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# MONITORING OF HEAVY METALS CONTAMINATION IN DRINKING GROUNDWATER FROM EGYPT

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## ABSTRACT

**The present work aims to assess the groundwater quality, which is already used as the main water resource for drinking in Abu Tisht area, Qena, Egypt. The results indicate that the groundwater that is still used for drinking purposes are not suitable in most locations, where the Fe, Mn, Cd and Zn exceeded the maximum contaminant limit of both the WHO and EPA standards. The concentrations of most pollutant heavy metals are increasing by time in different places, while the others are not clear, indicate irregular change in sources of water contamination. The results revealed that most of pH, $Cl^-$, $SO_4^{2-}$, $NO_3^-$, $NO_2^{2-}$, $NH_3$ and TDS are less than the acceptable limits, while the other are unsuitable. The sources of groundwater contamination come from the wastewater, excessive use of fertilizers in agriculture activities, and groundwater recharge from near and/or deep aquifer. It is strongly recommended to stop pumping from the high heavy metals concentrations wells and search or replace for new water resources for drinking. The excess use of heavy metals-polluted groundwater can cause many problems in humans, and so it must be treated.**

**KEY WORDS :** Groundwater, Drinking water quality, Pollution, Heavy metals, Qena.

## INTRODUCTION

In most parts of the world groundwater is used for agriculture, domestic and industrial purpose. The human activities release a large number of pollutants into the water bodies. Drinking water contaminated with heavy metals above the maximum permissible limits causes potential risk to human health.

The groundwater and aquatic ecosystems seem to be mostly vulnerable to any contaminations. In the environment, the heavy metal contaminations can be occurred from both anthropogenic and natural sources. The leaching from rocks and soils considered as natural sources of heavy metals that can reach to groundwater (Bradl, 2002; He *et al*., 2005). Agricultural and domestic use of metals and metal-containing compounds, mining, and industrial activities are from important anthropogenic sources of environmental contamination of heavy metals (Herawati *et al.,* 2000; He *et al*., 2005).

Metal-containing compounds that generated from different sources will reach by way to groundwater, which consider as the main drinking water resource of many places. It can cause many problems for both health and the environment. The kidney and liver more or less can affect or damage, at short or long time drinking heavy metals polluted water.

In Egypt, many studies have been carried out in the groundwater. Bassioni *et al*. (2015) studied heavy metals in water from groundwater wells located in Samalot, the EL-Minia governorate , Egypt and found that chromium, Iron, and lead are far above the maximum permissible limits set by WHO. Mandour and Azab (2011) studied nine heavy metals (Fe, Mn, Fe, Ni, Cr, Zn, Cu, Co, and Cd) in drinking groundwater samples from some districts of the Dakahlyia governorate, Egypt. They ended to that all samples, but two, were found suitable for drinking. Melegy *et al.* (2014) studied the concentration of Fe, Mn, Zn, Pb, and Cd in groundwater of Sohag Governorate, Egypt, and their impacts on human health. Their results recorded high contamination with cadmium and lead. Besides, about 50 % of samples are contaminated with iron and manganese at an alert level. Rashed *et al.* (1995) studied Major, minor, physicochemical components ($HCO_3$, $SO_4^2$, Cl, Ca, Mg, Na, K, pH, TDS) and trace elements (Ag, Cd, Co, Cu, Cr, Fe, Mn, Ni, Pb, Sr, and Zn) in Kalabsha wells and in the High Dam Lake water, Aswan, Egypt. The results showed higher values for conductivity, $HCO_3^-$, Cl , $SO_4^{2-}$, Ca, Mg, Na, K, TDS, Ag, Cd, Co, Cu, Cr, Fe, Mn, Ni, Pb, Sr and Zn in the water wells of Kalabsha area than in the Lake water.

Locking for and monitoring of non-polluted water resources are strongly recommended. The aim of the present work is attempting to assess the groundwater quality, which is already used as the main water resource for drinking inAbu Tisht area, Qena. It strongly recommended stopping and preventing use of polluted water for drinking, therefore they must be treated before consumption or replaced by other non-polluted water resources.

## Study Area

The study area is bounded by latitudes 25° 59′ and 26° 14′ N and longitudes 31 ° 58′ and32 ° 38′ E (Fig. 1). It lies to the southwest of the Qena city across the two banks of the Nile River to the limestone plateau from both the sides. The area extends from Abu Tisht to Qena cities covering approximately 1787 km$^2$. It's located in the arid zone dominated by very dry and hot weather condition.

## Geological setting

The geology of the west Qena area was studied by many authors (Said, 1990, Issawi and McCauley 1992, Mansour and Kamal El-Dein 2001). The study area is considered as part of the Nile valley and has different surface stratigraphic rock units with ages ranging from the Late Cretaceous/Lower Eocene to Quaternary as shown in the regional surface geological map (after the geological map of Egypt, CONOCO, 1987) (Fig. 2).

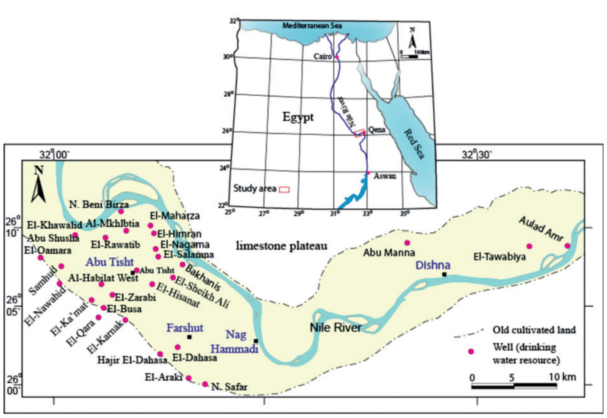


Fig. 1. Location map and groundwater sampling as the main drinking water resource.

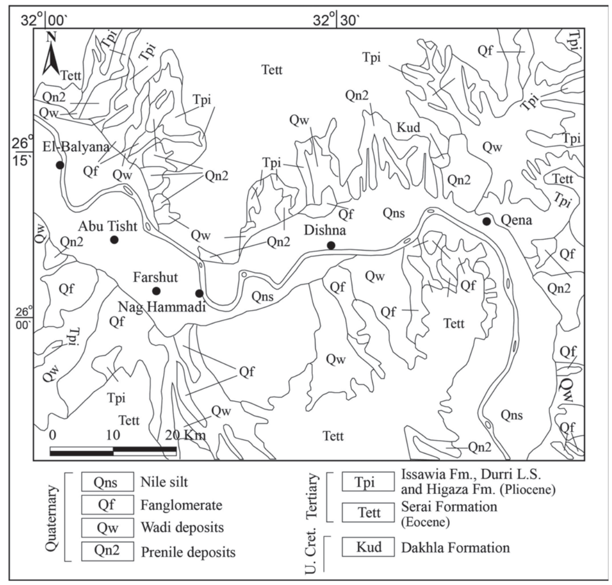


**Fig. 2.** Geological map of the study area (after the geological map of Egypt, CONOCO, 1987).

The sedimentary succession and the rock units can be classified from the oldest (bottom) to the youngest (top) as follows (Fig. 2):

- Upper Cretaceous sediments, including the Dakhla Formation. It represents the topmost Cretaceous unit where its lower part belonging to the Maastrichtion but its upper part is of Early Paleocene age. It forms from shales, limestone and calcareous clay.
- Lower Eocenesediments, including the Thebes Formation; which represented by Sierra Formation in the study area. It overlies Esna Formation and its top is uncovered. Its thickness reaches 250m and it's made up of fine grained, thinly bedded micritic limestone, and chalky with rare shale.
- Pliocene sediments represented by the Paleo-Nile deposits and made up of interbedded red-brown clay and thin fine-grained sand and silt. These sediments overly the eroded surface of the Eocene carbonate rocks.
- The Pleistocene sediments represented by the Pre-Nile deposits. They composed of cross-bedded fluvial sands with gravel and clay beds.

Thesesediments represent the main Quaternary aquifer in the Nile Valley and the study area.

- Late Pleistocene and Holocene sediments form of Neo-Nile deposits, alluvial deposits and recent Wadi deposits. The deposits of the Neonile are made up of silts and clays that forming the top layer of the floodplain of the modern Nile and are also found outside this plain in the form of benches that fringing the valley at elevations ranging from 1 to 12m above the modern floodplain.

**Hydrogeological setting**

Many studies attempt on the hydrogeological setting of the study area (Abd El-Bassier, 1997, Shedeid *et al.*, 2001; Zaghloul, 2006). They concluded that:

- The water-bearing layers, which represented the main groundwater aquifer in the study area composed of gravel and sand intercalated with the clay of the Quaternary age.
- In the floodplain area, the groundwater exists under semi-confined conditions where the Holocene sediments caped the water-bearing layers. They composed from clay, silty-clay and clayey-silt deposits and graded sand and gravel intercalated with clayey lenses. The unconfined conditions characterize the Quaternary aquifer in the desert fringes.
- The depth to groundwater decreases toward the Nile River and increases toward the desert fringes. It varies from a few meters to more than 30 m. Thickness of the aquifer varies from a few meters to more than 170 m.
- Aquifer hydraulic conductivity ranges from 60 m/day to 100 m/day and transmissivity from 2000 $m^2$/day to 6000 $m^2$/day (Abd El-Moneim, 1988; Abd El-Bassier, 1997).
- The Quaternary aquifer mainly recharged from different resources as the infiltration from irrigation activity (canals, drains, and irrigation return flows), separated and seasonal flash floods, upward leakage from the deep aquifers through fault planes. The aquifer discharged mainly from pumping wells that used for irrigation (especially in the desert fringes), drinking, and domestic purposes.

## MATERIALS AND METHODS

**Water samples Collection**

To monitoring of polluted groundwater as the main drinking water resource, all groundwater wells were sampled for chemical analysis. Water samples were obtained from the wells on each of the sites following standard water sampling procedure. Each sample was directly collected into a factory-fresh 1.5 L plastic bottle, with the cap securely tightened. After collection the bottles were placed inside ice coolers for transportation to the laboratory.

To study the fluctuation or change of pollutant heavy metals of drinking water supply of time, many water samples were taken in many places along two years (from January 2013 to June 2014).

**Chemical Analysis**

The total dissolved solids (TDS), electrical conductivity (EC), and pH of the groundwater samples measured at the sampling sites.

The groundwater samples were analyzed for major ions (Sodium (Na), Calcium (Ca), Magnesium (Mg), Chloride ($Cl^-$), Sulphate ($SO_4^{2-}$), nitrate $NO_3$, nitrite $NO_2$, ammonia $NH_3$, and heavy metals (iron, manganese, copper, cadmium, lead, and zinc) (Table 1).

The Atomic Absorption Spectrophotometer with graphite furnace unit (iCE 3500 Double Beam Dual Atomiser AAS) used to determine the concentration of Mg, Na, Ca, Fe, Cd, Al, Cu, Pb, Mn, and Zn. The spectrophotometer (S110) used for estimating $SO_4$, $NO_2$, $NO_3$ and $NH_4$. Chloride was determined volumetrically (Table 1). All chemical analyses of the groundwater samples in the study area performed according to standard methods of analysis of APHA (2017).

## RESULTS AND DISCUSSION

**Major ion contamination of drinking groundwater**

The TDS of the drilled well samples varies from 121.2 to 898 ppm with an average 367 ppm. The TDS values reflect that 12.55 % of analyzing samples are above the acceptable limits according to WHO (2011) and EPA (2018) standards drinking water. The unsuitable water located at Aulad Amr well no. 1, El-Tawabiya well no. 3, H. El-Dahasa wells no. 1, 2 and 3, Ez. El-Busa wells no. 1, 2 and 3, Samhud wells no. 1 and 3, El-Kanak well no. 3, and El-Qara wells no. 1, 3, and 5.

The nitrate ($NO_3$) values vary from 0.1 to 72 ppm, all samples are below the acceptable limit except at Beni Birza well no. 1, and El-Karnak wells no. 1 and 3. The nitrite ($NO_2$) concentrations vary from 0.04 to

**Table 1.** The average concentration of water samples with the acceptable concentration for drinking water according to the U.S. Environmental Protection Agency (EPA 2018) and World Health Organization (WHO 2011) standards.

| Constituent | Min | Max | Mean | Standard Deviation | EPA, (2018) | WHO, (2011) |
|---|---|---|---|---|---|---|
| Sodium (Na) ppm | 16.46 | 279.64 | 71.08 | 44.168 | 200 | 200 |
| Calcium (Ca) ppm | 21.14 | 120.33 | 72.21 | 19.768 | 75 | 200 |
| Total Dissolved Solids ppm | 121.20 | 898.00 | 367.03 | 132.881 | 500 | 500 |
| EC µs/cm | 253.00 | 1600.0 | 745.87 | 257.828 | – | – |
| pH | 7.15 | 8.30 | 7.61 | 0.147 | 6.5 - 8.5 | 6.5 – 8.5 |
| Magnesium (Mg) ppm | 1.17 | 52.56 | 21.58 | 10.084 | 30 | 125 |
| Ca Hardnes as $CaCO_3$ ppm | 52.8 | 300.5 | 180.33 | 49.367 | – | – |
| Mg Hardnes as $CaCO_3$ ppm | 4.8 | 216.5 | 88.87 | 41.535 | – | – |
| Chloride ($Cl^-$) ppm | 11.00 | 249.0 | 51.11 | 44.961 | 250 | 250 |
| Sulphate ($SO_4^{2-}$) ppm | 7.80 | 251.8 | 60.98 | 46.674 | 250 | 250 |
| Nitrate $NO_3$ ppm | 0.10 | 72.0 | 5.59 | 21.643 | – | – |
| Nitrite $NO_2$ ppm | 0.04 | 0.58 | 0.15 | 0.180 | – | – |
| Ammonia $NH_3$ ppm | 0.05 | 1.90 | 0.52 | 0.369 | – | – |
| Iron (Fe) ppm | 0.001 | 1.168 | 0.195 | 0.198 | 0.3 | 0.3 |
| Manganese (Mn) ppm | 0.001 | 0.975 | 0.436 | 0.256 | 0.05 | 0.4 |
| Cadmium (Cd) µg/L | 0.5 | 3.2 | 1.43 | 0.0008 | – | 3.0 |
| Copper (Cu) ppm | 0.001 | 0.023 | 0.0063 | 0.0052 | 1.0 | 2.0 |
| Lead (Pb) ppm | 0.001 | 0.003 | 0.0015 | 0.0007 | – | 0.01 |
| Aluminium (Al) ppm | 0.05 | 0.33 | 0.13 | 0.076 | 0.05-0.2 | 0.2 |
| Zinc (Zn) ppm | 0.002 | 0.068 | 0.027 | 0.018 | 5.0 | 0.01 |

0.58 ppm (with average 0.15 ppm) and all samples are below the acceptable limit except at El-Kanak wells no. 1, 3, and 6.

Ammonia ($NH_3$) values vary from 0.05 to 1.9 ppm (with average 0.52 ppm). 44.3 % of analyzed samples are unsuitable for drinking water and lie above the acceptable limit (at El-Tawabiya well no. 3, and Al-Mkhlbtia wells no. 1 and 3, Al-Habilat wells no. 3, 4, 5 and 6, El-Sheikh Ali well no. 1, El-Rawatib well no. 1, N. Safar wells no. 1 and 2, El-Nagama well no. 5, El-Salamna wells no. 1 and 3, El-Khawalid well no. 1, El-Dahasa wells no. 1, 2, 3, and 4, Bakhanis well no. 1, El-Qara wells no. 1 and 5, Ez. El-Busa well no. 1, Samhud well no. 4, Beni Birza wells no. 1, 3 and 4, El-Hisanat wells no. 1 and 2, and El-Kanak wells no. 1 and 6).

The Sodium values vary from 16.4 to 279 ppm (with average 71.08 ppm), all samples are below the acceptable limit according to WHO (2011) and EPA (2018) except at El-Dahasa well no. 2. The Chloride concentrations vary from 11 to 249 ppm (with average 51.1 ppm), all samples are below the acceptable limit according to WHO (2011) and EPA (2018). The Sulphate values vary from 7.8 to 251.8 ppm (with average 60.9 ppm), all samples are below the acceptable limit according to WHO (2011) and EPA (2018) except at El-Dahasa well no. 1.

### Heavy metals concentration

Heavy metals consider as an important major source of pollution in both surface and groundwater. Their compounds occur as suspended or partially dissolved in water columns and they can accumulate in many aquatic organisms. Heavy metals contamination of groundwater as the main drinking water resource can be cause many health and environment problems. The liver and kidney more or less are affected or damaged, at short or long time drinking heavy metals polluted water.

### Iron (Fe)

Iron is one of the most abundant elements in the Earth's crust in both water and sediments (WHO 2011). The concentrations of iron in the study area vary from 0.001 to 1.605 ppm. The high concentrations of iron (above the acceptable limits according to WHO (2011) and EPA (2018) standards drinking water) detected in the western part along Abu Tisht, Farshut, Nag Hammadi stretch. While the low concentrations of iron (below the acceptable limits) observed in the eastern part (Dishna) as shown in iron distribution map (Fig. 3).

The more polluted places which the iron concentrations exceed the upper standard limit of

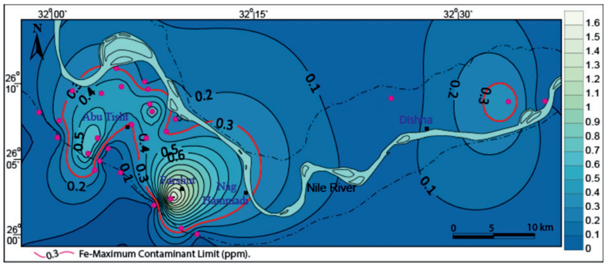


**Fig. 3.** Iron distribution contour map in the study area.

drinking water according to WHO (2011) and EPA (2018) are located in El-Qara well no. 1, El-Ka'mat wells no. 1 and 3, Al-Habilat west wells no. 5 and 6, Al-Mkhlbtia wells no. 2 and 4, El-Araki well no. 2, El-Dahasa wells no. 1, 2, 3 and 4, El-Hisanat wells no. 1, 2, 3 and 4, El-Nagama well no. 2, El-Rawatib well no. 1, El-Salamna well no. 1, and El-Tawabiya well no. 3 (Fig. 5)

The only purpose of these wells used for drinking water by the holding company for drinking and wastewater. It is strongly recommended to treat or stop pumping from these wells and search or replace for new water resources for drinking.

The problem of iron-polluted groundwater at low level concentrations can't detect by color and usually no noticeable taste. Because anaerobic groundwater may contain ferrous iron without turbidity or discoloration when directly pumped from a well. But if it's exposed to the atmosphere, the ferrous iron oxidizes to ferric iron giving a reddish-brown color to the water. This oxidation can deposit a very thin coating layer at the water flow path WHO (2011).

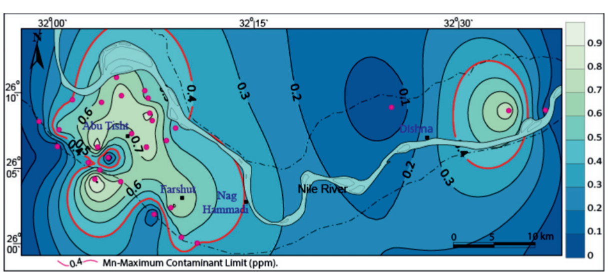


**Fig. 4.** Manganese distribution contour map in the study area.

## Manganese (Mn)

Manganese is one of the most abundant metals in the Earth's crust, usually occurring with iron. Mafic rocks contain the largest amounts of manganese (1200-2000 ppm) while sandstones contain relatively small amounts (100-500 ppm) (Kabata-Pendias and Pendias, 1992).

The concentrations of manganese in the study area vary from 0.001 to 0.975 ppm. The maximum limit for using water in drinking is 0.4 mg/L for manganese (WHO, 2011). Accordingly, 57.3 % of groundwater samples are unsuitable for drinking water and lie above upper limit (Fig. 5). At levels exceeding 0.1 mg/L, manganese in water supplies causes an undesirable taste in different domestic uses (WHO, 2011). 78.4 % from analyzed groundwater exceeding this level (Fig. 5).

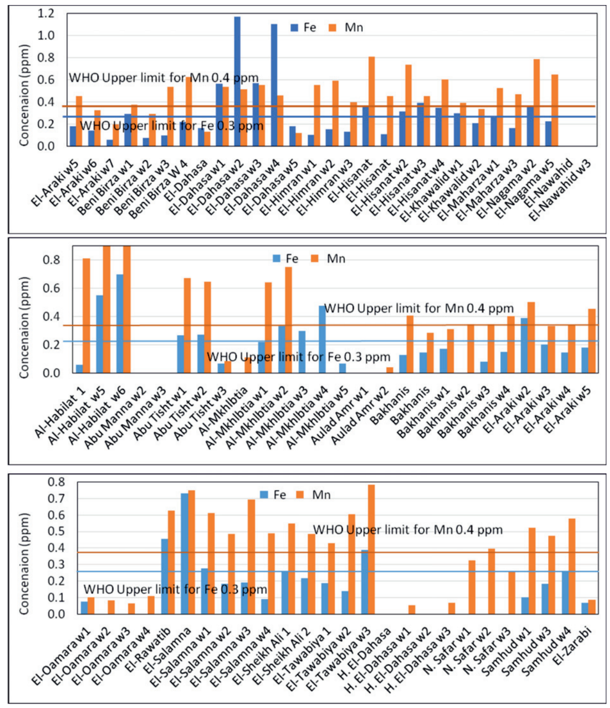


**Fig. 5.** Iron and manganese concentrations of drinking water supply at the study area.

The more polluted places which the manganese concentrations exceed the upper limit according to WHO (2011) are located in El-Kanak wells no. 1, 3 and 4, Ez. El-Busa well no. 3, El-Qara well no. 1, El-Ka'mat wells no. 1 and 3, Al-Habilat west wells no. 1, 5 and 6, Abu Tisht wells no. 1and 2, Al-Mkhlbtia wells no. 1 and 2,Bakhanis wells no. 1 and 4, El-Araki well no. 2 and 5, Beni Birza wells no. 3 and 4, El-Dahasa wells no. 1, 2, 3 and 4, El-Himran wells no. 1 and 3, El-Hisanat wells no. 1, 2, 3 and 4, El-Maharza wells no. 1 and 3, El-Nagama wells no. 2 and 5, El-Rawatib well no. 1, El-Salamna wells no. 1, 2, 3 and 4, El-Sheikh Ali wells no. 1 and 2, El-Tawabiya wells no. 1, 2, and 3, Samhud wells no. 1, 3 and 4 (Fig. 5)

The manganese distribution map (Fig. 4) indicates that the locations of high iron concentrations are nearly the same locations of high Manganese concentrations. They located in the western part along Abu Tisht, Farshut, Nag Hammadi stretch and in the eastern part (east Dishna). While the low concentrations of manganese observed in the central part and west Dishna

**Behavior of heavy metals pollutant by time**

To study the fluctuation or change of pollutant heavy metals (iron, manganese, copper, cadmium, lead, and zinc) of drinking water supply by time, many water samples were taken in many places along two years.The chosen places are El-Kanak wells no. 3 and 4, Ez. El-Busa wells no. 1 and 3, El-Qara well no. 1, El-Ka'mat well no. 1 (Fig. 6).

At El-Kanak wells no. 3 and 4, the manganese concentrations are increasing by time (from January 2013 to June 2014), but still exceeded the maximum contaminant limit of WHO (2011) standards drinking water (Fig. 6). The zinc concentrations are increasing by time, where at beginning water pumping (from January 2013 to June 2013 at well no. 3 and to May 2013 well no. 4) it is suitable for drinking. Then zinc concentrations continue increased and changed to exceed the maximum contaminant limit and become polluted drinking water supply (Fig. 6). The results indicate still present and continue sources of drinking water contamination. The concentrations of iron, copper, cadmium, and lead are nearly increasing by time (from January 2013 to June 2014), but they are below the maximum contaminant limit of both the WHO (2011) and EPA (2018) standards drinking water.

Ez. El-Busa wells no. 1 and 3 were used to examine the change of pollutant heavy metals of drinking water supply by time.At well no. 1, the behavior of most heavy-metals by time are not clear indicate irregular change in thesources of water

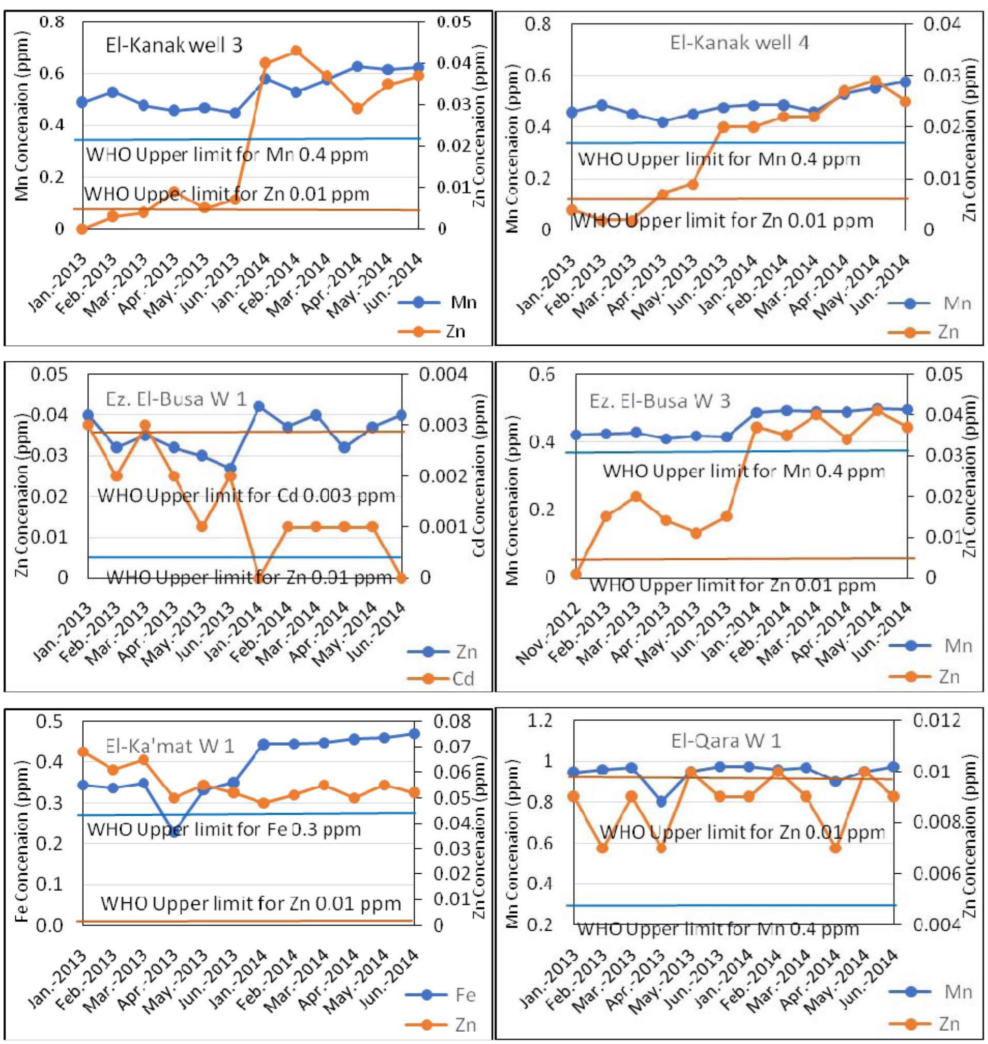


**Fig. 6.** Behavior of pollutant heavy metals by time.

contamination, while the concentrations ofcopper and zincare increasing by time. For zinc, all water samples (from January 2013 to June 2014) are above the maximum contaminant limit of standards drinking water (Fig. 6). At well no. 3, the concentrations of all heavy metals are increasing by time.Manganese and zinc of all samples along time are above the maximum contaminant limit of standards drinking water (Fig. 6). The other heavy metals (iron, copper, cadmium, and lead) are below the acceptable limits.

At El-Ka'mat well no. 1, iron and manganese concentrations are increasing by time. The other heavy metals have irregular change. For iron and zinc, all water samples (from January 2013 to June 2014) are above the maximum contaminant limit of standards drinking water (Fig. 6), while manganese, copper, cadmium, and lead are suitable for drinking water.

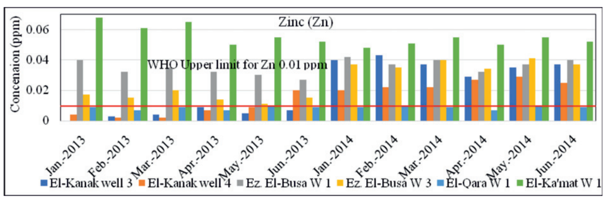


**Fig. 7.** Zinc concentrations in samples from drinking water supply of the study area.

Sampled of El-Qara well no. 1 show irregular behavior by time of most heavy-metals. All water samples of this well have manganese above the maximum contaminant limit of standards drinking water (Fig. 6). Most of iron, cadmium, and zinc are near or above the acceptable limits.

**Zinc (Zn)**

In the present study of groundwater as the main drinking water resource, zinc ranged from 0.002 to 0.068 ppm in groundwater samples.The maximum limit for using water in drinking is 0.01 mg/L for zinc (WHO, 2011). Accordingly, 72.3 % from groundwater samples, which collected (from January 2013 to June 2014) are unsuitable for drinking water and lie above the upper limit (Fig. 7). The other groundwater (27.7%) are very close to the acceptable limits according to WHO (2011). It strongly recommended to stop and prevent use of these locations for drinking therefore, they must be treatment before consumption or replace by other non-polluted water resources.

**Cadmium (Cd)**

Cadmium released to the environment in wastewater, and spread pollution caused by contamination from fertilizers and local air pollution. The values of cadmium concentration in water that used in drinking purposes in the study area vary from 0.0005 mg/L (0.5 μg/L) to 0.0032mg/L (3.2 μg/L). Most of cadmium values in groundwater samples lie under the limit as prescribed by WHO (2011) and only 8 % have cadmium exceed the acceptable limits of drinking water (Fig. 8).

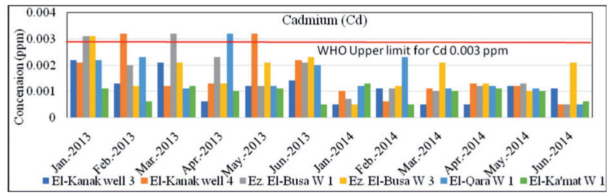


**Fig. 8.** Cadmium concentrations in samples from drinking water supply of the study area.

**Copper (Cu)**

Copper considers as one of drinking-water contaminant. Theacceptable limits of the EPA and WHO standards for copper concentrations should be less than 1.0 and 0.2 ppm respectively. The value of copper concentration in drinking water supply vary from 0.001 to 0.023 ppm. The copper level in groundwateris within the permissible limit set by both of the WHO (2011) and EPA (2018) standards drinking water (Fig. 9).

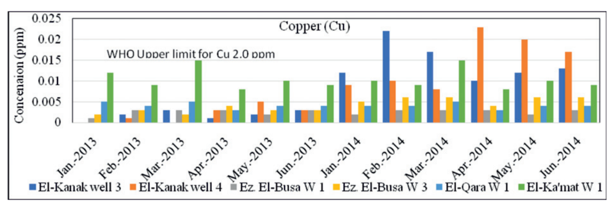


**Fig. 9.** Copper concentrations in samples from drinking water supply of the study area.

**Lead (Pb)**

The WHO (2011) international standards for drinking-water suggested that concentrations of lead should be less than 0.01 mg/L (10 μg/L). The acceptable limits of the EPA standard of lead should be less than 0.015 mg/L (15 μg/L).

The values of lead concentration in groundwater vary from 0.001 ppm (1 μg/L) to 0.003 ppm (3 μg/L). The lead level in groundwater is within the permissible limit according to both of the WHO (2011) and EPA (2018) standards drinking water (Fig. 10).

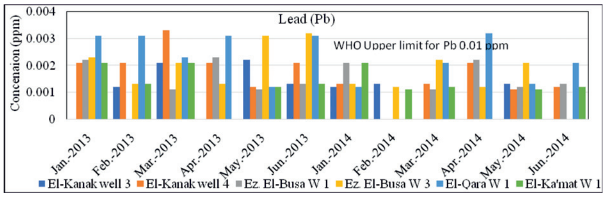


**Fig. 10.** Lead concentrations in samples from drinking water supply of the study area.

### Aluminium (Al)

It is the most abundant element found in the earth's crust (John De Zuane, 1990). It constitutes about 8.8 % and its content is the third after oxygen and silicon. It is the most widely spread among metals. The results obtained from its analysis vary from 0.05 to 0.33 ppm with an average of 0.13 ppm. Some of the groundwater samples, which used as sources of drinking water contained Aluminium above the specified WHO and EPAmaximum contaminant level (0.2 ppm). It located in Aulad Amr well no. 1, Al-Mkhlbtia wells no. 1 and 2.

The increase of the high heavy metals concentrations at the study area may be related to:

1. Wastewater sources, where the study area characterized by high urban activities and include many villages and cities with increase of population which most parts are not served by sewage network system. The increase of population lead to increase the infiltration of wastewater pollutants to groundwater by time.
2. The excessive use of fertilizers in agriculture activities where the study area is part from the old cultivated land.
3. The groundwater recharge from near and/or deep aquifer with high heavy metals Contaminations.

## CONCLUSION

In the studied groundwater samples most of sodium, sulphate, aluminium, nitrate and nitrite concentrations are below the acceptable limit,while TDS, ammonia are above the acceptable limits of drinking water standard (WHO). All chloride concentrations are below the acceptable limit. The iron concentrations vary from 0.001 to 1.605 ppm. The high Fe concentrations (above the acceptable limits) detected in the western part along Abu Tisht, Farshut, Nag Hammadi stretch, while the low values (below the acceptable limits) observed in the eastern part (Dishna). The manganese concentration was unsuitable for drinking water and lie above upper limit. The locations of high iron concentrations are nearly the same locations of high manganese concentrations. The concentrations of most pollutant heavy metals are increasing by time in different places, while the others are not clear, indicate irregular change in sources of water contamination.

Zinc level was very close to the acceptable limits. The values of cadmium,copper, and lead lie under the acceptable limit. The increase of the high heavy metals concentrations in groundwater may be related to the wastewater sources, excessive use of fertilizers in agriculture activities, and groundwater recharge from near and/or deep aquifer. It is strongly recommended stop pumping from the high heavy metals concentrations wells and search or replace for new water resources for drinking. The excess use of heavy metals-polluted groundwater along more or less time can cause many harmful effects.

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