et al.,* 2013).**

Confirmed test

The test tubes showing positive results by the accumulation of gas in the Derhum tubes were selected for the confirmed test to determine the presence of *Escherichia coli* in the respective water samples. The loopful samples from the broth which gave positive result in the presumptive test, were inoculated on eosin methylene blue (EMB) agar to detect as well as differentiate *Escherichia coli* and other Gram negative coliform bacteria. The plates were incubated at 37°C for 24 hr., **(Cappuccino and Sherman, 1996; APHA, 2005; Ahmed *et al.,* 2013).**

Completed test

This is the final part of the MPN test procedure which was completed after the confirmation of the indicator bacteria *E. coli* found in the EMB medium. The suspected *E. coli* from a single colony of green metallic sheen was introduced into a lactose fermentation broth again for the assurance of the gas production after fermentation of lactose. Gram staining was also performed for the confirmation of *E. coli* isolates **(Cappuccino and Sherman, 1996; APHA, 2005; Roy *et al.,* 2013).**

Quantitative tests

This test aims to perform a bacterial count of *E. coli* bacteria using Most Probable Number (MPN) were examined according to **APHA (2005) and WHO (2011).** Each sample about 0.1 ml of suspension was spread on plates nutrient agar (NA) for enumerating total viable bacteria (TVB). After incubation at 37°C for 24 hr., plates were examined. For estimating the total fecal coliform bacteria, 100 ml of water sample was passed through the membrane filter which was then put over membrane fecal coliform (MFC) medium and incubated at 44.5°C for 48 hr. **(Oliver, 2010; Rahman and Noor, 2012; Acharjee *et al.,* 2013; Noor *et al.,* 2013).**

Physicochemical tests of water

This test was conducted at the soil and water Dept. Laboratory at the Faculty of Environmental Agricultural Sciences, Arish University, Egypt. Water samples were collected and storage procedures should be kept at a smallest time interval for physicochemical analysis. Sample was stored in glass brown bottles at approximately 4°C in the dark. Sample bottles must be clean properly disinfection is not recommended **(Jain *et al.,* 2018)**.

Measurement of pH

At the time of sample collection, pH of all eight water samples were measured with the help of portable electrically operated pH meter (Model GLP pH/ORP meter WTW 720) with

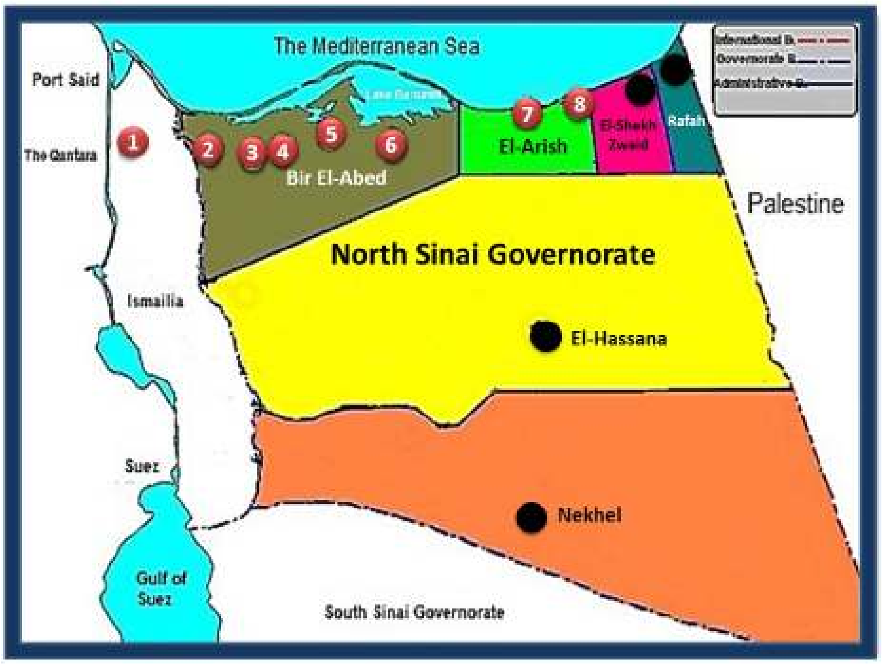

Fig. 1. A map of the Sinai Peninsula showing water sampling areas from water stations: (1) East Qantara, (2) Baluza, (3) Rummaneh, (4) Rabaa, (5) Bir El-Abed, (6) Talol , (7) Al-Arish and (8) Al-Risa

the help of glass electrode. The standard of water quality on pH base lies in the range of 6.5 to 8.5 **(WHO, 2017)**.

Electrical conductivity (EC)

The electrical conductivity of water samples were measured using pre-calibrated conductivity meter Model 3540, England. Before measurement, the beaker and conductivity cell must be washed several times in the distilled water and the measurements were taken at 25^{o}C. The instrument was calibrated first with standard KCl solution at 0.01 D. Then the samples were taken into the beaker, in enough capacity to dip the electrode, after that the button was adjusted to desired conductivity scale conductivity of each sample was then noted **(WHO, 2011)**.

Measurement of chlorides

This test is for the determination of chloride ions. These chlorides are in the salt form of sodium, potassium, calcium, magnesium *etc.* The permissible limit of chloride content in water is 260 mg/liter according to **WHO (2011)**. A solution of potassium chromate is used as indicator. Chlorides are precipitated as brick red in the solution because silver ion reacts with chloride ion forming brick red precipitate of AgCl, end point is the brick red coloration.

Measurement of bicarbonate and sulfate

Alkalinity is the measure of bicarbonate and sulfate ion content of water sample. Water sample is titrated with standard H_2SO_4 using indicator. Pink color of solution changes to colorless. This is the indication of end point. The alkalinity range set by **WHO (2011)** is 500 mg/l.

Measurement of calcium and magnesium

Calcium (Ca^{+}) and magnesium (Mg^{+}) measured according to standard methods **(APHA, 2005)**.

Measurement of sodium and potassium

Flame photometric estimation of sodium (Na^{+}) and potassium (K^{+}) ions using Flame photometer according **Chikhale and Pratibha (2017).**

Measurement of iron

The concentration of the iron ion (Fe^{+2}) was estimated in eight water samples using the atomic absorption method according to **APHA**

(2005) and Mahdii *et al.* (2016) at the Agricultural Research Center, Ismailia Governorate, Egypt. The World Health Organization have established well-defined standards for drinking water purity. The regulations limit the amount of iron to less than 0.3 mg.l^{-1} in municipal drinking water.

Statistical Analysis

This experiment was set in a randomized complete design (RCD) with 5 replicates of each station. DW samples were collected randomly from eight stations in the Sinai Peninsula, Egypt. Data were statistically analyzed using MSTATEC computer program **(Russell, 1986)**. Means values were then compared using Duncan's multiple range test at (0.05) level of significance **(Duncan, 1955).**

RESULTS AND DISCUSSION

Microbiological Assays

Qualitative analysis through MPN method

Presumptive test

The results in Table 1 and Fig. 1 indicate that accumulation of gas and colored yellow in the incorporated Derhum tubes was observed in variable number of tubes of all the eight drinking water samples tested which indicated the possible presence of coliform. The lowest count of MPN/100 ml was 2 which was detected in East Qantara and Al-Arish stations, followed by Al-Risa, Bir El-Abed and Talol stations (MPN/100 ml 21, 49 and 140), respectively. Most of the DW samples (Baluza, Rummaneh and Rabaa stations) showed the highest number ($\geq$ 2400) of MPN/100 ml. These results were in agreement with **Chandrima *et al.* (2013)**, they reported that yellow color tubes indicate the positive result of presence of bacterial contamination whereas no change in color of lactose broth medium shows no bacterial growth after 24 hr., from incubation of drinking water samples in India. The presence of the indicator bacteria did not necessarily mean that the fecal contamination was present. It only projected the chance of fecal contamination, although the samples tested in this study were treated by boiling, filtration. There might be a possibility that even after processing, the samples were contaminated with bacteria as a result of improper boiling, improper filtration, reuse of the same filter for many times without washing or changing during the filtration, collecting the water in jars or cans which might not have been properly washed or were washed by focally contaminated water **(Acharjee *et al.,* 2013; Ahmed *et al.,* 2013).**

Confirmed and completed tests

Results in Table 2 reveal that the positive samples which found in presumptive test, only 6 samples (Baluza, Rabaa, Rummaneh, Bir El-Abed, Talol and Al-Risa) showed to be positive for the presence of the indicator *Escherichia coli* by observing the green metallic sheen on EMB agar plates (Table 2). The presence of *E. coli* isolates was further confirmed by observing the gas formation in lactose fermentation broth and also by visualizing Gram negative, short rod cells under the bright field microscope.

Concerning, the completed test data in Table 2 showed that the microscopic examination of the water samples under study revealed the presence of red-colored *E. coli* in Baluza, Rabaa, Rummaneh, Bir El-Abed, Talol and Al-Risa bacteria in the form of *Bacillus* bacteria (presumptive and confirmed tests). However, there are no positive results of bacterial contamination with drinking water samples for both East Qantara and Al-Arish stations and satisfactory to be categorized as potable water compared to the **WHO (2017)** and **ES (2007)** guideline values. These results were in agreement with **Chandrima *et al.* (2013), Ahmed *et al.* (2013) and Jain *et al.* (2018)**. Therefore, it was assumed that the overall quality of drinking water sample was not satisfactory to be categorized as potable water heading a major source for public health associated problems experienced frequently **(Ahmed *et al.,* 2013).**

Quantitative test

The quantitative test of microbiological quality drinking water was evaluated by monitoring of total bacterial counts indicator in 1 cm^3 of pollution in water stations from Sinai Peninsula, Egypt. The results in Table 3 indicate that the total bacterial counts of

Table 1. Presumptive test for drinking water to detect the presence of coliform group according to ES (2007) and WHO (2017) guideline values

Water source	Mean of test tubes (containing 10 ml lactose fermentation broth)			MPN/100 ml
	10 ml	1 ml	0.1 ml	
East Qantara	0	0	1	**2**
Baluza	5	5	5	**≥2400**
Rummaneh	5	5	5	**≥2400**
Rabaa	5	5	5	**≥2400**
Bir El-Abed	5	2	0	**49**
Talol	5	3	2	**140**
Al-Arish	0	1	0	**2**
Al-Risa	4	1	1	**21**

Fig. 2. The gas accumulation and yellow color in the Durham tubes in the presumptive test

Table 2. Confirmed and completed tests for drinking water to detect the presence of fecal coliform group according to ES (2007) and WHO (2017) guideline values

Water source	Confirmed test	Completed test	Results
East Qantara	-	-	Potable
Baluza	+	+	Non potable
Rummaneh	+	+	Non potable
Rabaa	+	+	Non potable
Bir El-Abed	+	+	Non potable
Talol	+	+	Non potable
Al-Arish	-	-	Potable
Al Risa	+	+	Non potable

Table 3. The fecal coliform bacteria count of water sample in 1 cm^3 of Sinai Peninsula, Egypt compared to ES (2007) and WHO (2017) guidelines values

Water source	Total fecal coliform bacteria count (CFU. ml^{-1})								Guided values
	December	January	February	March	April	Mai	June	Mean	
East Qantara	45 g	44 e	56 e	59 d	65 d	66 e	87 e	60.29	**<100**
Baluza	192 c	211 b	189 c	165 c	225 b	257 b	310 bc	221.29	
Rummaneh	166 e	170 c	181 c	210 b	195 bcd	236 c	366 b	217.71	
Rabaa	227 b	325 a	300 b	320 ab	345 a	350 a	356 b	317.57	
Bir El-Abed	176 d	174 c	189 c	193 b	203 bc	234 c	245 c	202.00	
Talol	320 a	332 a	343 a	357 a	358 a	369 a	444 a	360.43	
Al-Arish	34 h	44 e	45 e	49 e	45 d	55f	67 f	48.43	
Al-Risa	144 f	156 d	178 d	167 c	189 cd	192 d	195 d	174.43	

Al-Arish and East Qantara stations under the study within the limits of the naturalization approved by the World Health Organization **WHO (2017)** and Egyptian standards of water quality **(ES, 2007)**. Highest total bacterial counts recorded at Talol station (360.43 CFU. ml^{-1}), followed by Rabaa station (317.57 CFU. ml^{-1}), while the lowest mean value of total bacterial count was recorded at Al-Arish (48.43 CFU. ml^{-1}) compared to **WHO (2017)** and **ES (2007)**. The statistical analysis shows significant differences between the stations during months, the highest reading was recorded in June at the Talol station (444 CFU. ml^{-1}). While, the lowest reading (34 CFU. ml^{-1}) was recorded in December at the Al-Arish station. These results were in agreement with **Mahdii *et al.* (2016).** The causes of this bacterial contamination may be attributed to the increase of temperature and the low concentration of chlorine used to sterilize and disinfect water from pathogens, or lack of closure of tank covers, characterized by water retention and high water temperature, which causes the growth and spread of green algae and bacteria, or is mixed with water when transported from reservoirs to the residential areas sewage water due to cracks or broken water pipe. The greatest microbial risks are associated with drinking water occur through ingestion of water that is contaminated with human or animal faeces **(Cabral, 2010).** Wastewater discharges in fresh waters and coastal seawaters are the major sources of fecal microorganisms, including pathogens **(Abd El-Salam *et al.,* 2017).**

Physicochemical Tests of Water

Measurement of pH

The results in Table 4 show that the pH of most of the eight water stations under the study within the limits of the naturalization approved by **ES (2007)** and **WHO (2011)**, mean values for pH was unstable through the study period which ranged between 6.03-7.58. The highest pH value was recorded in June at Rabaa station (8.00), while the lowest pH value was recorded in January at the Rummaneh station (5.99) (Fig. 3). Statistical analysis showed significant differences for pH mean values between stations through study period. These results are in agreement with **Mahdii *et al.* (2016)**. The increase in pH in water samples could be related to photosynthesis and growth of aquatic plants **(Abd El-Salam *et al.,* 2017)**.

Electrical conductivity (EC)

The results from Table 4 indicate that the electrical conductivity (EC) of eight water stations under the study were acceptable according to limits of the Egyptian specification **(ES, 2007)** and the World Health Organization guidance value **(WHO, 2017).** The statistical analysis shows significant differences between the stations, the highest reading was recorded in May at Baluza station (0.51 dS.m^{-1}), while, the lowest reading (0.35 dS.m^{-1}) was in December at the Rabaa station (Fig. 4). High electrical conductivity in May may be due to the high temperature that dissolve the salts and increase the conductivity of water **(Abd El-Salam *et al.,* 2017)**.

Table 4. Mean values of physicochemical tests drinking water of different stations from North Sinai compared to ES (2007) and WHO (2017) guidelines values

Water source	pH	EC ($dS.cm^{-1}$)	Anions ($mg.l^{-1}$)			Cations ($mg.l^{-1}$)				
			Cl^-	HCO_3^{--}	SO_4^{--}	Ca^{++}	Mg^{++}	Na^+	K^+	Fe^{++}
East Qantara	7.10 c	0.42 ab	2.09 ab	1.31 c	0.70 b	1.48 bc	1.30 a	0.90 ab	0.38 ab	0.19 b
Baluza	7.58 a	0.49 a	2.22 a	1.70 a	0.90 a	1.87 a	1.39 a	1.10 a	0.50 a	0.11 c
Rummaneh	6.03 d	0.39 ab	1.91 b	1.50 b	0.50 c	1.40 bc	1.20 a	0.69 c	0.60 a	0.12 c
Rabaa	7.64 a	0.36 b	1.58 d	1.22 c	0.69 b	1.69 b	1.29 a	0.31 d	0.22 b	0.15 bc
Bir El-Abed	7.43 ab	0.36 b	1.71 c	1.51 b	0.90 a	1.11 c	1.39 a	0.78 bc	0.40 ab	0.27 ab
Talol	7.32 b	0.37 b	1.69 c	1.24 c	0.91 a	1.18 c	1.31 a	0.81 abc	0.49 a	0.23 ab
Al-Arish	7.21 bc	0.38 ab	1.68 c	1.50 b	0.50 c	1.77 ab	1.30 a	0.62 c	0.30 b	0.36 a
Al-Risa	7.11 c	0.39 ab	2.06 ab	1.30 c	0.61 c	1.70 b	1.34 a	0.61 c	0.41 ab	0.12 c
ES (2007) g.v	6.5 – 9.0	1.56≤	250	400	250	200	50	200	12.0	0.30
WHO (2017) g.v	6.5 - 8.5	1.56≤	200	400	400	200	50	175	12.0	0.30

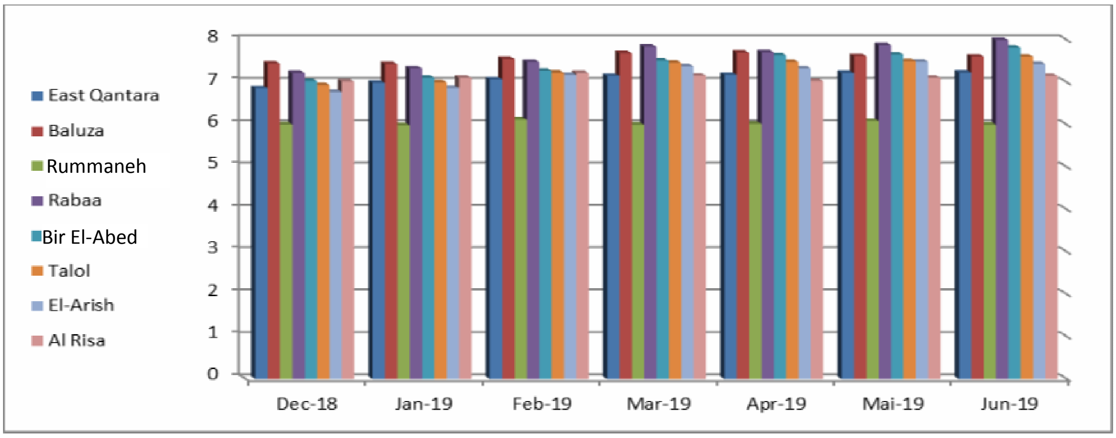

Fig. 3. The pH values of the DW samples of different North Sinai's stations from December 2018 to June 2019 compared to ES (2007) and WHO (2017)

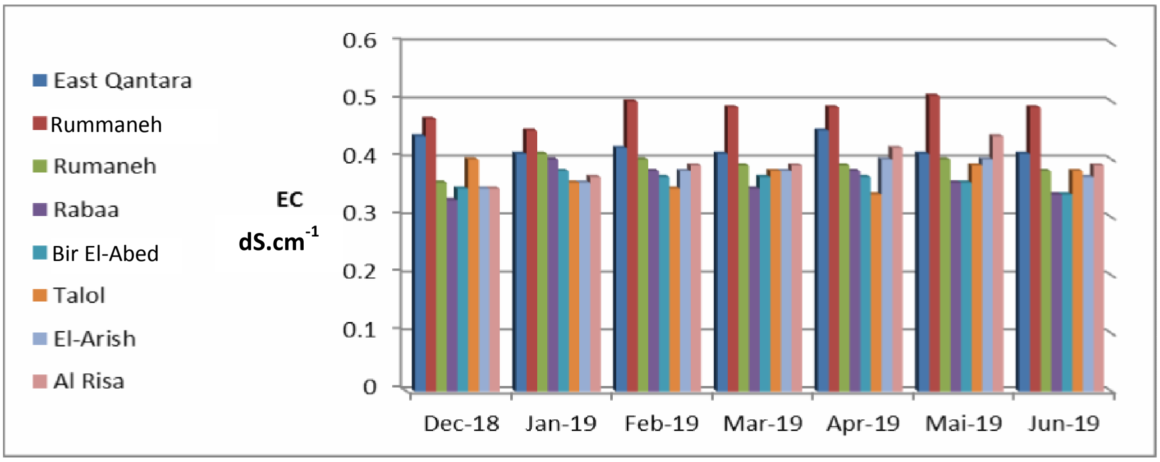

Fig. 4. The EC values of the DW samples of different North Sinai's stations from December 2018 to June 2019 compared to ES (2007) and WHO (2017)

Measurement of chloride

Results in Table 4 and Fig. 5 show that mean values for Cl^- <200 $mg.l^{-1}$ were acceptable for Egypt specification **(2007)** and the World Health Organization **(WHO, 2017)**. The statistical analysis shows significant differences between the stations. Cl^- recorded the lowest reading (1.44 $mg.l^{-1}$) in December at Rabaa water station and the highest reading (2.33 $mg.l^{-1}$) in June at the Baluza water station. Chloride readings tend to be high in June for the eight stations may be the treatment plant increased chloride addition to drinking water as precaution especially in summer season to destroy all pathogens **(Al-Qaisi, 2005)** or indication a possible problems like breakage in water distribution system **(EPA, 2006).**

Measurement of bicarbonate and sulfate

Results of Table 4 and Figs. 6 and 7 indicate that mean values for HCO_3^- and $SO4^{--}$ anions for the eight samples under study were within the permissible limits compared to **Egypt Specification (2007) and WHO (2017)** standard limits. Fig. 6 illustrated that HCO_3^- recorded the lowest reading (1.30 $mg.l^{-1}$) in December at the Rabaa and Talol stations, while the highest reading (1.74 $mg.l^{-1}$) was recorded in February at Baluza station. As for SO_4^{--}, from Fig. 7 recorded the lowest reading (0.45 $mg.l^{-1}$) in December at the Rummaneh water station and the highest reading (1.03 $mg.l^{-1}$) in June at Bir El-Abed water station compared to other stations.

Measurement of calcium and magnesium

Results in Table 4 illustrate that means values of Ca^{+2} and Mg^{+2} cations for the eight stations under study were within the acceptable limits compared to **Egyptian specification (2007)** and World Health Organization **(WHO, 2017)** guidance values. Ca^{+2} recorded the lowest reading (1.11 $mg.l^{-1}$) at Bir El-Abed station and the highest reading (1.87 $mg.l^{-1}$) at Baluza station. Fig. 8 show that Ca^{+2} recorded the lowest reading (1.09 $mg.l^{-1}$) in December at Ber El-Abed station and the highest Ca^{+2} reading (1.97 $mg.l^{-1}$) in June at Baluza station compared to other stations. These results are in harmony with those previously reported by **Mahdii *et al.* (2016) and Abdel-Shafy *et al.* (2016)**. Explain the effect of temperature changes on CO_2 level which in turne increases calcium dissolving in water **(Maulood *et al.,* 1990).**

Results in Fig. 9 indicate that mean values for Mg^{+2} <50 $mg.l^{-1}$ were acceptable **for Egypt Specification (2007)** and World Health Organization **(WHO, 2017)**. Mg^{+2} recorded the lowest reading (1.11 $mg.l^{-1}$) at the Rummaneh station in December and the highest reading (1.45 $mg.l^{-1}$) at Baluza station in June. No significant differences between all stations on Mg^{+2} values. High readings for Mg^{+2} in June (summer) may be caused by dust storms **Mahdii *et al.* (2016)**, because the metal structure(Ca^{+2} and Mg^{+2}) of dust particles leads to increase the metals concentration in water **(Kim *et al.,* 1998).**

Measurement of sodium and potassium

Mean values of Na^+ and K^+ in the collected drinking water samples are given in Table 4. The mean level of sodium and potassium were ranged from 1.10 to 0.31 $mg.l^{-1}$ and from 0.60 to 0.22 $mg.l^{-1}$, respectively. The acceptable guideline of these metal ions in drinking water is 175 $mg.l^{-1}$ for Na^+ and 12 $mg.l^{-1}$ for K^+ **(WHO, 2017)**. From these results it could be reported that the detected characteristics of drinking water samples are within the acceptable levels according to the **Egyptian Specification (2007)** and the World Health Organization **(WHO, 2017)** guidance values.

Results in Fig. 10 show that Na^+ recorded the lowest reading (0.23 $mg.l^{-1}$) in December at Rabaa station and the highest reading (1.20 $mg.l^{-1}$) in April at the Baluza station. Fig. 11 indicated that K^+ recorded the lowest reading (0.18 $mg.l^{-1}$) in December at the Rabaa station and the highest reading (0.63 $mg.l^{-1}$) in April and June at Rummaneh water station. These results are in harmony with that mentioned by **Abdel-Shafy *et al.* (2016)**.

Measurement of iron

Results in Table 4 reveal that mean values of iron in DW samples of different stations ranged from 0.36 to 0.11 $mg.l^{-1}$. The acceptable guideline of these metal ions in drinking water is 0.30 $mg.l^{-1}$. Results in Fig. 12 show that Fe^{+2} recorded the lowest reading (0.10 $mg.l^{-1}$) in December at the Baluza station and the highest

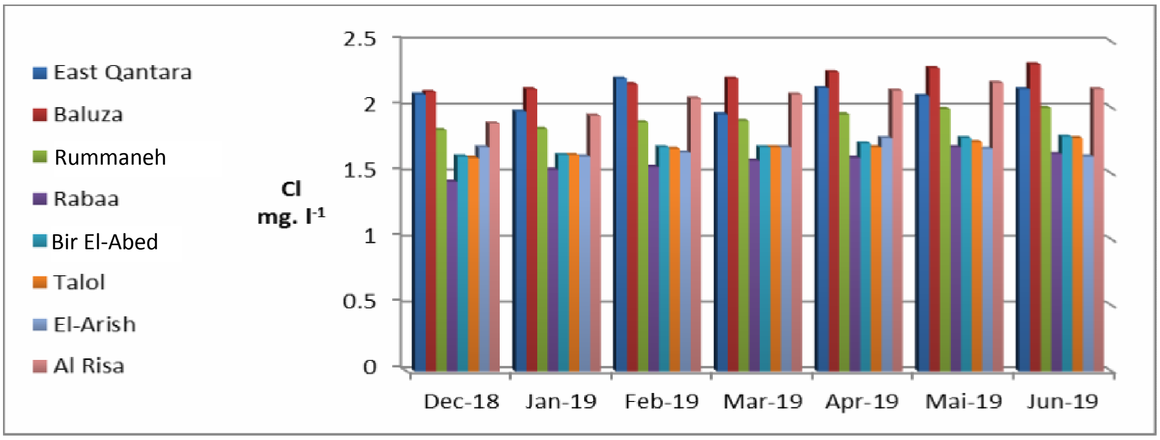

Fig. 5. The chloride content of the DW samples of different North Sinai's stations from December 2018 to June 2019 compared to ES (2007) and WHO (2017)

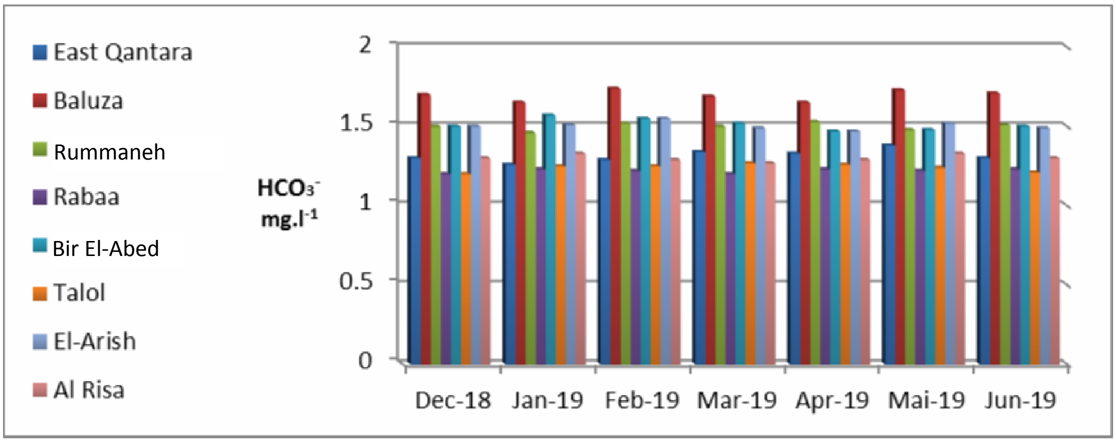

Fig. 6. The bicarbonate content of the DW samples of different North Sinai's stations from December 2018 to June 2019 compared to ES (2007) and WHO (2017)

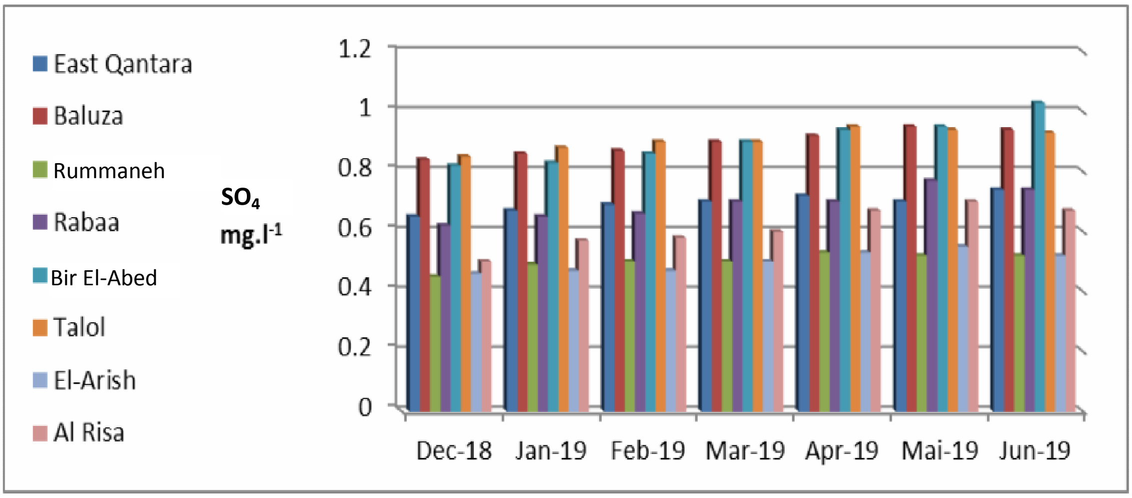

Fig. 7. The sulfate content of the DW samples of different North Sinai's stations from December 2018 to June 2019 compared to ES (2007) and WHO (2017)

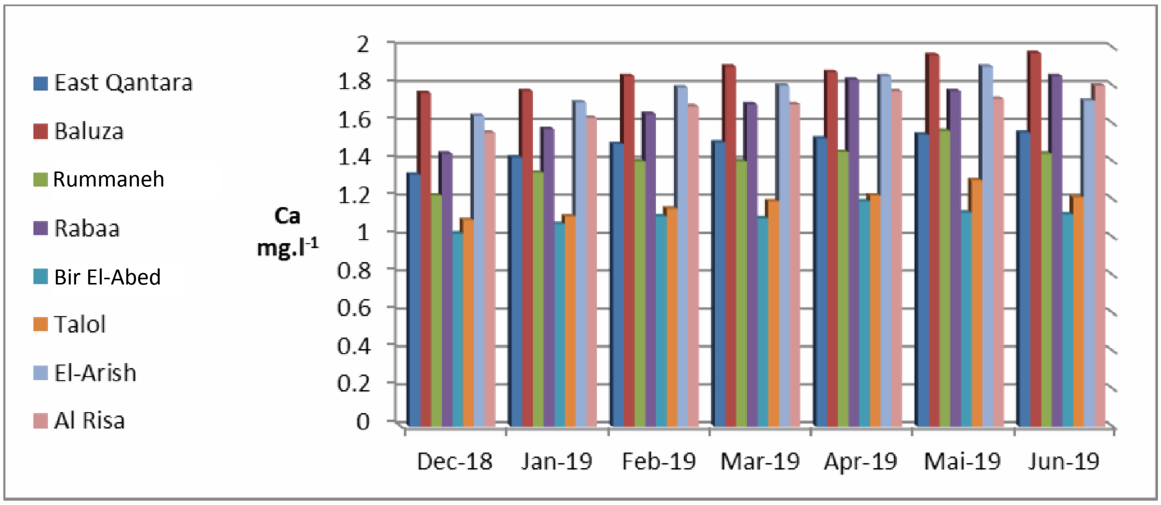

Fig. 8. The Ca^{+2} content of the DW samples of different North Sinai's stations from December 2018 to June 2019 compared to ES (2007) and WHO (2017)

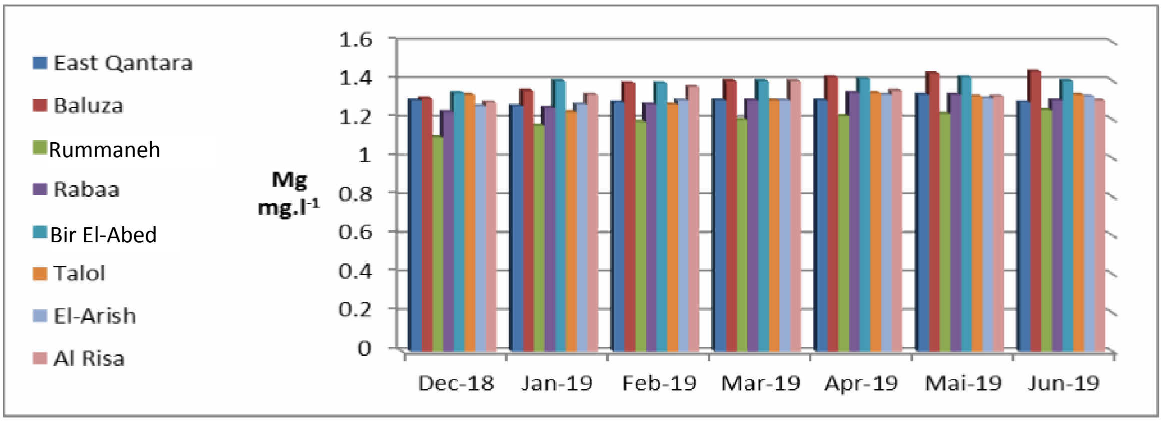

Fig. 9. The Mg^{+2} content of the DW samples of different North Sinai's stations from December 2018 to June 2019 compared to ES (2007) and WHO (2017)

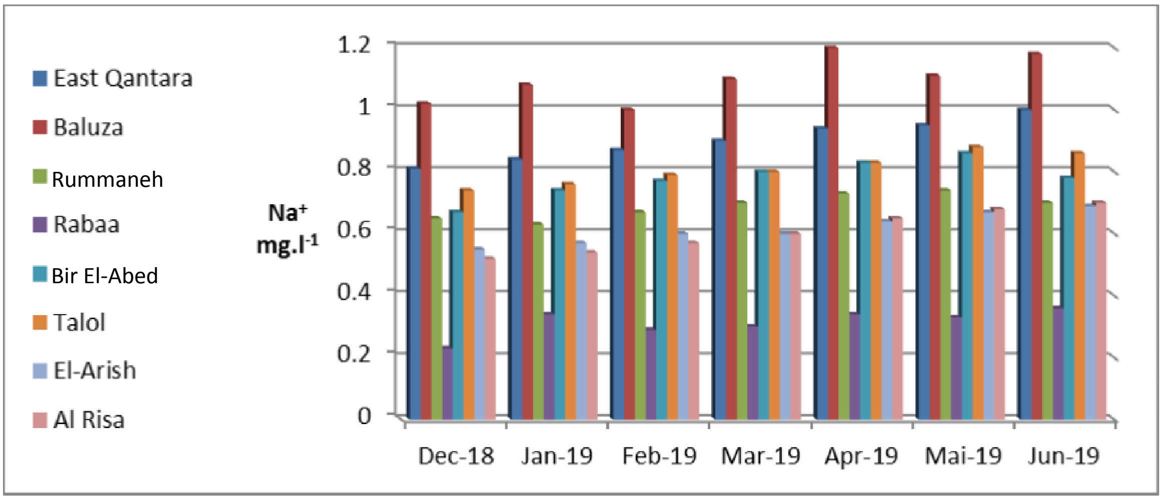

Fig. 10. The Na^{+} content of the DW samples of different North Sinai's stations from December 2018 to June 2019 compared to ES (2007) and WHO (2017)

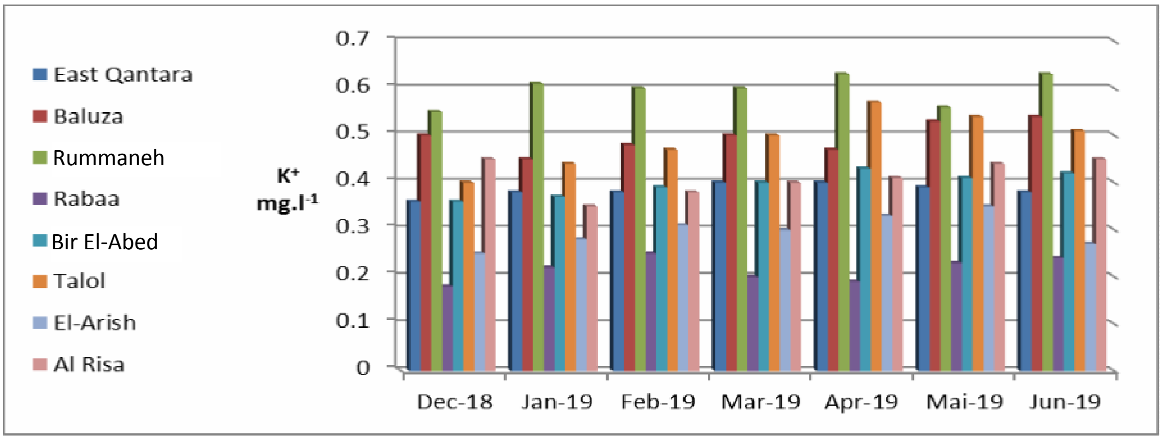

Fig. 11. The K^{+} content of the DW samples of different North Sinai's stations from December 2018 to June 2019 compared to ES (2007) and WHO (2017)

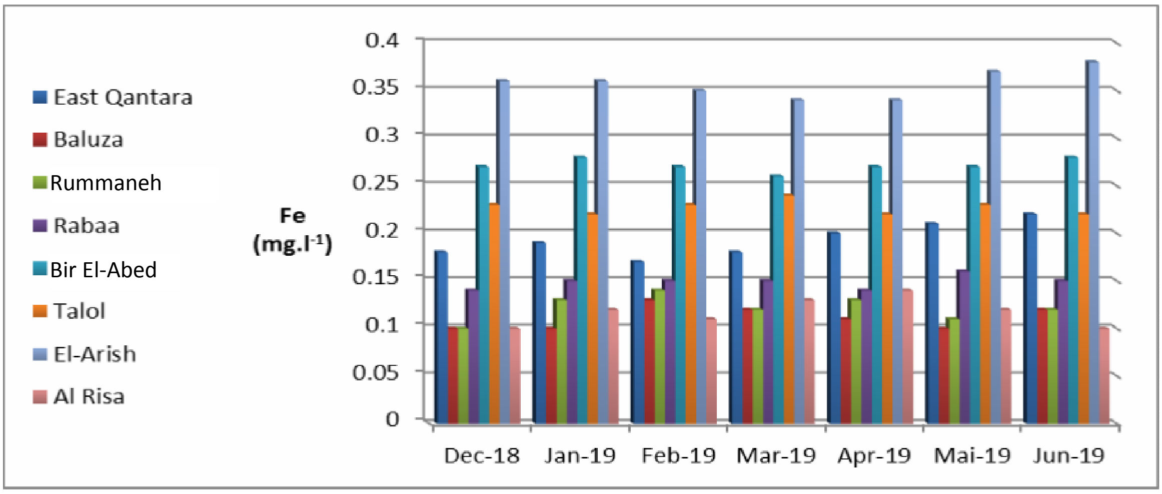

Fig. 12. The Fe^{+2} content of the DW samples of different North Sinai's stations from December 2018 to June 2019 compared to ES (2007) and WHO (2017)

reading (0.38 mg.l^{-1}) in June at the Al-Arish station. The most DW stations are within the relatively acceptable limits of **WHO (2017)** and **ES (2007)** except Al-Arish station has exceeded the iron ion values of the World Health Organization. The increase of Fe^{+2} content in the water samples may be due to two important factors: the first is the lack of attention to the maintenance process inside the body of the tank or tank cover, or the aging of the water pipes themselves and their interaction with drinking water. Secondly, the increase in the concentration of Fe^{+2} ion in water may be due to the sterilization of water with chloride instead of ozone, which is able to convert the Fe^{+2} ion into an insoluble form (Fe^{+3}) and remove it by filtration **(Nokes, 2008)**.

Conclusion

Finally, it can be concluded that:

- The Baluza, Rabaa, Rummaneh, Bir El-Abed, Talol and Al-Risa drinking water stations were found to be the most contaminated and then East Qantara and Al-Arish drinking water stations, being the least contaminated.
- If the contamination level is high (Baluza, Rummaneh, Rabaa and Talol stations), the user should demand for proper chlorination, but this process needs the hands of an expert chemist, as extra chlorination is harmful to human health.
- Higher MPN index indicates the presence of greater number of bacteria in drinking water

and presence of *E. coli*, in DW samples confirmed the presence of fecal contaminants in DW. *E. coli* is considered to be more closely associated with fecal contamination.

- Change the main water lines to be non-metallic plastic pressed according to the specifications of the World Health Organization, covering the tanks, and maintenance of maintenance ladder inside the body of the tank so as to overcome the increase in the concentration of iron element, especially water plant Arish.

The physicochemical tests of most of the eight water stations under the study within the limits of the naturalization approved by the World Health Organization **(WHO, 2017)** and Egyptian standard of water quality **(ES, 2007)** except Al-Arish station has exceeded the iron ion values of the WHO.

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تقييم جودة مياه الشرب في بعض المناطق الحضرية بشمال سيناء - مصر

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أُجريت هذه الدراسة بهدف معرفة مدى صلاحية مياه الشرب لثمان محطات مياه بمنطقة شبه جزيرة سيناء، القنطرة شرق، بالوظة، رمانة، رابعة، بئر العبد، التلول، العريش والريسة ومعرفة قابليتها للإستهلاك الآدمي طبقاً للقيم الإسترشادية لمنظمة الصحة العالمية (٢٠١٧) والمواصفات المصرية القياسية لجودة المياه (٢٠٠٧)، حيث تم اخذ العينات شهرياً ابتداء من شهر ديسمبر ٢٠١٨ وحتى شهر يونيه ٢٠١٩، شملت الدراسة الاختبارات البكتيرولوجية الوصفية والكمية والتي تتضمن الاختبار التحضيري والاختبار التأكيدي والاختبار التكميلي للتأكد من وجود مستعمرات بكتيريا الـ *E. coli* التي ظهرت علي اطباق بيئة eosin methylene blue (EMB) تابعه لمجموعه القولون، بالإضافة إلى إجراء عدد بكتيري لمجموع البكتيريا القولونية باستخدام طريقة العدد الأكثر احتمالا Most Probable Number (MPN)، كما تم دراسة بعض العوامل الفيزيائية الكيميائية (الرقم الهيدروجيني، التوصيلية الكهربية، تركيز الكلوريد، بيكربونات، كبريتات، الكالسيوم، المغنيسيوم، الصوديوم والبوتاسيوم ومحتويات أيونات الحديد)، أشارت النتائج البكتريولوجية (الاختبارات الكمية والنوعية) إلى أن محطات مياه الشرب بالوظة ورابعة ورمانة وبئر العبد والتلول والريسة هي أكثر المحطات تلوثاً ببكتريا القولون *E. coli* ، وتبين أنها غير صالحة للشرب، في حين أن محطتي مياه الشرب للقنطرة شرق والعريش هما الأقل تلوثًا، ولذا يجب على الحكومة أن تقوم بالمعالجة بالكلور بالتركيز المناسب، لأن هذه العملية تحتاج إلى أيدي كيميائي خبير حيث أن الكلور الزائدة ضارة بصحة الإنسان، وأظهرت النتائج أن الرقم الهيدروجيني والتوصيلية الكهربية لمعظم عينات المياه الثمانية قيد الدراسة ضمن الحدود المسموح بها وذلك مقارنة بقيم منظمة الصحة العالمية (٢٠١٧) والمواصفات المصرية القياسية (٢٠٠٧)، باستثناء عينة من محطة مياه رمانة خلال شهر يناير والتي سجلت قيم منخفضة، ومحطة مياه رابعة التي سجلت أعلى قيم الأس الهيدروجيني في شهر يونيو، سجلت عينة المياه في محطة رابعة أدنى القيم للتوصيلية الكهربية خلال شهر ديسمبر، في حين سجلت عينة المياه لمحطة بالوظة أعلى القيم خلال شهر مايو، واشارت النتائج أن جميع الكاتيونات (الكلسيوم والماغنيسوم والصوديوم والبوتاسيوم) والأنيونات (الكلوريد والبيكربونات والكبريتات) لجميع محطات المياه الثمانية قيد الدراسة ضمن الحدود المسموح بها، ما عدا محطة العريش والتي تجاوزت قيم أيون الحديد عن الحدود المسموح بها لمنظمة الصحة العالمية (٢٠١٧) والمواصفات المصرية القياسية (٢٠٠٧)، لذا وجب التوصية بأن تكون محطات المياه الرئيسية معزولة عن الظروف الجوية المحيطة مع عمل الصيانة الدورية وتطهير خزانات المياه للتغلب على الزيادة في تركيز الحديد، كما يجب تغيير خطوط المياه الرئيسية، التي كانت مصنوعة من الحديد الضارة بصحة الإنسان، لتحل محلها أنابيب البولي ايثيلين المضغوطة التي أوصت بها منظمة الصحة العالمية ووقاية حماية البيئة الأمريكية.

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