Assessment of groundwater quality for drinking purpose in Sadat city area and distribution network surrounding industrial zones

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Abstract

Groundwater is one of the most important sources of fresh water in Egypt with specific reference to cities located away from the Nile River such as in Sadat city where groundwater constitutes the main source for drinking water. The present study pertains to the evaluation of the physico-chemical characteristics of the groundwater in and around an industrial zones located in a semi-arid region wherein the people of the terrain are entirely dependent on the groundwater for their needs. The data obtained shows that the average concentration of 0.0018 for of NO_3^-, 0.028 for Cu, 0.013 for Pb, 0.0019 for Cd, 0.15 for Zn and non-detected for Cr^{6+} in groundwater wells and pipelines during the period of 2006 to 2008. These results revealed that although the levels of nitrite, lead and cadmium of most samples in the groundwater and pipelines undergoes the Egyptian limits but it sometimes exceeds more than the limits of WHO health-based guideline for drinking water by double to three fold.

Introduction

Distribution of fresh water resources is uneven throughout the world and the fresh water availability is becoming scarce day by day owing to population growth and diverse human activities. Groundwater is generally considered being a safer source for drinking water than surface water. But groundwater can be contaminated by different sources of pollution including landfill sites; lechate migration from agricultural lands, injection wells, and open dumps, residential disposal, above and in addition to underground storage tanks and Industrial activities (19). Unlike surface water, groundwater is not directly subject to pollution (8).

In the absence of fresh surface water resources, groundwater is exploited to meet the demand exerted by various sectors. Spatial variation in the quality of groundwater in response to local geologic set-up and anthropogenic factors warrants the evaluation of the quality of groundwater for any purposes including that for human consumption. Assessment of the water quality for drinking purpose involves the determination of the chemical composition of groundwater and the remedial measures for the restoration of the quality of water in case of its deterioration demand the identification of possible sources for the contamination of groundwater. This paper presents findings on the chemical composition of the groundwater and investigates the possible geogenic and anthropogenic sources for chemical solutes. Many researchers across the globe (2, 16, 12, 7) have carried out studies with spatial technologies and interpreted the quality of groundwater. Mapping the spatial distributions of major elements and their interpolation with the geology and land use/land cover maps in GIS environment (3, 19) have contributed for the better understanding of the chemical processes of water and the methods of their acquisition.

However, it should be noted that, owing to its generally very low flow velocity, groundwater once contaminated will often remain so for many generation to come the best way to protect groundwater resources from deterioration is through early detection of contamination . Pollution may disperse over a large area depending on nature and sources of the pollutant and on the hydraulic and transport parameters of the ground water system. Restoring an aquifer is not only costly but also time consuming. Because the process of groundwater pollution is generally lengthy (may also take several years) and also due to the low velocities of groundwater, contamination is more likely to be discovered after twenty or thirty years from its initiation. Effects are not recognized timely with causes. Sometimes it may be recognized after the abounded of the pollution source (13, 15).

In general, it is not enough to have a sufficient supply of water. Water must be safe and free of risk factors. Risk factors related to water can be divided into two basic categories: risk of chemical pollution and risk of biological pollution. Both categories derive from man and human activity which inevitably tend to modify water composition, with respect to its original state in nature [18].

A large groundwater reservoir is encountered beneath EL-Sadat city. The aquifer is mainly recharged through the water which leaks from the Nile River and adjacent canals. Excess of irrigation water also find its way to the underlaying aquifer. Hence, the aquifer is generally renewable, so the water quality. The groundwater forms the major source for freshwater in El-Sadat city, not only for drinking purposed but also for industrial and agriculture needs. The hydraulic gradient is directed from the North East (where the Nile River is located) towards the center of the city **[**11, 13**].**

Ground water pollution in Sadat city was established to wells as sole source of water and distribution system in addition to bottled water and swimming pools. The aim of this work was to study the pollutant loading in Sadat city water. The paper also provides an assessment on the suitability of the groundwater for drinking purposes comparing to Egyptian and WHO water quality standards. The present study pertains to the evaluation of the physico-chemical characteristics of the groundwater in and around an industrial zones located in a semi-arid region wherein the people of the terrain are entirely dependent on the groundwater for their needs.

Materials and Methods

Sadat City is one of the new communities, which was established in the early eighties, applying with the governmental strategy of population redistribution. Sadat City belongs administratively to Menufiya governorate, within the western Nile Delta region. It is located north of Cairo–Alexandria desert road between Km 95and Km103 from Cairo. The City is bounded by longitudinal 30° 19’ 30” -30° 40’ 27” E and latitude 30° 15’ 50” – 30° 34’ 00”N **(11).**

2-1. Water samples sources:-

Five types of water samples, i.e. well water, tap water, storage tank water, swimming pools water and bottled water were collected from different sites at Sadat city areas during 2011 - 2013. Grape samples were collected from the ground water wells of Sadat city. The samples were collected from the well in polypropylene containers. Samples was took from western station (near oxidation ponds) – supplying wells at industrial and residential zones –southern station (in the south area of the city). Samples covered most area of Sadat city as shown in Figure (1). Grape

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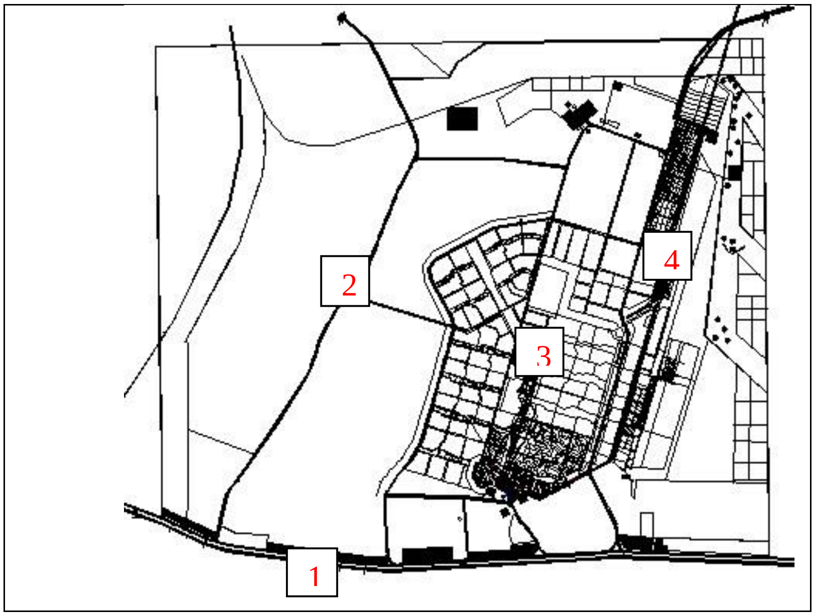
samples were collected from the well in polypropylene, glass containers. Grape samples were collected from the well in polypropylene, glass containers.



1- Cairo Alexandria desert road
2- Deserts
3- Residential zones
4- Industrial zones

Figure (1). Map of Sadat city illustrating the industrial zones, residential zones and water well distribution.

2.2. Physico-Chemical analyses of water sample

For chemical analysis, two liters grab water samples were collected and stored under cooling conditions. All physical and chemical analysis was determined by the procedures recommended in the Standard methods for the examination of water and wastewater **(1).** Hundred and twenty samples of well water were collected at different wells and distribution System for established of nitrite and heavy metals. Cover the most area of Sadat locations (Residential zones & Industrial zones). For Wells & distribution system analysis, Nitrite and heavy metals as lead, cadmium, cupper, chromium, and zinc in the period 10/2006 to 11/2007 were determined.

2.3. Determination of Nitrite

An aliquot 50 ml of water sample was treated with 1.0 ml of sulfanilamide solution (1%) then 1.0 ml of N-(1-naphthyl)-ethylenediamine dihydrochloride solution (1 %) was added and swirled to mix. The mixture was allowed to color development for 10 min. The color development was measured at 543nm. The nitrite concentration was calculated from the calibration curve and the dilutions of the sample are to be taken into account in evaluating the results **(1).**

2.4. Heavy metals samples digestion

A (100 ml) sample volume was mixed and transferred to 125-ml conical flask. 5 ml conc. HNO_3 was added and a few boiling chips, glass beads, brought to a slow boil and evaporated on a hot plate to the lowest volume possible (about 10 to 20 ml before precipitation occurs. Continue heating and adding conc. HNO_3 as necessary until digestion was completed as shown by a light – colored, clear solution and the samples didn't

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let dry during digestion. Flask walls washed down with water and two 5 ml portion of water was added, these rinsing was added to the volumetric flask. Cooled, diluted to mark and mixed thoroughly. Portions of this solution were taken for required metal determination (**1).**

2.5. Heavy metals determination by atomic absorption instrument (AAS). The determination of copper, lead, zinc, cadmium and chromium was performed by direct aspiration of pretreated samples into an air –acetylene flame with atomic absorption spectrophotometer instrument (AAS) model Thrmo Electron corporation S series, 10 cm burner head, single element hollow cathode lamp of metal under investigation (**1).**

Results and discussion

The main source of water supply in Sadat city is groundwater. A sewage system under gravity is present in Sadat city, both in the residential and industrial zone. Two pump stations transport the wastewater to the oxidation ponds north of Sadat city which represent residential and industrial regions [6].

Physico-chemical characteristics

Groundwater of the study area in terms of me/l, is characterized by Ca^{2+} > Mg+ > K^+ > Na^+ and HCO^{3-} > Cl^- > SO_4^{2-} > NO^{3-} > F^- > CO^{3-}. Average contribution of individual cations to total cations is 22.09 % Ca^{2+}, 49.86 % Mg^+, 28.81 % Na^+ and 0.24 % K^+. On an average, anions are made up of 51.62 % HCO^{3-}, 14.55 % SO_4^{2-}, 27.18 % Cl^-, and 6.64 % NO^{3-}. Averages me/l content of (Ca^{2+} + Mg^+) is higher than that of (Na^+ + K^+) and averages me/l content of (HCO^{3-} + SO_4^{2-}) is higher than that of (Cl^- + NO^{3-}).

Nitrite results

Most nitrate and nitrite to which humans are exposed is in their diet, Research Council report on the health effects of nitrate, nitrite, and N-nitroso compounds concluded that for more than 99% of the U.S. population, about 99% of nitrite intake comes from the diet. Vegetables are the primary source of nitrate and nitrite in food. Inorganic fertilizers and human and animal wastes (from livestock operations and septic tanks) are the primary sources of nitrate and nitrite contamination of drinking water. Nitrate released to soil as a result of human or animal activities can enter groundwater or surface water as a result of leaching or runoff. Some nitrate and nitrite exposure also originates in endogenous production of nitric oxide by many activities **[9].** The primary adverse health effect associated with human exposure to nitrate or nitrite is methemoglobinemia. Nitrite converts hemoglobin to methemoglobin by oxidizing the Fe^{2+}in heme to Fe^{3+}, which cannot transport oxygen. Concentrations above 10% can cause cyanosis, characterized by bluish skin and lips, and concentrations above 25% are associated with hypotension, rapid pulse, and rapid breathing, as a result of the vasodilator effects of nitrite. Concentrations above 50% can be fatal **[10].**

The results obtained from the residential zones showed an average values for all the five areas are 0.0015 mg/l. Generally, the result increased through 3/2011 to 11/2013. Samples of southern station ranged from 0.000 to 0.003 mg/l with an average 0.0022 mg/l. The supplying wells ranged from 0.000 to 0.003 mg/l with an average 0.001 mg/l. The samples of eastern station ranged from 0.000 to 0.004mg/l with an average 0.0025 mg/l. The measured concentration of nitrite in samples of industrial zones no. 2,3,4,5 ranges from 0.000 to 0.003 mg/l with an average for all zones 0.002

mg/l, as shown in Figure (3). All the results are below the Egyptian guidelines for drinking water quality (0.005 mg/l) but higher than the international guidelines for drinking water quality given by the World Health Organization **(17)** except the industrial zone no.2, industrial zone no. 3, industrial zone no. 4, industrial zone no. 5. From the obtained results it is clear that the results decrease in 1/2011&11/2013 and increase in 10/2011 & 5/2013 in industrial zones.

3.2. Copper results

The water sources copper values were report almost zero values residue in water. So, the Sadat water sources are suitable as drinking water sources. Figure (4) showed the copper results for different water samples locations. Copper content in the ground water samples of residential zones showed low concentration in all taken samples. The copper contents varied between 0.00 to 0.08 mg/l with an average of 0.037 mg/l for residential zones. Water samples of industrial zones showed low concentration ranged between 0.00 to 0.1 mg/l with an average of 0.065 mg/l. Southern station ranged between 0.00 to 0.25 mg/l and there were no detection Cu for southern tank. Supplying well contents varied between 0.00 to 0.08 mg/l with an average of 0.05, 0.025 and 0.03 mg/l for supplying wells No. 2, 4 and 7, respectively. Eastern station contents varied between 0.00 to 0.08mg/l with an average of 0.02 mg/l. The concentration of copper in the residential zones is below the Egyptian guidelines and international guidelines for drinking water quality (1.0mg/l) [4, 17]. Copper is required for adequate growth, cardiovascular integrity, lung elasticity, neovascularization and neuroendocrine function, and iron metabolism. Copper is obligatory for enzymes involved in aerobic metabolism. Copper in drinking water tardation, causes anemia, hypothermia, neutropenia, diarrhea, cardiac hypertrophy, bone fragility, impaired immune function, weak connective tissue, impaired central-nervous-system (CNS) functions, peripheral neuropathy, and loss of skin, fur (in animals), or hair color [10].

3.3. Lead Results

Lead average values and its standard deviation for all sampling points ranged between 0.01 to 0.017 mg/l. The wells water show values lower than distributed water. The water sources lead values were report almost 0.01 values residue in water. So, the Sadat water sources are suitable as drinking water sources according to Egyptian limits [4]. The concentration of lead ranged from 0.005 to 0.035 mg/l with an average of 0.012 mg/l for residential zone. From the obtained results as shown in Figure (5), it is clear that the average values for all the five areas are different. Although the concentration of lead in residential zones is below the Egyptian guidelines for drinking water quality (0.05mg/l) **[4],** but it is very close to the Egyptian limit and higher by three folds than the international guidelines for drinking water quality given by the World Health Organization **[17]** which is 0.01mg/l.

The concentration of lead ranged from 0.000 to 0.021 mg/l with an average of 0.015mg/l for industrial zone no.2, 0.005 mg/l for industrial. The concentration of lead ranged from 0.001 to 0.03 mg/l with an average of 0.005 mg/l for southern tank. The higher amount of lead in well number 1 of the southern area was detected 0.0095 mg/l. However, the concentration of lead in southern wells is below the Egyptian guidelines for drinking water quality (0.05mg/l). For supplying wells lead ranged from 0.000 to 0.02 mg/l with an average of 0.0047mg/l. The increase of lead in the wells of the industrial area might be attributed to the industrial releases or due to the erosion of the natural deposits. The concentration of lead ranges from 0.005 to 0.02 mg/l with an average of 0.013mg/l.

3.4 Cadmium Results

Exposure to cadmium in animal humans results in kidney dysfunction, hypertension, anemia, and liver damage and classified in EPA"s Group B1 (probable human carcinogen) **[14, 15]**. The cadmium average values and its standard deviation for all sampling points ranged between 0.0015 to 0.003 mg/l as in Figure 6. Cadmium in the ground water samples is relatively higher than the other elements in the studied samples. The results showed that cadmium contents varied between 0.001to 0.004 mg/l with an averages of 0.0015mg/l for residential zones. For industrial zone samples varied between 0.001to 0.004 mg/l with an average of 0.002 mg/l. Samples varied between 0.001to 0.004 mg/l with an average of 0.0027mg/l for southern tank, except of the wells no.1and 3 were 0.004 and 0.0032 mg/l, respectively. Samples varied between 0.000 to 0.004 mg/l with an average of 0.0007mg/l for supplying well. For eastern station Samples varied between 0.000 to 0.003 mg/l with an average of 0.002.

The water sources cadmium values were reported high results comparing to international guidelines for drinking water quality given by the World Health Organization **[17]** which is (0.003 mg/l) but still less than Egyptian limits. Cadmium Values were fluctuated in the same source water. So, El-Sadat water sources are suitable as drinking water sources according to Egyptian limits (0.005 mg/l) **[4]**. Cadmium is used for industrial activity as electroplating, paints, inks and plastics. Many of these uses will tend to make the element present in water that comes in contact with buried waste **[16].**

3.5. Zinc results

Zinc is found in crustal rocks, has only one oxidation state, Zn^{2+}, and essential in metabolism in plants and animals, Zinc is used for electroplating as a coating to inhibit corrosion of steel **[17]**. Figure (7) shows that all points below the Egyptian limits (5mg/l) during sampling period and the water contents are very low comparing to Egyptian limits. Zinc average values and its standard deviation for all sampling points ranged between 0.25 to 0.45 mg/l. The zinc average of residential zones, industrial zones, southern station, supplying wells and eastern station were 0.160, 0.007, 0.2470, 0.036 and 0.330 mg/l, respectively. It is clear that the obtained results were below the Egyptian guidelines for drinking water quality (5.0mg/l) **[8]** and the international guidelines for drinking water quality given by the World Health Organization **[17]** which is 5.0 mg/l.

3.6. Chromium results

Chromium found in rock in trivalent form Cr^{3+}. Dissolved chromium may be present as Cr^{3+} or Cr^{6+} and the predominate form are $Cr(OH)^{2+}$ and Cr $(OH)_2$. Industrial application, electroplating, painting, and other chemical operations .wastes may enter groundwater through runoff leaching**.** it is clear from obtained results were below the Egyptian guidelines for drinking water quality and the international guidelines for drinking water quality given by the World Health Organization (WHO) is 0.05mg/l. The data obtained showed that all samples taken from wells have not been contaminated with chromium Cr^{3+} or Cr^{6+} from industrial activities in the city or erosion of the natural deposits.

4. CONCLUSION

The data obtained shows that the average concentration of 0.0018 for of NO_3^-, 0.028 for Cu^{2+}, 0.013 for Pb^{2+}, 0.0019 for Cd^{2+}, 0.15 for Zn^{2+} and non-detected for Cr^{6+} in groundwater wells and pipelines during the period of 2006 to 2008. These results revealed that although the levels of nitrite, lead and cadmium of most samples in the groundwater and pipelines undergoes the Egyptian limits but it sometimes exceeds more than the limits of WHO health-based guideline for drinking water by double to three fold.

It is clear that the average value of the concentration of copper in the different stations area were lower concentrations and below the international guidelines and the Egyptian guidelines for drinking water quality (1.0mg/l) **[4, 17].** Finally we indicate that all wells have not been contaminated with copper by any industrial activities in the city.

The concentration of lead in El-Sadat city is below the Egyptian guidelines for drinking water quality (0.05mg/l) **[4]**, but it is near too the limit and higher by three folds than the international guidelines for drinking water quality given by the World Health Organization (WHO) which is 0.01mg/l **[17]**.

Cadmium water content results with an average 0.0019 mg/l were below the Egyptian guidelines for drinking water quality (0.005 mg/l) **[4]**, and the international guidelines for drinking water quality given by the World Health Organization (WHO) **[17]**, which is 0.003 mg/l. excepted residential zone no,7 at 3/2007 was 0.004 mg/l

From Zinc measurements in El-Sadat city with an average 0.15 mg/l, it is clear that the obtained results were below the Egyptian guidelines for drinking water quality (5.0mg/l) **[4]** and the international guidelines for drinking water quality given by the World Health Organization (WHO) **[17]**, which is 5.0 mg/l.

For chromium Cr^{3+} and Cr^{6+}, the data obtained showed that all samples taken from residential zones, industrial zones, wells have not been contaminated with chromium Cr^{3+} or Cr^{6+}.

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