Menoufia J. Soil Sci., Vol. 3 December (2018) : 257 - 266

EFFECT OF WASTEWATER AND FERTILIZER APPLICATION ON CALCAREOUS SOIL AND FOOD CROPS IN BORG EL ARAB – EGYPT

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Received: Aug. 14 , 2018 Accepted: Sep. 16, 2018

ABSTRACT: ***This paper summarizes the available information on the pollution of groundwater and irrigation canals from anthropogenic sources (sewage effluences and industrial waste water, and intensive fertilization) in northwestern Egypt Borg El Arab that leading to contamination of the soil-plant-animal. Excessive applications of fertilizers to field and vegetable crops lead to nitrate and phosphate contamination of groundwater and irrigation canals. In certain situations, nitrates exceed the dangerous level of 10 mg N/L. Industrial effluents, released without any treatment to sewage drains, contain potentially toxic elements with a concentrations that are several fold higher than those in domestic sewage water and exceed the maximum permissible limits for their disposal onto agricultural lands. The mean concentrations of Pb, Co, Cd and Ni in sewage water were, respectively 21,133, 700, and 2200 times higher than those in artesian water. The recommendation possible mitigation options for water pollution. There is an urgent need to effectively enforce regulations for the release of industrial effluents pertaining to primary, secondary and tertiary treatments. Educating farmers and public at large about the consequences of non-overkill Nitrogen fertilizer, pumping out shallow polluted water for drinking and domestic purposes, depleting groundwater resources, etc., is desirable***

Key words: ***Groundwater pollution, Borg El Arab, Irrigation water quality, Anthropogenic, contamination, nitrate, phosphate, cadmium, lead, cobalt, nickel***

INTRODUCTION

Worldwide efforts have increasingly been focused on environmental pollution and its hazardous ill effects on humans and animals. The agricultural sector is the major consumer of water. In Egypt, agriculture accounts for 89% of total water use, as against 8% by domestic sector and 3% by industrial sector (CAPMAS, 2014).

Rapid industrialization and urbanization during the past few decades have increased the demand for available water and put stress on the already dwindling water resources. In northwestern Egypt in new reclaimed soils which constitute the subtropical region, the expansion of irrigation facilities has supported 2-3 crops annually, and new reclaimed soils region is regarded as the ‘food basket of the country. However, the groundwater is depleting at a fast rate because of its excessive use and mismanagement (Shata *et al.,* 1969).

Nitrate leaching into groundwater, P movement into surface water and groundwater in soil can be associated with inefficient or excessive application of fertilizers and manures (Elsokkary, 1980).

The most important anthropogenic factor responsible for groundwater

pollution is urban and industrial wastewater. Direct release of untreated effluents to land and irrigation canals can potentially contaminate surface and groundwater as well as soils and eventually the crops grown on these soils which affect the quality of the food produced (Aisueni *et al.,* 2009).

This paper synthesizes the results of several studies conducted to investigate the impact of agricultural, urban and industrial activities on water pollution, which lead to contamination of the soil-plant-animal-human food chain, and explore possible options for mitigating water pollution (Abdel-Migeed *et al.,* 2007).

MATERIALS AND METHODS

Location of the research areas

The studied area is a part of the eastern section of the north – western costal region of Egypt. It was selected at Borg El Arab, 48 Kilometer west of Alexandria – Marsa Matruh road. It lays approximately between latitudes $30^\circ 45$ and $30^\circ 55$ N, and longitudes 29° 30 and 29° 50 E The study area cover about 5000 feedan Map and has differences in elevation and relief. The elevation varies between zero and more than 40 m. above sea level Fig (1).

Soil and sewage sludge properties

The soil was used a loamy clay (calcareous) taken from the surface layer of Borg El Arab - Alexandria Governorate. The sludge was the activated type and was municipal sewage sludge. The soil and sludge samples were air dried and crushed so as to pass a 2 mm sieve.

Nitrate-N

Regarding plant analysis, plant samples were oven dried at 60°C to preserve nitrogenous compounds and ground. A sample was wet-digested by Kjeldahl method according to Jackson, (1973) using sulfuric acid and hydrogen peroxide to determine N. Nitrogen was measured by titration of ammonia against standard HCl.

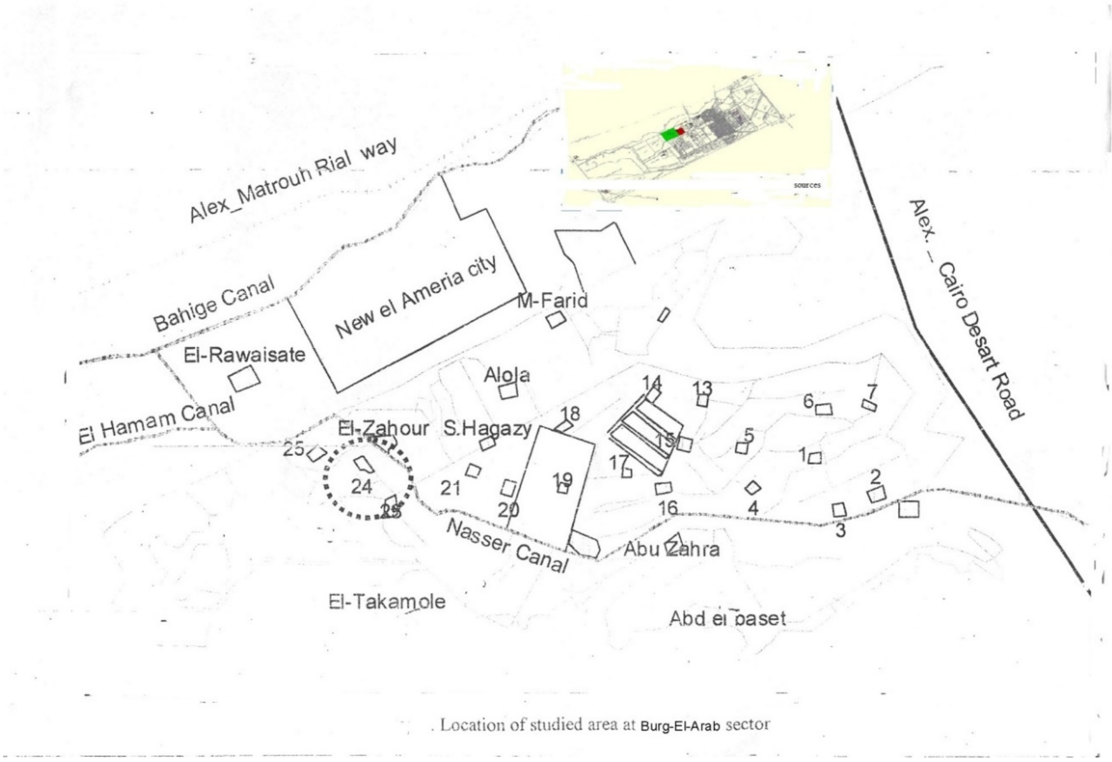

Figure (1): location of the research from the polluted sources in Borg El Arab

Olsen-P

Available P was determined according to (Olsen *et al.,* 1965) and the P content determined by the Murphy and Riley method (Murphy and Riley, 1962).

pH

pH and Ec were measured in a 1:2.5 water extract (Richards, 1954) lime was determined according to (Richards, 1954).

Concentration of toxic elements (mg/L)

Soil sample were extracted for available Fe, Zn, Pb, Ni, Cd and Co in DTPA solution (0.005M DTPA +0.005 M $CaCl_2$ +0.1 M TEA (triethanolamine) pH (7.3), (Lindsay and Norvell, 1978). All the solutions of Fe, Zn, Pb, Ni, Cd and Co were analyzed by atomic absorption spectrophotometer.

Statistical analysis

Regression analysis and correlation coefficient were recruited to verify the relationship between the different variable responses that were measured in this work according to Gomez and Gomez, (1984).

RESULTS AND DISCUSSION

Agricultural activities

Increased use of fertilizers in farming because of large-scale adoption of high-yielding, fertilizer-responsive crops and varieties has led to a gradual buildup of nutrients in soil and groundwater. Movement of N and P below the root zone and leaching into the groundwater can cause human and animal health problems.

If the drinking water has more than the safe limit of 10 mg NO_3^{--}N/L, ingested nitrate is converted to nitrite that is absorbed in blood, causing methemoglobinemia, commonly known as 'Blue Baby Syndrome', and gastric cancer (Abdelrazek, 2017).

There are reports of eutrophication of irrigation canals due to both high nitrate and phosphate concentration. The concentrations of P that cause eutrophication range from 0.01 to 0.03 mg/L (Khadr *et al.,* 2004)

Nitrogen

High rates of leaching and denitrification in permeable or porous soils and relatively high fertilizer N rates combine to make nitrate-leaching a serious problem in many irrigated soils (Youness , 2002).

Intensively cultivated semiarid subtropical region of Egypt where average fertilizer N consumption increased from 56 to 188 kg N/ feedan/y during 2015 to 2017, NO_3^{--} N concentration in the shallow-well waters increased by almost 2 mg/L.

In some central districts said darwiesh village in Borg El Arab region, fertilizer N levels exceed 250 kg N/ feedan /y and on several farms, fertilizers are poorly managed. The soils in this region are predominantly fine textured and about 75% of the total rainfall of more than 200 mm is received during the winter period (November –February). A survey of groundwater samples from 25-100 meter-deep tube wells located in cultivated fields in various blocks revealed that 78% water samples had less than 5 mg NO_3^{--} N/L and 22% samples had 5-10 mg NO_3^{--} N/L. Sixty percent of water samples from shallow-depth (11-19 m) Artesian water had 5-10 mg NO_3^{--} N/L and 2% samples had more than 10 mg NO_3^{--}N/L. excessive use , mismanagement and overkill Nitrogen fertilizer (Nitro) appear to be the major contributors to high NO_3^{--} N in groundwater. Vegetation retards $NO_3^{- -}$ N leaching from the root zone by absorbing nitrate and water.

Rooting habits/patterns of different plants influence NO_3^{-} - mobility in the rooting zone. Maximum leaching of NO_3^{--} N below the root zone occurs from heavily fertilized shallow-rooted crops, such as potato, maize and Tomato as well as heavily manures vegetable crops. In the predominant Tomato-wheat cropping system of Borg El Arab NO_3^{-} leaching to 40 cm during the Tomato crop was used by the subsequent wheat crop, which has a deeper and more extensive root system (Figure 2).

Application of 120 kg fertilizer N/feedan to each of these two crops for 4 years resulted in 35 kg of residual NO_3^{--} N/ feedan in the 150-cm soil profile, whereas only 17 kg NO_3^{--} N/ feedan remained where 120 kg N/ha was applied through the consecutive use of 20 t/ feedan of fresh Alfalfa green manure and fertilizer N, decreasing potential for groundwater nitrate contamination

Phosphorus

Excessive accumulation of residual P in soil may enhance downward movement of P, which may eventually reach groundwater.

Calcareous soils have a large number of macropores and thus the resultant by-pass flow can lead to greater and deeper leaching of P in such soils.

Besides the Tomato and wheat crops for groundwater contamination, P lost from agricultural soils through leaching may be intercepted by artificial drainage or subsurface flow, accelerating the risk of P transport to irrigation canals with serious implications for water quality (Hartikainen, 1991). Long-term studies, where fertilizer P has been applied at different rates, frequencies and periods, have revealed the possibility of P leaching especially in coarse textured soils (Jalali and Ranjbar 2010) After 2 years of using Tomato and wheat crops – based cropping systems, 45 to 256 kg of residual fertilizer P accumulated as Olsen-P/ha in 150- cm soil profile (43-58% below 60 cm depth), illustrating enormous movement of fertilizer P to deeper layers in a coarse-textured soil having low absorption and retention capacity for nutrients (Table 1). Recent studies with different cropping systems have further revealed that interplay between the fertilizer P management, amount of labile P accumulated in soil profile, and soil characteristics (silt, clay and organic C) largely control P leaching in subtropical soils (Agbenin, and Goladi 1997).

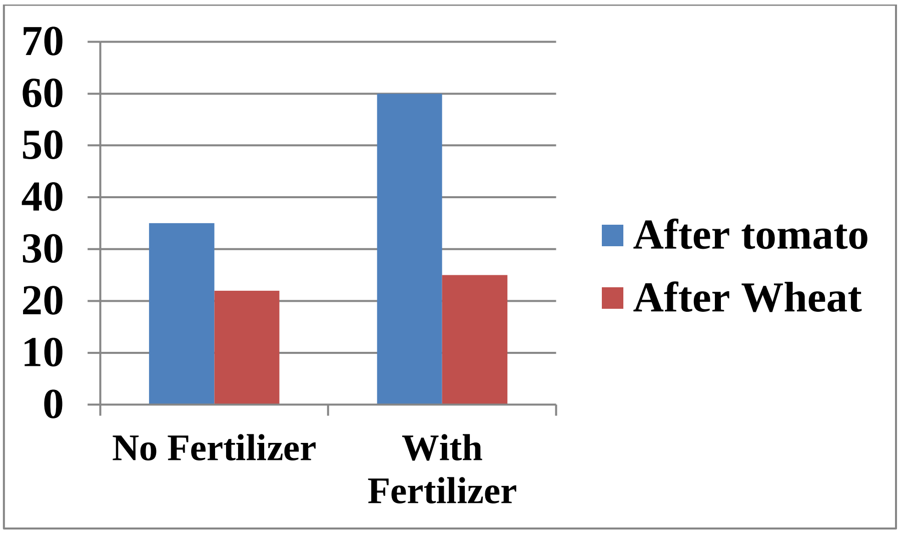

Figure (2): Nitrate-N in 60 cm soil profile after 2-years of Tomato and wheat crops

Table (1). Olsen-P accumulation and leaching in soil profiles of no-P control and four fertilizer P treatments after 2-years of Tomato and wheat crops – based cropping systems

Soil depth(cm)	Olsen-P(mg P kg^{-1})
control	
4	5
25	7
45	8
70	8
110	10
130	10
Winter-applied P1	
3	9
26	8
45	3
70	3
110	13
140	14
Winter-applied P2	
2	14
30	14
50	12.5
80	11
115	14
125	14
Cumulative-applied P1	
2	14
30	15
45	12.5
72	7.5
110	11
135	11
Cumulative-applied P2	
2	20
15	20
50	20
73	15
115	17.5
145	20

Urban and industrial activities

Application of sewage sludge to agricultural soils, and irrigation of field crops with sewage water and untreated industrial effluents alone, or in combination with ground/canal water are common practices, especially in the vicinity of large cities, as these are considered reusable sources of essential plant nutrients and organic C. It is estimated that more than 11000 million liters of sewage water is produced every day in Egypt which approximately contributes 3.2 million t of N, 1.4 million t of P and 1.9 million t of potassium (K) per annual with an economic value of about Egyptian EP 884 million (US$ 52 million). However, some of the elements present in sewage water and untreated industrial effluents could be toxic to plants and pose health hazards to animals and humans (Abdelrazek, 2017).

Chemical composition of sewage waters

The concentration of potentially toxic elements was higher in sewage water of industrial towns as compared with less or non-industrial towns (Abdelrazek , 2014).

Further, the composition of sewage water varies within a city. The domestic zone sewage contained relatively low amounts of toxic elements whereas the effluents from the electroplating area contained toxic elements, such as cadmium (Cd), nickel (Ni) and cobalt (Co), in amounts higher than maximal tolerable limits for disposal on agricultural lands

The chemical analysis of sewage-water samples collected from different locations of an open drain, commonly known as Borg El Arab Industrial area, Mary Mina area and El-Rawaisate area downstream from entry into, Bahig area revealed that the concentration of metals in the drain increases many folds as it passes through Bahig area (Table 2).

The mean concentrations of Fe, Zn, Cd, Pb, Ni, and Co the sewage-water samples collected at the entry point, were 0.03, 0.04, 0.005 0.004, 0.002 and 0.001 mg/L, respectively, which increased to 10.8, 0.78, 2.10, 0.075, 0.28 and 0.26 mg/L, respectively, in the samples collected from about 15 km downstream of the entry point. This is because the number of industries pouring their untreated effluents increased as the distance downstream increased turning it into a highly polluted sewage channel.

A study of industrial complex in Borg El Arab city, comprising leather (Zakhary Company manufacturing factories, Ceramics (Lecico company) and faience factories, revealed that the concentration of both Co and Ni drastically increased in the sewage water after the disposal of effluents from the industrial complex (El-Gendi *et al.,* 1997: Abdel-Sabur *et al.,* 1995).

The concentration of both the elements at 200 m from the polluted source of the leather complex increased many fold as compared with that from 500 m upstream, indicating the high pollution potential of these elements. However, the concentration of Co decreased 2 km from the polluted source of the industrial complex because of settling of some of the elements at the base of the drain.

Table (2). Concentration of toxic elements (mg/L) and pH of the effluents in Borg El Arab

Sampling sites	pH	Fe	Zn	Pb	Ni	Cd	Co
Entry point	8.3	0.40	0.05	0.005	0.003	0.004	0.07
2 km from sources	7.6	6.8	0.19	0.080	0.23	0.180	1.70
15 km from sources	7.1	11.7	0.69	0.076	0.39	0.280	2.30

Effects of polluted water on soil

It has well been documented that irrigation with sewage water increases soil electrical conductivity and organic C, decreases soil pH, and could result in the accumulation of heavy metals in the plow layer of agricultural soils.

Ahmed, (2001) found that mean concentrations of DTPA-extractable Pb, Ni, Cd, Zn, Mn and Fe in surface soils (0-15 cm) surrounding the densely industrialized city in the Kafer El-Dawar industrial area.

Irrigated largely with sewage effluents, were 4.2, 3.6, 0.30, 11.9, 25.4 and 49.2 mg/kg as compared, with 2.8, 0.40, 0.12, 2.1, 8.3, 10.9 mg/kg, respectively, in the soils around a less industrialized city of Mary Mina area Indicating greater loading of soils of Bahig area with potentially toxic metals through sewage irrigation. In industrialized cities of Borg El Arab Industrial area, Mary Mina area mean concentrations of these metals, except Pb and Zn in Borg El- Arab, were in-between the values for Bahig area and Rawaisate area.

Effects of polluted water on plants

Plant species absorbed higher concentration of potentially toxic metals like Pb, Cu, Co, Cd, Ni, Zn, Mn, and Fe in different plant parts when grown in sewage-irrigated soils, as compared with tubewell-irrigated soils. For example, the concentration of Cd in aboveground parts of maize (*Zea mays* L.), rapeseed Turnip (*Brassica rapa*.) and lady's finger (*Abelmoschus esculentus* L.) grown on polluted soils was 2.0–3.5 times the amount of Cd when grown on non-polluted soils. The increase in Ni concentration in various crops with waste-water-irrigated crops was 16 to 136% higher than that in tubewell-irrigated crops (Abu Zeid, 1991).

The roots of all the crops, with a few exceptions, accumulated higher amounts of potentially toxic elements than aboveground parts. Vegetables like spinach (*Spinacea oleracea* L.), cauliflower (*Brassica* oleracea L. var botrytis) and cabbage (Brassica oleracea L. var capitata) tended to accumulate relatively higher concentrations of potentially toxic elements as compared with cereal crop like maize. Among the four vegetables, spinach accumulated the highest amount of all the metals.

Recommendations

Possible mitigation options for water pollution

Contamination of groundwater and irrigation canals due to agricultural, urban and industrial activities poses a threat to ecosystem of Borg El Arab Industrial area.

Several studies are evidently (obviously) appeared that the dangers of groundwater pollution are genuine, and in some cases, the situation is alarming particularly overkill Nitrogen fertilizer (Nitro).

Excessive applications of fertilizers to some crops lead to augment the nitrate and phosphate leaching. Formulation and adoption of careful strategies for applying appropriate amounts of fertilizers and manures at proper times, using correct methods, should help synchronize nutrient supply with crop need and avoid excessive use in crops in turn, reduce nitrate and phosphate pollution of groundwater and irrigation canals.

Water-pollution potential in industrialized cities like Borg El Arab Industrial area, Mary Mina area is many-folds higher as compared with non- or less-industrialized cities. Therefore, sewage-water of such cities can only be used safely for irrigation after proper treatment. Local bodies need to install effluent treatment plant and only treated

waste water should be allowed to be disposed of in irrigation canals.

Efforts should be made to encourage the industries to install their own plants within some agreed time frame to become zero discharge industries. Since very high cost is involved in the installation of treatment plants, many industries cannot install their own treatment plants. Therefore new industries should be allotted plots in such a way that a cluster of identical industries are grouped together so that common treatment plants could be set up for effective treatment economically.

There is an urgent need to effectively enforce regulations for the release of industrial effluents pertaining to primary, secondary and tertiary treatments. Educating farmers and public at large about the consequences of non-overkill Nitrogen fertilizer, pumping out shallow polluted water for drinking and domestic purposes, depleting groundwater resources, etc., is desirable. Farm yard manure, calcium carbonate, phosphate, zinc and zeolites are suitable ameliorants for mitigating pollutant toxicity in soils. On the other hand some crops belonging to brassica (a plant of a genus that includes cabbage, turnip, Brussels sprout, and mustard), Species and aromatic grasses that accumulate to higher amounts of pollutants in the shoots and roots may be utilized. The hyper-accumulation capability of these crops could be exploited for phytoremediation of toxic elements from polluted soils. Growth of timber and floriculture crops and use of aquatic macrophytes and constructed wetlands need to test for the removal of toxic pollutants.

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تأثير استخدام مياه الصرف الصحي والأسمدة على التربة الجيرية والمحاصيل الغذائية ببرج العرب – مصر

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معمل بحوث الاراضى الملحية و القلوية بالاسكندرية – معهد بحوث الاراضى و المياه والبيئة –
مركز البحوث الزراعية – الجيزة– مصر

الملخص العربى

تلخص هذه الورقة المعلومات المتاحة عن تلوث المياه الجوفية والمياه السطحية من المصادر البشرية في شمال غرب مصر مما يؤدي إلى تلوث التربة والنبات والحيوان ففى بعض الحالات نجد ان النترات تتجاوز مستوى السمية ١٠ ملليجرام نيتروجين لكل لتر، فيؤثر هذا على السلسلة الغذائية للإنسان، ويؤدى الاستخدام المفرط للأسمدة في المحاصيل الحقلية والخضر إلى رشح وفقد النترات والفوسفات مما يؤدى إلى تلوث المياه الجوفية والمياه السطحية.

كذلك أدى القاء النفايات الصناعية السائلة لمصانع برج العرب فى مصارف الرى والمسطحات المائية دون معالجة والقائها فى الأراضى الزراعية الى التلوث بالعناصر الثقيلة بتركيزات تتجاوز اضعاف تركيزات هذه العناصر فى مخلفات الصرف الصحى المنزلى وزيادتها عن للحدود القصوى المسموح بها. وقد وجد ان تركيزات الرصاص، والكوبلت، والكادميوم والنيكل في مياه الصرف الصحي، كانت على التوالي ٢١, ١٣٣ ،٧٠٠ و ٢٢٠٠ وهى أعلى من تلك الموجودة في المياه الأرتوازية القريبة من المنطقة الصناعية ببرج العرب والمتاثرة بمياه الصرف الصحي والصناعى.

الكلمات المفتاحية : تلوث المياه الجوفية، برج العرب، نوعية مياه الرى، النشاط الانسانى، التلوث، النترات، الفوسفات، الكادميوم، الرصاص، الكوبالت، النيكل.

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