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Seasonal physico-chemical and microbiological pollutants of potable groundwater in Qena governorate, Egypt: A case study

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In 9 districts of Qena governorate, Egypt, groundwater is used for human consumption. This study was carried out to evaluate the quality of these water sources. In each district, 2 wells were sampled in different seasons and physico-chemical and microbiological parameters were determined and compared with the Egyptian standards. All the tested wells had problems in physico-chemical or microbiological parameters or both. The overall seasonal magnitude of pollution was as follows: winter (45.5%) > spring (27.3%) > autumn (18.2%) > summer (9%). Permanent pollutants (pronounced in all seasons) were only physico-chemical mainly in Mn and iron. High percentages of bacterial pollutants, within wells and districts, were recorded. The highest values (for all parameters) within districts were total bacteria at 22, 35°C and total coli (88.9% for both), turbidity (66.8%), magnesium hardness, iron and manganese (66.7%), fecal streptococci (55.6%) and fecal coli (44.4%). Within the tested wells, the highest problems were total bacteria at 35 (72.2%) and at 22°C (66.7%), total coliform (61.1%) and manganese (55.6%). It is recommended to stop using these polluted sources for human consumption and to search for alternative high quality water sources or to start programs for treatment of the irreplaceable current sources.

Key words: Drinking water quality, physico-chemical parameters, microbiological quality, potable groundwater.

INTRODUCTION

Groundwater is a source of potable water, in addition to treated surface water from the river Nile, in Qena governorate that is located in the South of Egypt. Nine districts belonging to Qena governorate are partially or totally depending on groundwater for drinking.

In general, groundwater is naturally replenished by surface water from precipitation, streams and rivers (Agbaire and Oyibo, 2009). Water resources are under threat either from over exploitation or pollution caused by human activities (Efe et al., 2005). Most of the water resources are gradually becoming polluted due to the addition of foreign materials from the surroundings. These

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materials include organic matter of plant and animal origin, land surface washing, and industrial and sewage effluents (Ramachandramoorthy et al., 2010). In Egypt, the major problem is that, because population and industry are centered on the river Nile valley, all surface waters continually receive domestic sewage, agricultural drainage and industrial effluents (Sabae and Rabeh, 2007). This will affect both surface and underground water bodies on the long run (Soo et al., 2008; Hacioglu and Dulger, 2009).

Groundwater is not as susceptible to pollution as surface water but once polluted, treatment is a long term and difficult process (Henry and Heinke, 2005; Agbaire and Oyibo, 2009). Groundwater quality is also threatened by a combination of over abstraction, chemicals such as nitrate and pesticides and microbiological contaminations from different diffusing sources (Fuest et al., 1998; Reid et al., 2003). The composition of groundwater is also affected by human activities through changes in land use and intervention in natural flow patterns (Schot and Van der Wal, 1992; Reid et al., 2003).

The World Health Organization (WHO) has repeatedly insisted that the single major factor adversely influencing the general health and life of a population in many developing countries is the access to clean drinking water (Hoko, 2005). Improved water quality normally leads to better health, increased fitness and production (Ajibade, 2004). Water quality monitoring is a helpful tool not only to evaluate the impacts of pollution sources but also to ensure an efficient management of water resources (Strobl and Robillard, 2008). Due to use of contaminated drinking water, human population suffers from a variety of water borne diseases (Manjare et al., 2010). Polluted water and inadequate sanitation kill two children every minute worldwide (Shareef et al., 2009). Diseases contacted through drinking water are responsible for $1/6^{th}$ of the world's population sicknesses (WHO, 2004; Shittu et al., 2008). On the other hand, water-related diseases are responsible for 80% of all illnesses/deaths in the developing countries (UNESCO, 2007).

The quality of water is typically determined by monitoring microbial presence and physico- chemical parameters (EPA, 2003; Hacioglu and Dulger, 2009). Pathogenic bacteria and other organisms such as viruses, protozoa and worms are the main cause of human diseases with a wide range of pathogenic microorganisms such as *Salmonella* and *Shigella* that can be transmitted to humans via water contaminated with fecal material (Kacar, 2011). Various physico-chemical parameters such as pH, alkalinity, total hardness, total dissolved solid, calcium, magnesium and nitrate have a significant role in determining the potability of drinking water (Shaikh and Mandre, 2009). Physical parameters that give rise to customer's complaints are colour, taste, odour, temperature and turbidity (WHO, 1997; Hoko, 2005).

Continuous monitoring of water quality is very essential to determine the state of pollution. This information is important for the general public and the government in order to develop policies for the conservation of fresh water resources (Ali et al., 2000; WHO, 1997). On the other hand, groundwater exploitation schemes in the developing countries are designed without careful attention on water quality (Foster, 1995; Hoko, 2005).

Therefore, the current study was conducted to evaluate the seasonal variations in quality of the tested potable groundwater, in different districts of Qena governorate, and to what extent these waters are chemically and microbiologically contaminated.

METHODOLOGY

Water samples were collected from 18 wells in 9 districts (two wells in each district). Samples were collected during the year 2010 in all seasons (winter, spring, summer and autumn). Three replicate samples, for each location, were collected in the morning between 9 am and 12 pm. Samples subjected to physico-chemical analysis were collected in pre-washed high density polyethylene bottles. These bottles were washed with diluted hydrochloric acid and rinsed 3-4 times with sample water. Concentrated nitric acid (3 ml) was added to the bottles subjected to iron and manganese analysis (APHA, 2005). Samples used for microbiological analysis were collected in sterilized 1 L glass bottles under aseptic conditions, kept in an ice box and transferred to the laboratory within 3 h of collection for analysis. Water pH and conductivity were recorded at the time of sample collection. All physico-chemical parameters and microbiological indicators were determined according to APHA (2005). Measurements were carried out in triplicate for all parameters and indicators. All parameters were compared with the limits of the Egyptian Ministry of Health standards (decision of the Minister of Health no. 458, 2007).

Determination of physico-chemical parameters

The pH was determined by using "HACH Sension 156, Loveland Co., USA" pH meter. Turbidity was determined using "HACH 2100 N, USA" Nephelometer. Total dissolved solids (TDS) were determined by filtration of 100 ml sample on a 45 µm glass fiber filter connected to vacuum pump and weighing the filtrate. Electrical conductivity at 25°C was determined by using a "HACH Sension 156, Loveland Co., USA" conductivity meter. Total hardness and calcium hardness were measured by EDTA titrimetric method using Eriochrome black T and murexide as indicators, respectively. Magnesium hardness was calculated by subtracting the value of calcium hardness from the total hardness multiplied by 0.243 (APHA, 2005). Nitrate concentration was determined by measuring at 420 nm using "HACH TUV, USA" spectrophotometer and potassium nitrate for preparing the standard curve.

Iron and manganese concentrations were determined using atomic adsorption spectroscopy (Varian AA240Z, Australia). A calibration curve was prepared by using at least three concentrations of standard metal solutions. Samples were prepared by digestion with 3 ml concentrated HNO_3. Then blank reagent (acidified deionized water) was introduced in the instrument followed by the sample.

Microbiological analysis

Samples were analyzed directly after collection to minimize changes in the bacterial population. All media and chemicals were supplied by Merck Co., England, prepared with deionized water and autoclaved at 121°C for 15 min prior to use.

Heterotrophic plate (total bacterial) count at 35 and 22°C

The media used were nutrient agar and buffer peptone water (APHA, 2005). The used sample volumes were 1 and 0.1 ml. Sterile agar medium was melted and kept in a water bath at 44- 46°C until used. One set of three plates was set up for each temperature. The melted medium was mixed thoroughly with sample in the plates by swirling. After being solidified, the plates were incubated for 48 ± 3 ho at 35 ± 0.5°C and 68 ± 4 h at 22 ± .0.5°C. At the end of incubation, the number of colonies developed on each plate was counted to determine the plate count as colony forming unit (CFU) per ml of sample.

Determination of total coli, fecal coliform and fecal streptococci by membrane filter technique

The used culture media were M- Endo agar, M- FC agar, M- Enterococcus agar, Buffer peptone water, Lauryl tryptose broth, Brilliant green bile broth, Aesculin bile azide agar and EC broth as indicated for each test (APHA, 2005).

For the detection of total coliform, sample bottle was shaked vigorously and the sample filtered through 45 µm membrane fitter. The filter was then placed on the M- Endo agar plate and incubated for 22 to 24 h at 35 ± 0.5°C. After incubation, red colonies with metallic golden sheen were counted as coliform bacteria. Verification of all typical and non-typical coliform colonies was carried out by picking up two typical and two atypical colonies from a membrane filter with a sterile loop, placing in lauryl tryptose broth tubes that were incubated at 35 ± 0.5°C for 48 h. Tubes that produced gas were verified in brilliant green lactose broth (incubated at 35 ± 0.5°C for 48 h). Gas formation in lauryl tryptose broth and confirmed in brilliant green lactose broth within 48 h were verified as coliform cultures.

Detection of fecal coliform

Detection of fecal coliform was carried out by repeating the steps used for total coliform on M- FC medium. The plates were then incubated for 24 ± 2 h at 44.5 ± 0.2°C. After incubation, colonies with blue colour were counted as fecal coliform bacteria. Verification of typical and atypical fecal coliform colonies was carried out as above in lauryl tryptose broth and gas production was verified in EC broth (tubes incubated at 44.5 ± 0.2°C for 48 h). Gas formed in lauryl tryptose broth and confirmed in EC within 48 h verified the colony as fecal coliform bacteria.

Detection of fecal streptococci

Detection of fecal strptococci was carried out by repeating the steps used in total coliform on M- *Enterococcus* agar and the plates were incubated for 48 h at 35 ± 0.5°C. After incubation, colonies with red colour were counted as fecal *Streptococcus* bacteria. All colonies that showed red, maroon or pink colour were identified as typical colonies that were verified as follows: after sample filtration, the filtrate was transferred onto a plate of bile aesculin azid agar. The plates were incubated at 44°C ± 0.2 for 2 h. Colonies that showed a tan to black colour in the surrounding media were counted as fecal streptococci.

RESULTS AND DISCUSSION

The pysico-chemical and microbiological water quality parameters that exceeded the Egyptian Standard Limits, are shown in Tables 1 to 9 for all the tested wells. All the other values, that were within the acceptable limits, were shown as "A" in the tables for simplicity. Parameters that exceeded the limits were as follows:

1. Abou-Tesht district: high turbidity only in El- Maharza well in winter, iron and manganese in all seasons, total bacterial counts in winter at both 22 and 35°C for the same well, in autumn (at 35°C) and autumn and summer at 22°C in El-Karnak well. Total coli was also high in winter and manganese in all seasons except summer in El- Karnak well (Table 1).
2. Farshot district: in El- Dahasa well turbidity was high in winter, Mg hardness in spring, iron and manganese in all seasons, total count at 35°C in winter and summer, total coli in winter, spring and autumn, fecal coli and fecal streptococci in spring. In El-Araky well, high Mn was recorded in autumn, TC (total bacterial count) at 35 and 22°C in summer and autumn in addition to spring at 22°C and total coli, fecal coli and fecal streptococci in spring (Table 2).
3. Nag-Hammadi district: For El-Salamyia well, high turbidity and Mn were recorded in all seasons, Mg hardness in autumn, and iron and TC (at both 35 and 22°C) in winter (Table 3).
4. El- Wakf district: In Hager El- Gabal well only TC was high at both 35 and 22°C in winter and autumn. In El-Marashda well, high turbidity was recorded in winter, Mn in summer and autumn, iron in all seasons, TC at both temperatures in winter and spring and total coli in autumn (Table 4).
5. Deshna district: in El-Samata Bahary well, high turbidity was recorded in winter, Mg hardness in autumn, iron and Mn in all seasons and TC, at both temperatures, in winter and spring. In Nag- Azooz well, high values were turbidity in winter and autumn, Mg hardness in winter, total coli in all seasons except winter and both fecal coli and streptococci in autumn (Table 5).
6. Qena district: in Karm Omran well, only TC at both 35 and 22°C was high in winter and spring, at both temperatures and summer for the latter one. In Awlad Soroor well, high values were turbidity, Mg hardness and iron in all seasons except spring, total hardness in summer and autumn, Ca hardness in all seasons except winter, iron in winter and autumn, TC at 35°C in spring and autumn, TC at 22°C in spring, summer and autumn, total coli in spring and fecal streptococci in summer (Table 6).
7. Qeft district: in El- Koom El- Kebly well, high values were Mg hardness in summer and total coli, fecal coli and streptococci in autumn. In Anbar well, high values were Mg hardness in winter, spring and summer, TC at 35°C in winter and spring, TC at 22°C in the same

Table 1. Potable groundwater parameters above the standard Egyptian limits in Abou-Tesht district.

Wells and seasons	El- Maharza				El- Karnak			
Water quality parameters*	**Winter**	**Spring**	**Summer**	**Autumn**	**Winter**	**Spring**	**Summer**	**Autumn**
Turbidity (< 1 NTU)	2.5 ± 0.0	A	A	A	A	A	A	A
Iron (< 0.3 mgl^{-1})	0.45 ± 0.05	0.39 ± 0.002	0.38 ± 0.004	0.45 ± 0.0	A	A	A	A
Mn (< 0.4 mgl^{-1})	0.59 ± 0.008	0.7 ± 0.003	0.71 ± 0.002	0.66 ± 0.014	0.53 ± 0.029	0.42 ± 0.001	A	0.55 ± 0.002
Total bacterial count at 35°C (< 50 cell/ cm^3)	86 ± 4.32	A	A	A	A	A	A	89 ± 3.74
Total bacterial count at 22°C (< 50 cell/ cm^3)	89 ± 0.82	A	A	A	A	A	56 ± 2.45	300 ± 0.0
Total coli (< 2 cell/ 100 ml)	A	A	A	A	5 ± 2.16	A	A	A

*Numbers between parenthesis are the Egyptian Standard Limits according to the Minister of Health decision no. 458 (2007). A = Values are within limits, all values ± SD (n= 3).

Table 2. Potable groundwater parameters above the standard Egyptian Limits in Farshot district.

Wells and seasons	El- Dahasa				El- Araky**		
Water quality parameters*	**Winter**	**Spring**	**Summer**	**Autumn**	**Spring**	**Summer**	**Autumn**
Turbidity (< 1 NTU)	1.28 ± 0.0	A	A	A	A	A	A
Mg hardness (< 150mgl^{-1})	A	286 ± 0.82	A	A	A	A	A
Iron (< 0.3 mgl^{-1})	0.42 ± 0.0	0.83 ± 0.001	0.81 ± 0.0	1.43 ± 0.0	A	A	A
Mn (< 0.4 mgl^{-1})	0.65 ± 0.0	0.51 ±0.0	0.52 ± 0.0	0.7 ± 0.008	A	A	0.45 ± 0.0
Total bacterial count at 35ºC (< 50 cell/ cm^3)	84 ± 1.63	A	74 ± 2.16	A	A	73 ± 1.63	300 ± 0.0
Total bacterial count at 22ºC (< 50 cell/ cm^3)	A	A	A	A	212 ± 0.82	69 ± 7.35	300 ±0.0
Total coli (< 2 cell/ 100 ml)	6 ± 0.82	19 ± 0.82	A	67 ± 3.27	A	200 ± 0.0	A
Fecal coli (0.0 cell/ 100 ml)	A	1 ± 0.82	A	A	A	14 ± 0.82	A
Fecal *Streptococcus* (0.0 cell/ 100 ml)	A	2 ± 0.82	A	A	A	52 ± 2.16	A

*Numbers between parenthesis are the Egyptian standard limits according to the Minister of Health decision no. 458 (2007). ** All values were within limits in winter. A = Values are within limits, all values ± SD (n= 3).

Table 3. Potable groundwater parameters above the standard Egyptian Limits in Nag-Hammadi district.

Wells and seasons	El- Salamyia				El- Masalha			
Water quality parameters*	**Winter**	**Spring**	**Summer**	**Autumn**	**Winter**	**Spring**	**Summer**	**Autumn**
Turbidity (< 1 NTU)	1.75 ± 0.008	1.1 ± 0.082	1.1 ± 0.0	1.03 ± 0.0	A	A	A	1.61 ± 0.0
Mg hardness (< 150 mgl^{-1})	A	A	A	203.4 ± 0.082	206.6 ± 0.082	164 ± 0.816	A	A
Iron (< 0.3 mgl^{-1})	0.383 ± 0.0	A	A	A	0.38 ± 0.0	0.34 ± 0.0	A	A
Mn (< 0.4 mgl^{-1})	1.097 ± 0.0	0.92 ± 0.0	0.86 ± 0.0	0.745 ± 0.0	0.91 ± 0.0	0.65 ± 0.0	0.561 ± 0.0	0.53 ± 0.0

Table 3. Contd.

Total bacterial count at 35°C (< 50 cell/ cm^3)	193 ± 0.82	A	A	A	A	A	A	A
Total bacterial count at 22°C (< 50 cell/ cm^3)	192 ± 2.45	A	A	A	A	A	A	A

*Numbers between parenthesis are the Egyptian standard limits according to the Minister of Health decision no. 458 (2007). A = Values are within limits, all values ± SD (n= 3).

Table 4. Potable groundwater parameters above the standard Egyptian limits in El-Wakf district.

Wells and seasons	**Hager El- Gabal****		**El- Marashda**			
Water quality parameters*	**Winter**	**Autumn**	**Winter**	**Spring**	**Summer**	**Autumn**
Turbidity (< 1 NTU)	A	A	7.26 ± 0.05	A	A	A
Iron (< 0.3 mgl^{-1})	A	A	0.84 ± 0.0	0.8 ± 0.008	0.79 ± 0.0	0.85 ± 0.0
Mn (< 0.4 mgl^{-1})	A	A	A	A	0.41 ± 0.001	0.45 ± 0.0
Total bacterial count at 35°C (< 50 cell/ cm^3)	64 ± 3.27	96 ± 3.27	54 ± 4.9	300 ± 0.0	A	A
Total bacterial count at 22°C (< 50 cell/ cm^3)	69 ± 7.37	60 ± 8.17	60 ± 4.9	300 ± 0.0	A	A
Total coli (< 2 cell/ 100 ml)	A	A	A	A	A	14 ± 1.63

*Numbers between parenthesis are the Egyptian standard limits according to the Minister of Health decision no. 458 (2007). ** All values were within limits in both spring and summer. A = Values are within limits, all values ± SD (n= 3).

Table 5. Potable groundwater parameters above the standard Egyptian limits in Deshna district.

Wells and seasons	**El- Samata Bahary**				**Nag- Azooz**			
Water quality parameters*	**Winter**	**Spring**	**Summer**	**Autumn**	**Winter**	**Spring**	**Summer**	**Autumn**
Turbidity (< 1 NTU)	1.8 ± 0.082	A	A	A	1.47 ± 0.022	A	A	1.3 ± 0.008
Mg hardness (< 150mgl^{-1})	A	A	A	176 ± 0.29	185.5 ± 0.163	A	A	A
Iron (< 0.3 mgl^{-1})	0.656 ± 0.001	0.611 ± 0.001	0.601 ± 0.001	0.51 ± 0.0	A	A	A	A
Mn (< 0.4 mgl^{-1})	0.52 ± 0.0	0.53 ± 0.001	0.56 ± 0.001	0.59 ± 0.0	A	A	A	A
Total bacterial count at 35°C (< 50 cell/ cm^3)	110 ± 7.79	67 ± 6.48	A	A	A	A	A	A
Total bacterial count at 22°C (< 50 cell/ cm^3)	110 ± 7.48	67 ± 2.16	A	A	A	A	A	A
Total coli (< 2 cell/ 100 ml)	A	A	A	A	A	21 ± 0.82	24 ± 3.74	34 ± 3.56
Fecal coli (0.0 cell/ 100 ml)	A	A	A	A	A	A	A	2 ± 0.0
Fecal Streptococcus (0.0 cell/ 100 ml)	A	A	A	A	A	A	A	1 ± 0.0

* Numbers between parenthesis are the Egyptian Standard Limits according to the Minister of Health decision no. 458 (2007). A = Values are within limits, all values ± SD (n= 3).

seasons in addition to summer and total coli in winter (Table 7).

8. Qous district: in El-Akola well, only total coli, fecal coli and streptococci were high in spring.

In Hagaza Kebly well, high Mg hardness only was recorded in spring, summer and autumn (Table 8).

Table 6. Potable groundwater parameters above the standard Egyptian limits in Qena district.

Wells and seasons	Karm Omran**			Awlad Soroor			
Water quality parameters*	**Winter**	**Spring**	**Summer**	**Winter**	**Spring**	**Summer**	**Autumn**
Turbidity (< 1 NTU)	A	A	A	1.16 ± 0.033	A	2.7 ± 0.016	1.08 ±0.008
Total hardness (< 500 mgl^{-1})	A	A	A	A	A	591.6 ± 0.216	782 ± 0.497
Ca hardness (< 350mgl^{-1})	A	A	A	A	448 ± 0.0	379.2 ±0.082	501 ±0.0
Mg hardness (< 150 mgl^{-1})	A	A	A	152 ± 0.0	A	212.4 ± 0.082	281 ± 0.0
Iron (< 0.3 mgl^{-1})	A	A	A	0.32 ± 0.0	A	A	0.43 ± 0.0
Total bacterial count at 35°C (< 50 cell/ cm^3)	300 ± 0.0	182 ± 7.48	A	A	300 ± 0.0	A	300 ± 0.0
Total bacterial count at 22°C (< 50 cell/ cm^3)	300 ± 0.0	149 ± 4.32	99 ± 2.94	A	300 ± 0.0	150 ± 6.98	159 ± 4.55
Total coli (< 2 cell/ 100 ml)	A	A	A	A	65 ± 3.74	A	A
Fecal *Streptococcus* (0.0 cells/ 100 ml)	A	A	A	A	A	4 ± 2.16	A

* Numbers between parenthesis are the Egyptian standard limits according to the Minister of Health decision no. 458 (2007). ** All values were within limits in autumn. A= Values are within limits, all values ± SD (n= 3).

Table 7. Potable groundwater parameters above the standard Egyptian limits in Qeft district.

Wells and seasons	El- Koom El- Kebly[1]		Anbar[2]		
Water quality parameters*	**Summer**	**Autumn**	**Winter**	**Spring**	**Summer**
Mg hardness (< 150mgl^{-1})	204 ± 0.0	A	197 ± 0.0	157 ± 0.0	206.8 ± 0.082
Total bacterial count at 35ºC (< 50 cell/cm^3)	A	A	97 ± 2.16	53 ± 2.16	A
Total bacterial count at 22 ºC (< 50 cell/cm^3)	A	A	136 ± 2.16	62 ± 3.56	70 ± 2.16
Total coli (< 2 cell/ 100 ml)	A	15 ± 0.82	27 ± 2.16	A	A
Fecal coli (0.0 cell/ 100 ml)	A	5 ± 2.16	A	A	A
Fecal Streptococcus (0.0 cell/100 ml)	A	2 ± 0.82	A	A	A

*Numbers between parenthesis are the Egyptian standard limits according to the Minister of Health decision no. 458 (2007). 1 = All values were within limits in winter and spring, 2 = All values were within limits in autumn. A = Values are within limits, all values ± SD (n= 3).

9. Nakada district: in Asmant 2 well, high values were Mn hardness in all seasons except summer, TC at both 35 and 22°C and total coli in all seasons except spring. In Asmant 4 well, high values were Mn hardness in all seasons except spring, TC at 35 and 22°C only in summer and total coli in summer and autumn (Table 9).

Finally, the pH values for all the tested wells were within limits except for El-Marashda well (El-Wakf district) and Karm Omran (Qena district) that were slightly lower than limits (5.99, 5.85, respectively). No problems were found in nitrate concentrations in all the tested samples (data not shown).

The percentage of each pollutant (those values that exceeded the Egyptian standard limits) was calculated for seasons, districts and the tested wells as presented in Table 10. There were problems of pollution in all the tested wells but with variations between wells, seasons and districts for both physico-chemical and microbiological

Table 8. Potable groundwater parameters above the standard Egyptian Limits in Quos district.

Wells and seasons	El- Akola[1]	Hagaza Kebly[2]		
Water quality parameters*	Spring	Spring	Summer	Autumn
Mg hardness (< 150 mgl^{-1})	A	199 ± 0.49	152 ± 0.74	179 ± 0.36
Total coli (< 2 cell/100 ml)	2 ± 0.82	A	A	A
Fecal coli (0.0 cell/100 ml)	1 ± 0.82	A	A	A
Fecal Streptococcus (0.0 cell/100 ml)	1 ± 0.0	A	A	A

*Numbers between parenthesis are the Egyptian standard limits according to the Minister of Health decision no. 458 (2007). 1 = no values exceeded limits in winter, summer and autumn, 2 = No values exceeded limits in winter. A = Values are within limits, all values ± SD (n= 3).

Table 9. Potable groundwater parameters above the standard Egyptian limits in Nakada district.

Wells and seasons	Asmant I				Asmant II			
Water quality parameters*	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn
Mn (< 0.4 mgl^{-1})	0.46 ± 0.08	0.63 ± 0.001	A	0.536 ± 0.001	0.798 ± 0.0	0.573 ± 0.0	A	0.631 ± 0.001
Total bacterial count at 35°C (< 50 cell/ cm^3)	100 ± 10.8	A	300 ± 0.0	300 ± 0.0	A	A	300 ± 0.0	A
Total bacterial count at 22°C (< 50 cell/ cm^3)	129 ± 8.64	A	300 ± 0.0	300 ± 0.0	A	A	300 ± 0.0	A
Total coli (< 2 cell/100 ml)	14 ± 3.56	A	200 ± 0.0	50 ± 2.16	A	A	200 ± 0.0	80 ± 5.89

*Numbers between parenthesis are the Egyptian standard limits according to the Minister of Health decision no. 458 (2007). A = Values are within limits, all values ± SD (n= 3).

Table 10. Percentages of groundwater pollutants according to its appearance in seasons, districts and wells.

Pollutants (higher than limits)	Total cases (in all seasons)*	% in different seasons				% of districts and wells	
		Winter	Spring	Summer	Autumn	Districts (Total 9*)	Wells (Total 18*)
Turbidity	14	50	7.14	14.29	28.57	66.8	44.4
Total hardness	2	0.0	0.0	50	50	11.1	5.6
Ca hardness	3	0.0	33.3	33.3	33.3	11.1	5.6
Mg hardness	16	25	25	25	25	66.7	50
Iron	21	33.33	23.8	19.05	23.82	66.7	38.9
Mn	32	25	25	18.75	31.25	66.7	55.6
Total bacterial count at 35°C	22	40.9	22.7	18.2	18.2	88.9	72.2
Total bacterial count at 22°C	26	30.8	23.07	26.9	19.23	88.9	66.7
Total coli	18	22.22	22.22	22.22	33.33	88.9	61.1
Fecal coli	5	0.0	40	20	40	44.4	27.8
Fecal streptococci	5	0.0	40	40	20	55.6	33.3

*Considered as 100% for percentage calculation.

characteristics as shown in Table 10.

Providing adequate amounts of drinking water, with an acceptable quality, is a basic necessity that ensures sustainable long-term supply of such water and is of national and international concern (Reid et al., 2003; Rizak and Hrudey, 2008). Special bodies have been found to ensure that drinking water meets high standards and the product complies with legislation and safety rules (Smeti et al., 2009). For effective maintenance of water quality through appropriate control measures, continuous monitoring of large number of quality parameters (microbial and physico-chemical) is essential (EPA, 2003).

Although turbidity has no health effect, it can interfere with disinfection, provide a medium for microbial growth and indicate the presence of microbes that may be disease-causing (Shareef et al., 2009; Shittu et al., 2008). Ideal drinking water should have a turbidity value <1 NTU for aesthetic quality as well as for efficient disinfection (Chakrabarty and Sarma, 2011). The obtained results (Tables 1 to 9) showed that turbidity exceeded the limits in 6 districts (66.8 %) and 8 wells (44.4%) with 50% of the total cases recorded in winter (Table 10).

As regard to pH values, it regulates most of the biological processes and biochemical reactions (Mathur et al., 2008). The recorded pH values, for different districts and wells, were within the acceptable limit except for two districts in autumn with slightly acidic pH but close to the lower limits (5.95, 5.85). Similar results (low pH levels) were recorded in wet seasons (Shaikh and Mandre, 2009; Shittu et al., 2008).

Electric conductivity (EC) of water is a direct function of total dissolved solids, organic compounds and temperature of water (Jayalakshmi et al., 2011). Conductivity of the tested water samples were all considered accepted as there were no defined limit in the Egyptian standards.

Total dissolved solids (TDS) is an important parameter for drinking water and water with high solid content is of inferior palatability and may produce unfavorable physiological reaction in the transient consumer (Abdul Jameel, 2002; Basavaraddi et al., 2012). Groundwater TDS in all wells was within acceptable limits in all seasons but close to the highest limit (data not shown). Similar high levels of groundwater TDS was reported earlier (Rao, 2006).

Water hardness is the traditional measure of the capacity of water to react with soap and hard water requires considerably more soap to produce lather. Hardness is due to natural accumulation of salts from contact with soil and geological formation or from direct pollution by human activities (Sheikh and Mandre, 2009). Hardness of the tested groundwater recorded higher values than limits only in 11.1% of districts and 5.6% of wells with 50% in both summer and autumn indicating that this is not a permanent problem in the tested wells. Calcium in water does not impart any adverse health impact but can contribute towards hardness of water (Chakrabarty and Sarma, 2011). Calcium hardness, that exceeded the limits, recorded the same percentages, as for total hardness, for both districts and wells with a percentage of 33.3 in spring, summer and autumn (Table 10). Magnesium hardness, in the tested groundwater, was distributed among the four seasons (25% each) and was recorded in 66.7% of districts and 50% of wells (Table 10) suggesting that it is a permanent problem in the concerned wells (Tables 1 to 9).

Water containing iron does not show deleterious effect on human health but excessive iron makes the water turbid, discoloured and imparts an astringent taste to water (Trivedi et al., 2010). In the current study, most of the high iron levels were recorded in winter (33.33%) and is represented in 66.7% of districts and 38.9% of the tested wells (Table 10). Most of these values were recorded in some wells in all, or almost all, seasons representing another permanent problem in these wells (Tables 1 to 9).

Another permanent problem is the high manganese level in the tested wells. High levels of manganese were recorded in 66.7% of districts and 55.6% of wells with the highest percentage in autumn (31.25%) as shown in Table 10. Most of these values were recorded in all seasons in wells of the northern part indicating that the problem is related to the northern districts of Qena governorate.

Heterotrophic plate count (HPC) measures a range of bacteria that are naturally present in the environment (EPA, 2003; Shittu et al., 2008). Environmental Protection Agency (EPA), USA considers HPC as a primary standard based on health considerations (Shittu et al., 2008). Groundwater is usually contaminated due to improper construction, shallowness, animal wastes, proximity to toilet facilities, sewage, natural soil- plant- bacteria contact, refuse dump sites, and various human activities around the well (Bitton, 1994; EPA, 2003; Shittu et al., 2008).

In the current study, the highest total counts at both 35 and 22°C were recorded in winter season (40.9 and 30.8%, respectively). Total bacterial count is another permanent problem in Qena exhibited in 88.9% of districts and 72.2, 66.7% of wells for both temperatures (Table 10). The distribution of these bacterial contaminants is shown in Tables 1 to 9. Values of bacterial counts that exceeded the limits, after winter, were recorded in spring, summer and autumn, respectively (Table 10).

Another microbiological indicator for water quality is the total coliform bacteria (Hacioglu and Dulger, 2009). Counts higher than limits were obtained, in the current study, in different seasons and districts with the highest percentage in autumn (Tables 1 to 10). A wet season after dry one results in high loading of coliform bacteria from soil to groundwater and subsequent high coliform densities in natural spring water originating from groundwater (Pritchard et al., 2007). High counts were represented in 88.9% of Qena districts and 61.1% of the tested wells (Table 10). The high total coliform counts are generally indicative of poor sanitary handling and/or environmental conditions affecting the wells (Dionisio et al., 2002; Ejechi et al., 2007).

Fecal coliforms are one of the most important parameters for assessing the suitability of drinking water because of the infectious disease risk (WHO, 1997). Fecal coliform indicates contamination by mammals and bird wastes (faces) and signify the possible presence of pathogenic bacteria and viruses responsible for waterborne diseases such as cholera, typhoid, diarrhea-related illnesses and may contain human enteric pathogens (EPA, 2003). Fecal coli was found in 5 wells within 4 districts representing 27.8 and 44.4% respectively. The high loads of fecal coli bacteria were recorded in spring and autumn (40% for both) as shown in Table 10. As indicated above, for total coli, the high load of fecal bacteria is related to seasons with mild temperatures (spring and autumn) as temperature is an important factor for its growth (An et al., 2002).

Fecal streptococci is commonly used as indicator organisms for the microbiological quality of water and wastewater (Masamba and Mazvimavi, 2008). Fecal streptococci, higher than limits, was detected in 55.6% of districts and 33.3% of the tested wells. The higher percentages were recorded in both spring and summer (40%) as shown in Table 10. These results indicate that there is a pollution caused by domestic sewage and untreated human and animal waste (Mallin et al., 2000).

Conclusions

In general, all the tested wells had either physico-chemical or microbiological problems or both. Permanent problems (exceeding limits in all seasons) were in physico-chemical parameters as follows: iron and manganese in three districts (Abou-Tesht, Farshot and Deshna), Mn and turbidity in Nag Hammadi only and iron only in El-Wakf district (Tables 1 to 9). On the other hand, microbiological pollution is obviously more pronounced within wells and districts expressed as high percentages of all the bacterial indicators (Table 10). It is therefore, recommended to carry out both chemical and microbiological treatment for the irreplaceable contaminated wells especially for those with permanent problems, as indicated above. The alternative is to avoid these wells as potable water and a search for higher quality sources should be carried out immediately.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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