J.Soil Sci. and Agric. Eng., Mansoura Univ., Vol. 8 (10): 515 - 520, 2017

Spatial Distribution of Drainage Water Resource Quality Parameters at Northern Dakahlia Governorate

Hammad, S. [1]; A. El-Ghamry[1]; A. Mosa [1] and A. E. Khamlaj [1]
[1] Soils Department, Faculty of Agriculture, Mansoura University, 35516 Mansoura, Egypt

ABSTRACT

In regions with water scarcity, especially in arid and semi-arid countries, there is an urgent need for reusing low-quality water resources (e.g. agricultural drainage water) for agricultural purposes. However, preparatory restricted procedures (e.g. quality assessment) should be undertaken to avoid the hazardous effect of using these low-quality water resources on arable soils. For this purpose, 20 geo-referenced agricultural drainage water samples were collected by the aid of Global Positioning System (GPS) from Belkas District, Dakahlia Governorate to assess water quality for agricultural purposes. Results indicated that most of the investigated water resources lie between slight to moderate restriction in use based on their salinity value (0.7-3.0 dSm^{-1}). The highest concentrations of total soluble salts were recorded in the northern sites (6-7 dS m^{-1}), and the lowest concentrations (1-2 dS m^{-1}) were recorded in areas located at southern sites. Potential salinity values were relatively high with ranging values between 8-24 meq L^{-1} in most of investigated sites. Sodicity hazard was relatively low, and most of investigated water resources were classified as class 1, except those at northern parts, which were classified as class 2. This result was further confirmed by the results of RSC index, which showed low potentiality for sodium carbonate formation due to the high concentrations Ca^{2+} and Mg^{2+} ions in water. Boron concentration in most water resources were relatively low with some restrictions for sensitive plants irrigation, especially with samples located at northern sites. Cadmium concentrations in all investigated sites was very low (<0.003 mg L^{-1}) suggesting low heavy metals contamination threats. In conclusion, these water resources showed a good suitability for reusing in irrigation under restricted monitoring procedures.

Keywords: Spatial distribution, Quality, Drainage water, Irrigation

INTRODUCTION

There is a growing debate concerning the rapid water shortage crisis in Egypt and worldwide as a result of fast growing population and industrialization with the stability of fresh water resources (Mosa *et al*., 2016; Xiao *et al*., 2017). The total water supply of the Egyptian water budget is estimated as 66 BCM (55.5 BCM from the Nile River, 4.0 BCM from effective rainfall in the Northern parts of the Mediterranean Coast and Sinai, and 6.5 BCM from the non-renewable deep groundwater resources); however, the total current water demands for different sectors is estimated as 79.5 BCM/yr (Sallam, 2014). This wide gap between resources and demands (13.5 BCM/yr) should be filled by untraditional water resources. Beside the limitation in freshwater resources, there are additional losses associated with several anthropogenic and/or environmental reasons including: (1) evaporation and seepage from the open canals, (2) huge consumption by the wild aquatic plants and weeds, (3) expansion in cultivating highly water consumption crops (e.g. rice and sugarcane), lack of awareness regarding water shortage crisis, and several defects in the optimized irrigation systems (e.g. excessive water application, gates control, land leveling, pumping, drip and sprinkler irrigation systems installation).

Proper management practices, therefore, should be undertaken by the Egyptian Government in order to work in filling the wide gap between water supplies and demands. Among the proposed management practices, the reusing of secondary water resources (e.g. drainage and low quality water resources) could be considered as the most effective and affordable approach to fill the wide gap in water demands (Mosa *et al*., 2011). On the other hand, restricted procedures should be applied in order to avoid the potential hazards associated with the accumulation of heavy metals, pesticides, and pharmaceutical in the rhizosphere. Additionally, biological risk hazards may be associated with high microbial levels of bacteria, protozoa, helminths and viruses. Further to this, the long-term irrigation by low quality water resources could lead to substantial increase in soil salinity and sodicity levels. Therefore, regular monitoring programs should be directed toward assessing the environmental impact of reusing low-quality water resources in the agricultural sector. Risk assessment scenarios, regular monitoring of secondary water resources, geographic variability of wastewater utilization, and regular monitoring programs by public agencies are essential to protect public health and improve water management. Unfortunately, till now the local laws and legislation controlling wastewater reusing programs are not restrictedly executed.

The objective of this investigation is to highlight on agricultural drainage water availability, determine the chemical constants in the studied drainage water and subsequently its quality for irrigation purposes and its effects on soils and plants grown in north Nile Delta, Egypt.

MATERIALS AND METHODS

1. Water sampling.

Twenty geo-referenced agricultural drainage water samples were collected by the aid of Global Positioning System (GPS) technique to provide a represented distribution of environmental resources in the studied area (Belkas District, Dakahlia Governorate) on December 2014 (Fig. 1). Clean bottles with uniform-sized volume were used for water sampling. Bottles were rinsed gently three times with representative water samples. Samples were directly inserted into the bottles leaving a proper head-space at the top of the bottle, and the cap bottle was tightly closed to prevent contamination. Water samples were placed directly in the fridge without freezing.

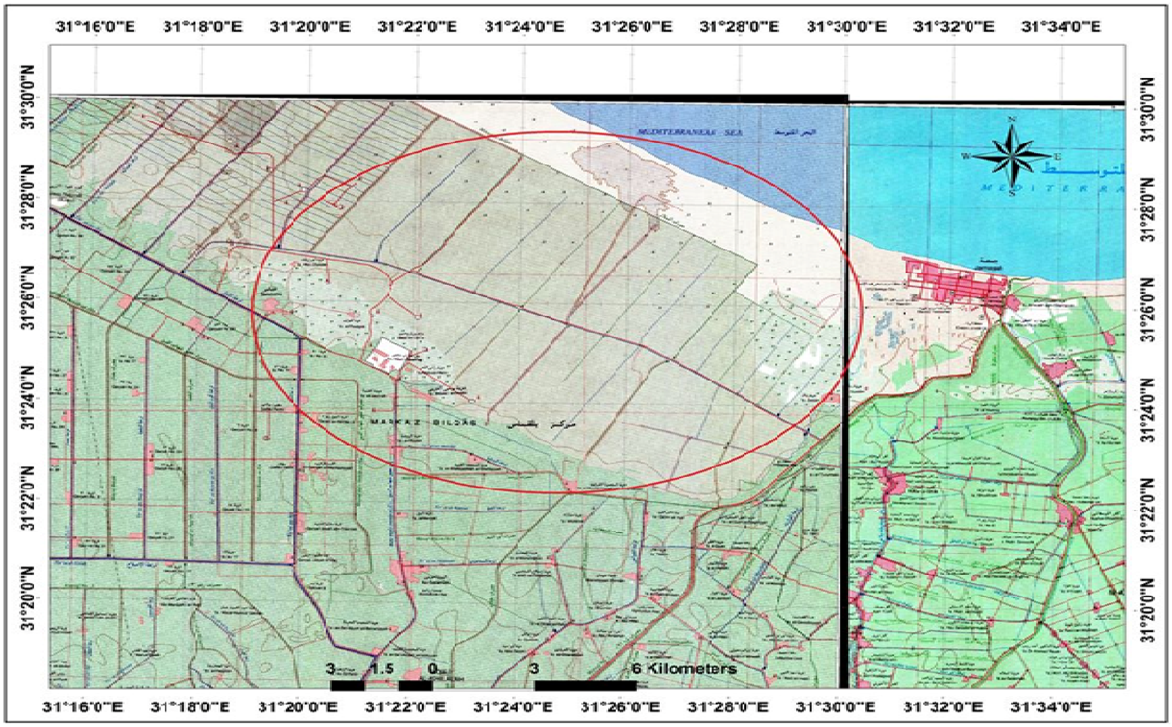

Fig. 1. Location of the study area, and the sampled drains.

2. Water analyses

To Judge perfectly water chemical properties, these methods were used according to the global standard methods (CHAPMAN and PRATT, 1962):

- Electrical conductivity of water was determined by Ec-meter (*HANNA* instrument HI5522-01).
- Soluble calcium and magnesium ions (Ca^{2+} and Mg^{2+}) were determined through titration method using standardized versenate solution.
- Soluble sodium and potassium (Na^{+} and K^{+}) ions were determined by using a flame photometer (Sherwood, MODEL 360).
- Carbonate and bicarbonate (CO_3^{2-} and HCO_3^{-}) ions were determined through titration with standardized sulfuric acid solution.
- Chloride (Cl^{-}) was titrated with silver nitrate solution.
- Sulphate ions were calculated as the difference between sum of cations (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}) and anions (CO_3^{2-}, HCO_3^{2-}, Cl^{-}).
- Boron concentration was determined by colorimetric method as mentioned by Bingham (1982).
- Cadmium concentration was determined by atomic absorption spectroscopy (SensAA-GBC Scientific Equipment).

Water quality indices were calculated according to FAO guidelines (Ayers and Westcot, 1985):

- The Residual Sodium Carbonate (RSC) expressed as meq L^{-1} was calculated as follows:

$$\mathbf{RSC = (CO_3^{2-}+HCO_3^{-})-(Ca^{+2}+Mg^{+2})}$$

- Potential salinity was calculated as the sum. of chloride and half sulfate ions as follows:

$$\textbf{Potential salinity} = \mathbf{Cl + 1/2\ SO_4^{2-}}$$

- Sodium Adsorption Ratio (SAR) (meq/L^{-1}) was calculated by the following equation:

$$SAR = \frac{\mathbf{Na}}{\sqrt{\frac{\mathbf{Ca+Mg}}{\mathbf{2}}}}$$

3. Geo-statistical analysis.

The ordinary Kriging was used to study the spatial distribution of the water quality indices throughout the geo-referenced samples. It is working under the geostatistical analyst extension in ArcGIS desktop software (version 10.3). Using Landsat imagery, the geo-referenced sites were plotted onto photos downloaded from earth explorer website (http://earthexplorer.usgs.gov/).

RESULTS AND DISCUSSION

1. Total soluble salts

It is clearly noticeable that the highest concentrations of soluble salts were recorded at the northern sites (6-7 dS m^{-1}), and the lowest concentrations (1-2 dS m^{-1}) were recorded in areas located at southern sites (Fig. 2). Many hydrogeological studied have focused on the sharp interface between fresh water resources and seawater across coastal areas, especially in the transition zone between fresh water and salt water. These transition zones are highly vulnerable to salt deterioration hazards from seawater intrusion. There are several factors controlling the intrusion rate of seawater from the transition zone between seawater and the arable coastal zones (e.g. changes in sea levels where climate change scenarios play vital roles, hydrological characteristics of groundwater aquifers (charge and discharge), hydrologic conditions of upstream, tidal and seasonal fluctuations of sea water

(Zhou, 2011). Recently, the progressive urbanization and agricultural exploitation projects led to withdrawal of huge amounts of freshwater resources from the groundwater aquifers to cope with water resources needs, which led to intrusion of seawater in these transition zones.

The Egyptian Mediterranean coast lies at the South Eastern sector of the Levantine sub-basin, from longitudes 25°30′ E to 34° E and extends northwards to latitude 33° N. Based on the results of water survey carried out along the Egyptian Mediterranean coast from Arish to Salloum, average contents of major ions were as follows: Na^+ (12337 mg L^{-1}), K^+ (381 mg L^{-1}), Ca^{+2} (403 mg L^{-1}), Mg^{2+} (1506 mg L^{-1}), and SO_4^{2-} (3068 mg L^{-1}) (Nessim *et al*., 2015). These high concentrations of salt ions will threat the quality of freshwater resources (surface and groundwater) in the northern coastal zones of Egypt. In addition, these dissolved ions that contribute to a salinity hazards are readily transported by water to accumulate in the root zone (rhizosphere).

According to the FAO guidelines, most of the investigated water resources lie between slight to moderate restriction in use (0.7-3.0 dSm^{-1}). Besides, there are other water resources, especially in the northern areas, classified as severe for their uses in agricultural purposes (> 0.3 dSm^{-1}). Restricted procedures, therefore, should be undertaken for using in irrigation (e.g. resistant plants to salinity stress, leaching requirements, soil quality management, and efficient plant nutrition). Several sensitive plants (e.g. bean, turnip, carrot, clover, and strawberry) should be avoided from irrigation by these water resources. Conversely, highly resistant plants (e.g. barley, cotton, sugar beet, and date palm) can be used without potential losses in the targeted economic yield (Ayers and Westcot, 1985).

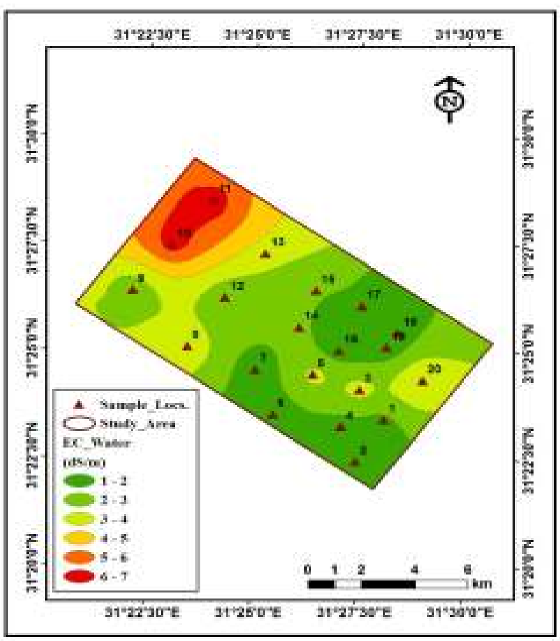

Fig. 2. Spatial distribution of water electrical conductivity (Ec) in different investigated sites.

2. Potential salinity

Potential salinity is an important criterion introduced by (EATON, 1950) as the submission of Cl^- and half SO_4^{2-} ions expressed as meq L^{-1}.

Potential salinity = Cl^- + 1/2 SO_4^{2-}

In this criterion, it is supposed that the accumulation of soluble salts from waters containing various cation combination of SO_4^{2-} applied to soil having different ratios of Ca^{2+} and Mg^{2+} on the exchangeable complex caused approximately half of the SO_4^{2-} to be precipitated as $CaSO_4^{2-}$ while the other half remained in the soluble form of Na-$MgSO_4$ in soil.

According to data given by Fig. (3), potential salinity values were relatively high. Most of investigated sites were in the range of 8-24 meq L^{-1}. These water resources are classified as Class 3 in slowly drained soils (e.g. clay soils), and class 2 in well drained soils having low colloidal contents (e.g. sandy soils). The northern sites showed very high levels of potential salinity (42-48 meq L^{-1}) because of the seawater intrusion effect. These waters are classified as class 3 in all soil types, and proper management practices (e.g. selection of tolerant crops and soil fertility management) should be undertaken to avoid the potential hazardous effect of salinity.

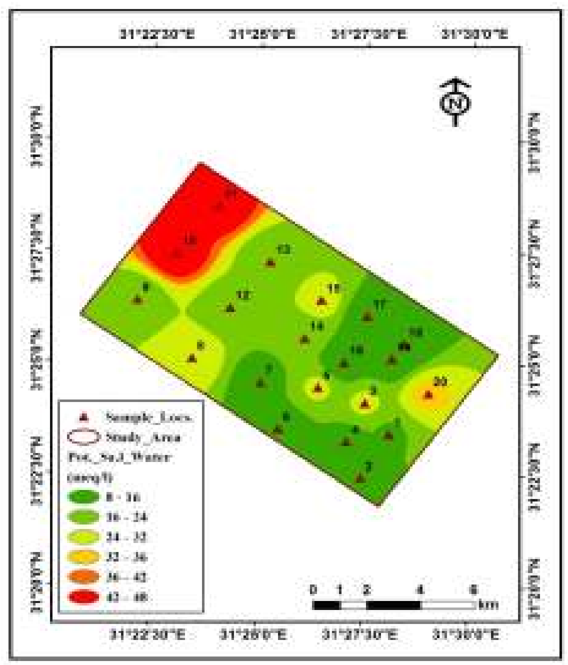

Fig. 3. Spatial distribution of potential salinity (meq L^{-1}) in different investigated sites.

3. Sodium Adsorption Ratio (SAR)

Sodium adsorption ratio (SAR) is an important parameter for assessing water quality for agricultural purposes. It is a ratio expressing the tendency of sodium (Na^+) ions be sorbed onto the exchangeable sites of soil at the expense of other major ions particularly calcium (Ca^{2+}) and magnesium (Mg^{2+}). Under the dominance of Na^+ ions, soil exhibits a dispersed condition with low impermeable to water inputs through rain and/or irrigation due to plugging and sealing of the surface pores. Other related hazards (e.g. soil crusting, lack of aeration, potential formation of sodium carbonate, plant and root diseases, wide spreading pest and weeds due to waterlogging conditions) could be occurred with the long-term irrigation with waters containing high SAR levels.

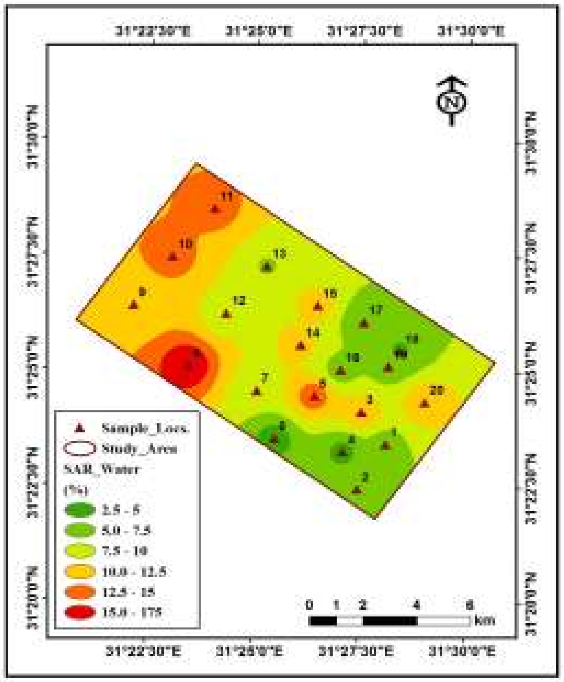

Fig. 4. Spatial distribution of SAR in different investigated sites.

Data of our study revealed that most of investigated water resources are classified as class 1 according to FAO guidelines. Other sites, including those at northern parts, as classified as class 2. Gypsum requirements should be taken into consideration in case of using class 2-water for irrigation in clay soils.

4. Residual Sodium Carbonate

The Residual Sodium Carbonate (RSC) is an index of irrigation water used for describing the potential alkalinity hazard of soils, especially in those with high CEC. When dissolved sodium in comparison with dissolved calcium and magnesium is high in water, clay soil swells or undergoes dispersion which drastically reduces its infiltration capacity

$$\textbf{Clay-Ca} + \mathbf{CO_3^{2-}}\ \textbf{[from water]} + \mathbf{2Na+}\ \textbf{[from water]} = \textbf{Clay-Na} + \mathbf{CaCO_3}$$

Clay-Na results in increase in ESP. High ESP causes high pH

In regions with water scarcity, particularly those located at arid and semi-arid regions, the extensive use of secondary waters with high residual sodium carbonate (RSC) often cause severe deterioration in soil fertility indices including the salinisation and sodification of the soil profile, which adversely affect the crop growth.

Several studies have reported the long–term effect of high RSC values of water on soil quality and plant nutritional status. According to Prasad *et al*., (2001), the long-term irrigation with high RSC-waters caused an increase in soil pH, soil salinity, exchangeable sodium percentage (ESP), and, hence, considerable reduction in herb and oil yield of both the palmarosa and lemongrass. In another long-term experiment carried out in India, water with high RSC values (10-12.5) meq L^{-1} were applied with or without gypsum and organic matter application to explore their ameliorative effect to the potential sodicity hazard. The results showed that the long-term use of this water without gypsum or organic matter application led to gradual increase in soil pH and ESP and severe deterioration in soil physical properties, which decreased the economic yield of both rice and wheat (Choudhary *et al*., 2011).

Results of our study showed relatively low potential hazardous effect due to the low RSC index as most of these values were minus except only one location. The calcium content of soil and water in Egypt has a beneficial effect on reducing the alkalinity hazards. These water resources, therefore, could be used for irrigation under proper conditions without potential sodium carbonate threats.

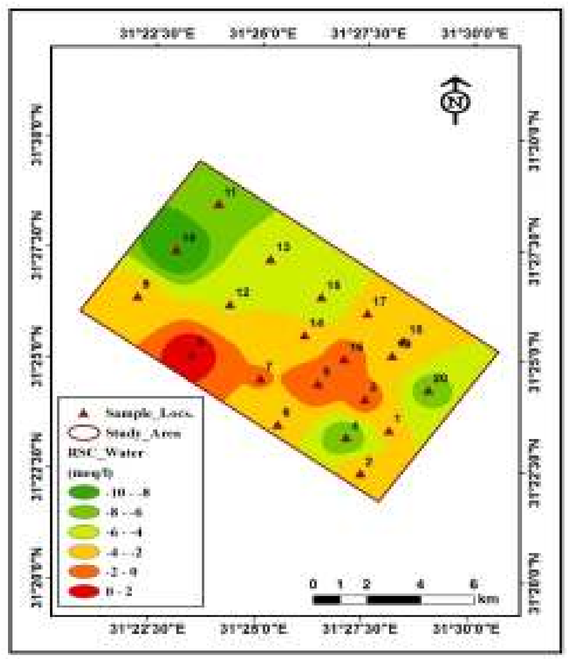

Fig. 5. Spatial distribution of RSC in different investigated sites.

5. Boron concentration.

Boron is an essential metalloid for plant growth. It plays several important roles in plant including sugar transport, hormones behavior, seed development, cell wall strength, and cell division (Han *et al*., 2008). Boron is needed for plant physiological reactions in relatively small amounts; however, and if present in amounts appreciably greater than needed, it becomes toxic. For some crops, if 0.2 mg L^{-1} boron in water is essential, 1 to 2 mg L^{-1} may be toxic (Ayers and Westcot, 1985). These toxicity symptoms may appear in significant reductions in plant growth and elongation, reduction in photosynthetic capacity and sever damage in plant tissues and leaf margins.

Data illustrated in Fig. (6) indicated that boron concentration in all irrigation samples did not exceed 1.0 mg L^{-1} (0.34-0.96). Most of boron concentrations ranged between 0.4-0.6 mg L^{-1}. The highest boron concentrations in the studied sites were associated with the adjacent sea sites (0.8-0.96 mg L^{-1}), and the lowest boron concentrations were observed in southern locations. These results highlighted the effect of Mediterranean Sea on increasing boron in drainage water resources. Within the past few decades, the water quality in many of the coastal aquifers along the Mediterranean Sea has rapidly degraded (Vengosh *et al*., 2005).

According to FAO guidelines, these water resources are suitable for irrigation with some restrictions on very sensitive (<0.5 mg L^{-1}) and sensitive (0.5-1.0 mg L^{-1}) plants including citrus, peach, onion, garlic, sweet potato, sunflower, bean and peanut.

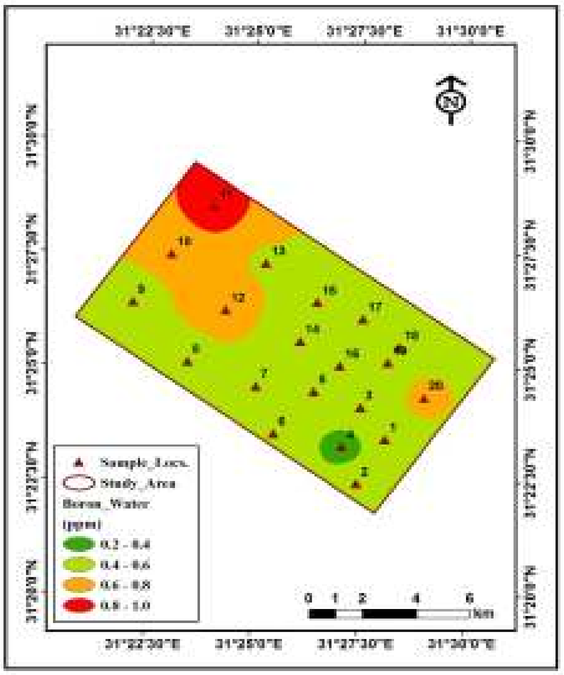

Fig. 6. Spatial distribution of boron in different investigated sites.

6. Cadmium concentration.

Data illustrated in Fig. (7) cleared that cadmium concentration in all studied sites was below the maximum allowable limit given by FAO guidelines (0.01 mgL^{-1}). Most of these concentrations are ranged between 0.002-0.003 mgL^{-1}; however, some spots (sites 12 and 16) showed relatively higher Cd^{2+} concentration (0.003-0.004 mgL^{-1}). Presumably due to some specific anthropogenic activities (e.g. recharge batteries). Beside the industrial anthropogenic activities, phosphate fertilizers can be considered as important sources for cadmium contamination. The average concentration of cadmium in phosphate fertilizers is mainly about 18.0 mg g^{-1}. The extensive use of super phosphate fertilizers, therefore, could be considered as an important source for cadmium release into the agro-environment (Benredjem *et al*., 2016).

It appears that Cd does not replace Ca in the apatite structure, since as a rule no correlation is found between P_2O_5 and Cd in phosphorites (sedimentary apatite). Although the well-known detoxification effect of calcium on reducing heavy metal hazards, there is a lack of Cd–Ca substitution in both sedimentary and magmatic apatites (although the radii of Cd^{2+} and Ca^{2+} are almost identical) due to the high degree of covalence present in the Cd–O bond (Baioumy, 2005).

These results are in great accordance with those obtained by Mohamed *et al*., (1998) who reported that Cd^{2+} concentration is 14 times less than the maximum allowable levels of international standards.

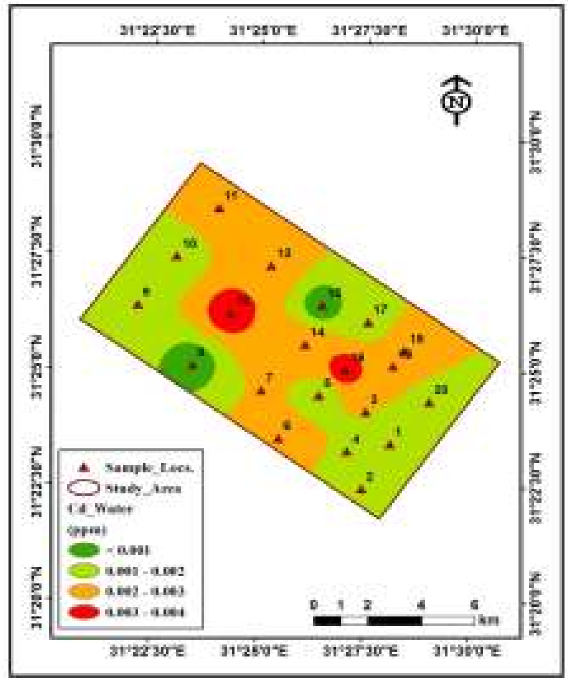

Fig. 7. Spatial distribution of Cadmium in different investigated sites.

ACKNOWLEDGEMENTS

Authors would like to acknowledge Dr. Abdelhamid Elnaggar for assistance in geo-statistical analysis.

REFERENCES

Ayers, R.S., Westcot, D.W., 1985. Water quality for agriculture. Food and Agriculture Organization of the United Nations.

Baioumy, H.M., 2005. Preliminary data on cadmium and arsenic geochemistry for some phosphorites in Egypt. Journal of African Earth Sciences 41, 266-274.

Benredjem, Z., Delimi, R., Khelalfa, A., 2016. Cadmium extraction from phosphate ore. Effect of microwave. Arabian Journal of Chemistry 9, S446-S450.

Bingham, F.T. ,1982. Boron. In A.I. Page *et al.* (eds.): Methods of Soil Analysis. Agronomy 9. Am. Soc. Agronomy 9, Soil Sc. Soc. Am. Inc. Madison, Wis.., p. 431-442.

CHAPMAN, Homer D.; PRATT, Parker F. Methods of analysis for soils, plants and waters. *Soil Science*, 1962, 93.1: 68.

Choudhary, O.P., Ghuman, B.S., Bijay, S., Thuy, N., Buresh, R.J., 2011. Effects of long-term use of sodic water irrigation, amendments and crop residues on soil properties and crop yields in rice–wheat cropping system in a calcareous soil. Field Crops Research 121, 363-372.

EATON, F.M., 1950. SIGNIFICANCE OF CARBONATES IN IRRIGATION WATERS. Soil Science 69, 123-134.

Mohamed, M.A.M., Osman, M.A., Potter, T.L., Levin, R.E., 1998. Lead and cadmium in Nile River water and finished drinking water in Greater Cairo, Egypt. Environment International 24, 767-772.

Mosa, A.A., El-Ghamry, A., Trüby, P., 2011. Chemically Modified Crop Residues as a Low-Cost Technique for the Removal of Heavy Metal Ions from Wastewater. Water, Air, & Soil Pollution 217, 637-647.

Mosa, A., El-Ghamry, A., Trüby, P., Omar, M., Gao, B., Elnaggar, A., Li, Y., 2016. Chemo-mechanical modification of cottonwood for Pb2+ removal from aqueous solutions: Sorption mechanisms and potential application as biofilter in drip-irrigation. Chemosphere 161, 1-9.

Nessim, R.B., Tadros, H.R.Z., Abou Taleb, A.E.A., Moawad, M.N., 2015. Chemistry of the Egyptian Mediterranean coastal waters. The Egyptian Journal of Aquatic Research 41, 1-10.

Prasad, A., Kumar, D., Singh, D.V., 2001. Effect of residual sodium carbonate in irrigation water on the soil sodication and yield of palmarosa (Cymbopogon martinni) and lemongrass (Cymbopogon flexuosus). Agricultural Water Management 50, 161-172.

Sallam, O.M., 2014. Water footprints as an indicator for the equitable utilization of shared water resources: (Case study: Egypt and Ethiopia shared water resources in Nile Basin). Journal of African Earth Sciences 100, 645-655.

Vengosh, A., Kloppmann, W., Marei, A., Livshitz, Y., Gutierrez, A., Banna, M., Guerrot, C., Pankratov, I., Raanan, H., 2005. Sources of salinity and boron in the Gaza strip: Natural contaminant flow in the southern Mediterranean coastal aquifer. Water Resources Research 41, n/a-n/a.

Xiao, Y., Xue, Y., Gao, F., Mosa, A., 2017. Sorption of heavy metal ions onto crayfish shell biochar: Effect of pyrolysis temperature, pH and ionic strength. Journal of the Taiwan Institute of Chemical Engineers 80, 114-121.

Zhou, X., 2011. A method for estimating the fresh water–salt water interface with hydraulic heads in a coastal aquifer and its application. Geoscience Frontiers 2, 199-203.

التوزيع المكاني لخصائص نوعية مياه الصرف الزراعي في شمالي محافظة الدقهلية

سامي حماد ، أيمن الغمري ، أحمد موسي وعبد الباسط خملج
قسم الأراضي- كلية الزراعة- جامعة المنصورة - ٣٥٥١٦ المنصورة ، مصر

في الأقاليم التي تعاني من ندرة المياه -خاصة في البلدان الجافة وشبه الجافة- هناك حاجة ماسة لاعادة استخدام المياه المنخفضة الجودة (مثل مياه الصرف الزراعي) لأغراض الري. ولمثل هذه النوعيات من المياه المنخفضة الجودة يجب اتباع اجراءات صارمة (بداية من تقييم جودة المياه) لتجنب التأثير الضار لهذه المياه علي الأراضي المنزرعة. لهذا الغرض تم تجميع ٢٠ عينة مياه صرف زراعي جغرافيا باستخدام تقنية نظام تحديد المواقع العالمي (GIS) من مركز بلقاس- محافظة الدقهلية لدراسة التوزيع المكاني لخصائص نوعية المياه لأغراض الري. أظهرت النتائج أن معظم عينات المياه المدروسة يمكن استخدامها تحت قيود استخدام قليلة إلي متوسطة من خلال محتواها الملحي الذي تراوح بين ٧,٠-٣,٠ ديسيمنز/متر. كانت أعلي نتائج تركيز الأملاح الذائبة مسجلة في المواقع الشمالية (٦,٠ إلي ٧,٠ ديسيمنز/متر), وأقل التركيزات (١,٠-٢,٠ ديسيمنز/متر) كانت مسجلة في المواقع الجنوبية. قيم جهد الملوحة كانت مرتفعة نسبيا في معظم المواقع محل الدراسة وكانت تتراوح بين ٨,٠ إلي ٢٤,٠ ملليمكافيء/لتر. كان الضرر الصودي قليلاً نسبيا حيث صنفت معظم المياه المدروسة علي أنها في الدرجة الأولي ما عدا تلك المواقع الشمالية التي صنفت علي أنها درجة ثانية. تم تأكيد هذه النتائج أيضا بنتائج مدلول كربونات الصوديوم المتبقية والتي أشارت إلي احتمالية قليلة لتكوين كربونات الصوديوم بسبب زيادة تركز أيونات الكالسيوم والمغنسوم في المياه محل الدراسة. كان تركيز البورون منخفضا في العينات المدروسة مع بعض التحفظات علي استخدامها لري النباتات الحساسة للبورون في المواقع الشمالية. كان تركيز الكادميوم في كل المواقع المدروسة منخفضا جدا (أقل من ٠,٠٠٣ مجم/لتر) دلالة علي عدم وجود تهديد بالتلوث بالعناصر الثقيلة. إجمالاً, أظهرت عينات المياه محل الدراسة صلاحية جيدة لاعادة الاستخدام في الري مع اجراءات متابعة صارمة.