Evaluation of human risks of surface water and groundwater contaminated with Cd and Pb south of El-Minya Governorate, Egypt.

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Abstract:

Water pollution with cadmium (Cd) and lead (Pb) has worldwide concern because of their health impact. Determination of their concentrations and potential human health risks in surface and groundwater at south El-Minya Governorate, Egypt is the main aim of this study. Fifty-five samples were collected; 30 samples surface water and 25 samples groundwater. The samples were analyzed using Atomic Absorption Spectrometry (AAS) to determine Cd and Pb contents. Their levels in surface and groundwater exceeded the maximum allowable level for drinking water which set by WHO. The hazard quotient (HQ) showed that the surface and groundwater may be pose health risk to residents, especially the children. However, the water can be used safely for irrigation.

1. Introduction

Water resources pollution was becoming a worldwide problem. To protect the environment and public health, it is important to have precise knowledge on concentration and type of water pollutants especially heavy metals. Because the heavy metals have long biological half-life, they are threat the human health in case of excessive concentrations (Albji et al., 2013). Cd and Pb are of the most chemical pollutants that threaten the water quality for different uses. Monitoring of their concentrations in water is of critical importance for protecting ecological and human health, because of their harmful effects and persistence (Nazar, et. al., 2012).

Cadmium has a major environmental concern and ranked as the sixth significant human health hazard toxic substances (ATSDR, 1997). It is released into the aqueous system from metal plating, smelting, mining, cadmium-nickel batteries, phosphate fertilizers, paint industries, pigments and alloy industries as well as from sewage (Kadirvalu and Namasivayam, 2003). The nervous system appears to be the most sensitive target of Cd toxicity. Cadmium exposure can produce a wide variety of acute and chronic effects in humans such as renal failure, lung insufficiency, bone lesions and hypertension (Sun and Li, 2011).

Pb is the most common environmental contaminant (Chiang et. al, 2012). It doesn't undergo degradation or decomposition. Thus, its long persistence in the environment exacerbates its threat to human health. Pb is used in many industries including lead smelting and processing, batteries manufacture, pigments, solder, plastics, cable sheathing, fuel, ammunition and ceramics. Due to urbanization, Pb and other metals are regularly discharge into fields, water and soils through sewage sludge, urban runoff and automobile exhaust (Elnazer et al. 2015). Pb absorbed by human body disturbs many processes and is harmful to many organs such as heart, bones and nervous systems (Bruce et. al., 2012).

The application of human health risk assessment model has many advantages than comparison with drinking water guidelines as WHO guideline. Because, it takes in consideration the age, body weight, metal concentration, exposure duration and daily intake. So, quantifying human risk (carcinogenic and non-carcinogenic risks) of Cd and Pb to children and adults is important issue. The hazard quotient (HQ) of the USEPA (1989) is extensively used to characterize the carcinogenic and non-carcinogenic health effects of toxic metals by comparison of their exposure effects to a reference dose (R*f*D) (Qu et al., 2012). It was documented in many investigations by taking into consideration exposure scenarios of metal intake through contaminated water (Muhammad et al., 2011; Shah et al., 2012; Dou and Li, 2012). So, the objective of the present study is the determination of Cd and Pb concentrations and potential human health risks in the surface and the ground water systems in the western part of the River Nile between Abu Qurqas and Dyer Mawas districts, south El-Minya Governorate, Egypt.

2. Material and methods

2.1. Location

The study area occupied the middle part of the Nile Valley between longitudes 30° 29′ and 30° 54′E and latitudes 27° 37′and 27° 56′N (Fig. 1). It is bounded by the River Nile from the east and the calcareous plateau at the west between Abu Qurqas northward and Dyer Mawas at the south. The water resources in the study area are represented by the River Nile, canals and drains as well as groundwater (Fig. 1). The stratigraphic succession (Fig. 2) in El-Minya area is represented by Tertiary and Quaternary sedimentary rocks (Said 1981). The main aquifer in the study area is represented by Pleistocene sediments which compose of sand and gravel of different sizes with some clay intercalation (Sadek 2001). The aquifer is semi-confined in the old cultivated land (at the eastern part of the study area) and unconfined in the desert fringes (at the western part of the study area). The groundwater flows generally from the southern part to the northern part of the study area. The aquifer is recharged by Nile water, irrigation system, drains, agricultural infiltration and vertical upward from the deeper saline aquifers (Abdalla et al. 2009). The main sources of water for different purposes in the study area are Nile, canals, drains and groundwater. The study area contains many industrial zones, agricultural activities and urban areas.

2.2. Sampling and analyses

In November 2014, thirty water samples were collected from surface water resources at the study area (Fig. 1 and Table. 1). In addition, 25 groundwater samples were collected from the Quaternary aquifer (Fig. 1). Pre-rinsed polypropylene bottles were filled with the samples sealed tightly, acidified (pH < 2) with nitric acid to prevent precipitation, microbial activity and sorption losses to container walls. At lab the samples were filtered through filter paper (Whatman No. 42) and digested with nitric acid (APHA, 1995). Samples were analyzed using atomic absorption spectrometer instrument (model: Perkin Elmer 400) in National Research Centre Laboratories.

For health risk assessment, non-carcinogenic (HQ_{nc}) and carcinogenic (HQ_c) hazard quotient for each contaminant was calculated according to the following equations (Kelepertzis 2014):

$$\mathbf{HQ_{nc} = CDI / R\mathit{f}D} \quad \mathbf{(1)}$$

$$\mathbf{HQ_c = CDI * SF} \quad \mathbf{(2)}$$

$$\mathbf{CDI = C*IR*ED*EF/BW*AT} \quad \mathbf{(3)}$$

where CDI, C, IR, ED, EF, BW, AT and R*f*D represent chronic daily intake (mg/kg/day), concentration of metal in water (mg/L), average daily intake rate (2 L/day for adult and 1.2 L/day for children), exposure duration (15 years), exposure frequency (350 days), body weight (70kg for adult and 28kg for children), average time (ED*365 days for non-carcinogenic and lifetime*365 for carcinogenic risk) and toxicity reference dose. According to USEPA (2011) the R*f*D for Cd and Pb is 0.0005 and 0.055 mg/kg/day respectively and slope factor (SF) is 0.38 and 0.055 mg/kg/day respectively. The average life time for adult is 65 years and 6.5 years for children.

3. Results and discussion

3.1. Surface water

River Nile and its tributaries (canals and drains) are the main source of water in Egypt especially for the governorates allocated on the river banks and on its branches. Cadmium concentrations (Table 2), ranged from 1 to 48µg/l, exceed the permissible limit (3µg/l) for drinking water according to WHO (2011). Excess Cd could accumulate in the kidney and remains for many years causes irreversible kidney damage (Goyer, 1996). The kidney patients in the study area is presumed to have increased from 10 patient/million in 1974 to about 165 patient/million in 1995 and in 2005 it was 260 patient/million in El-Minya Governorate (El-Minshawy and Kamel, 2006). The highest concentration of Cd was recorded in sample number S_8 of 48µg/l close to Abu Qurqas Sugar factory (Al-Shiekh Sharf canal). The lower concentration was recorded in sample number S_6 (1µg/l) which was collected from the River Nile. These results are in line with those obtained Toufeek (2011) who recorded average Cd concentration 12.5 µg/l at Aswan (southern Egypt), while Melegy et al. (2014) found that the Cd level in samples collected from Sohag Governorate were flocculated around 16µg/l. Osman and Kloas (2010) mentioned that the average Cd concentration in the River Nile at Assuit was 6 µg/l.

Lead concentration ranged from 54 to 329µg/l in the studied surface water samples (Table. 2). The study samples content of Pb passes the permissible limit (10µg/l) for drinking water according to WHO (2011). Lead adsorbed by human body disturbs many body processes and is harmful to many organs and tissues such as heart, bones, nervous system (Bruce et al., 2012). The highest concentration of Pb was recorded in sample number S_{28} (329µg/l) from Al-Nasriyah canal, while sample number $S_{6,}$ which was collected from the River Nile at Abu Qurqas district, contains the lowest concentration (54µg/l). These results are in agreement with those obtained by Toufeek (2011) who reported about 214µg/l Pb in the

River Nile at Aswan. In addition, Osman and Kloas (2010) proved that the average Pb concentration in the River Nile at Assuit is nearly 24µg/l.

Agricultural activities are considered as the most important source for Cd and Pb, where the used super-phosphate fertilizers in the study area contain about 8.5 and 16 ppm Cd and Pb, respectively (Asmoay 2017). In addition, vehicle exhaust, industrial activities and urban runoff contribute to great extent in the pollution of water with these metals (Elnazer et al. 2018). The River Nile and canals contain higher Cd and Pb concentrations than the agricultural drains owing to the presence of these canals penetrating urban areas, closed to roads and industrial areas.

3.2. Groundwater

Groundwater is the second important water resources in the study area and it used for irrigation as well as for domestic and drinking in desert fringes and some villages which doesn't have drinking water network. The groundwater samples exhibit relative wide range of the Cd level varying from 2 to 49µg/l with mean value 24µg/l (Table 3). The groundwater Cd level decreased eastward (Fig. 3) due to mixing with the surface water from River Nile and the role of the silty clay layer in the adsorption of Cd and prevent it to reach the aquifers. However, there are three hot spots of Cd resulted from the intensive human activities and fuel stations. Cd hot spot in the NW part of the study area adjacent to the western desert road is vulnerable as a result of the unconfined condition of the aquifers.

Also, the measured Pb content of the analyzed groundwater samples show relative wide range varying from 90 to 410µg/l with an average of 242µg/l (Table. 3). The marked high level of Pb content implies that the anthropogenic activities (agricultural and urban runoff) are the main source of Pb. The results are in agreement with Melegy et al (2014) who mentioned that Cd and Pb concentration in the groundwater of Sohag were around 21 and 383 μg/l, respectively. Pb level in the groundwater of the study area was increased at Abu Qurqas district resulting from the effect of the sugar factory, cesspits and fuel stations (Fig. 4).

All the samples are unsuitable for drinking purpose where they possess Cd and Pb values above the permissible limit of 3μg/l for Cd and 10 μg/l for Pb (WHO, 2011). On the other hand, surface and ground water are suitable for irrigation purposes according to NAS-NAE (1973), where they contain less than 10000 and 5000000μg/l of Cd and Pb, respectively. But unfortunately, using the groundwater for drinking in some villages of the study area represents serious health impact.

3.3. Health risk assessment

Water from the River Nile and canals as well as groundwater is used for drinking and domestic purposes. Unfortunately, the applied treatment techniques (flocculation and coagulation with alum) in drinking water stations (Donia 2007) in the study area are ineffective for the removal of toxic metals (Fatoki and Ogunfowokan 2002). It was observed, too, that great number of residents in rural areas use groundwater from hand pumps for drinking because they don't have access to the tap water. El-Minshawy and Kamel (2006) mentioned that the use of unsafe water for drinking contributes up to 71.8% of the renal failure in the study area. Therefore, health risk assessment surface water and groundwater was carried out in this study. The results of HQ_{nc} and HQ_{c} due to metal exposure in surface water and groundwater samples are provided in Tables (4) and (5).

The calculated HQ_{nc} average values for Cd in surface water for adults and children were 1.30 and 1.96, respectively while; HQ_{nc} average values for Pb were 0.11 and 0.17 (Table 4). On the other hand, the calculated HQ_{nc} average values for Cd in groundwater for adults and children were 1.29 and 1.94, respectively while; HQ_{nc} average values for Pb were 0.12 and 0.18 (Table 5). According to USEPA (2011), Cd can cause non-carcinogenic health problems because its HQ_{nc} values were more than 1. While Pb presence in water hasn't adverse health impacts (HQ_{nc}<1), however its concentration exceeded WHO (2011) guidelines.

The calculated HQ_c values for Cd in the surface water for adults range from $0.17*10^{-4}$ to $7.9*10^{-4}$ and for children from $0.1*10^{-5}$ to $4.8*10^{-3}$ (Table 4). The calculated HQ_c values for Pb varied from $6.2*10^{-3}$ to $37*10^{-3}$ for adults and varied from $3.7*10^{-2}$ to $22*10^{-2}$ for children (Table 4). While, the calculated HQ_c values for Cd in the groundwater ranged from $4.8*10^{-6}$ to $1.2*10^{-4}$ for adults and from $2.9*10^{-5}$ to $7.11*10^{-4}$ for children (Table 5). the calculated HQ_c values for Pb varied between $3.13*10^{-5}$ and $14.3*10^{-5}$ for adults and varied from $1.67*10^{-9}$ to $86.1*10^{-5}$ for children (Tables 5). According to USEPA (2011) recommenden value ($HQ_c<10^{-6}$) the studied surface and groundwater consumption could cause carcinogenic health risks in adults and children.

4. Conclusion

Cadmium and lead contents of the studied samples from River Nile, canals and drains as well as groundwater exceed the permissible limits for drinking water and could be disturbing many adverse health impacts. The calculated HQ_{nc} indicted the health hazards of the presence of Cd in water resources in the study area in opposite to the presence of Pb. This result supports the importance of application of health risk assessment model than the comparison with drinking water guidelines. Unfortunately, the presence of Cd and Pb in surface and groundwater of the study area have carcinogenic health impacts. The water resources in the study area (surface and groundwater) are suitable for irrigation purposes. Source of pollution in the investigated area were derived from anthropogenic activities such as industries, agriculture, mining and urban runoff.

It is recommended to apply effective treatment agents for removing toxic metals in drinking water stations, connect the houses in rural parts of the study area with safe drinking water lines and regular monitoring of water resources and the end user water lines.

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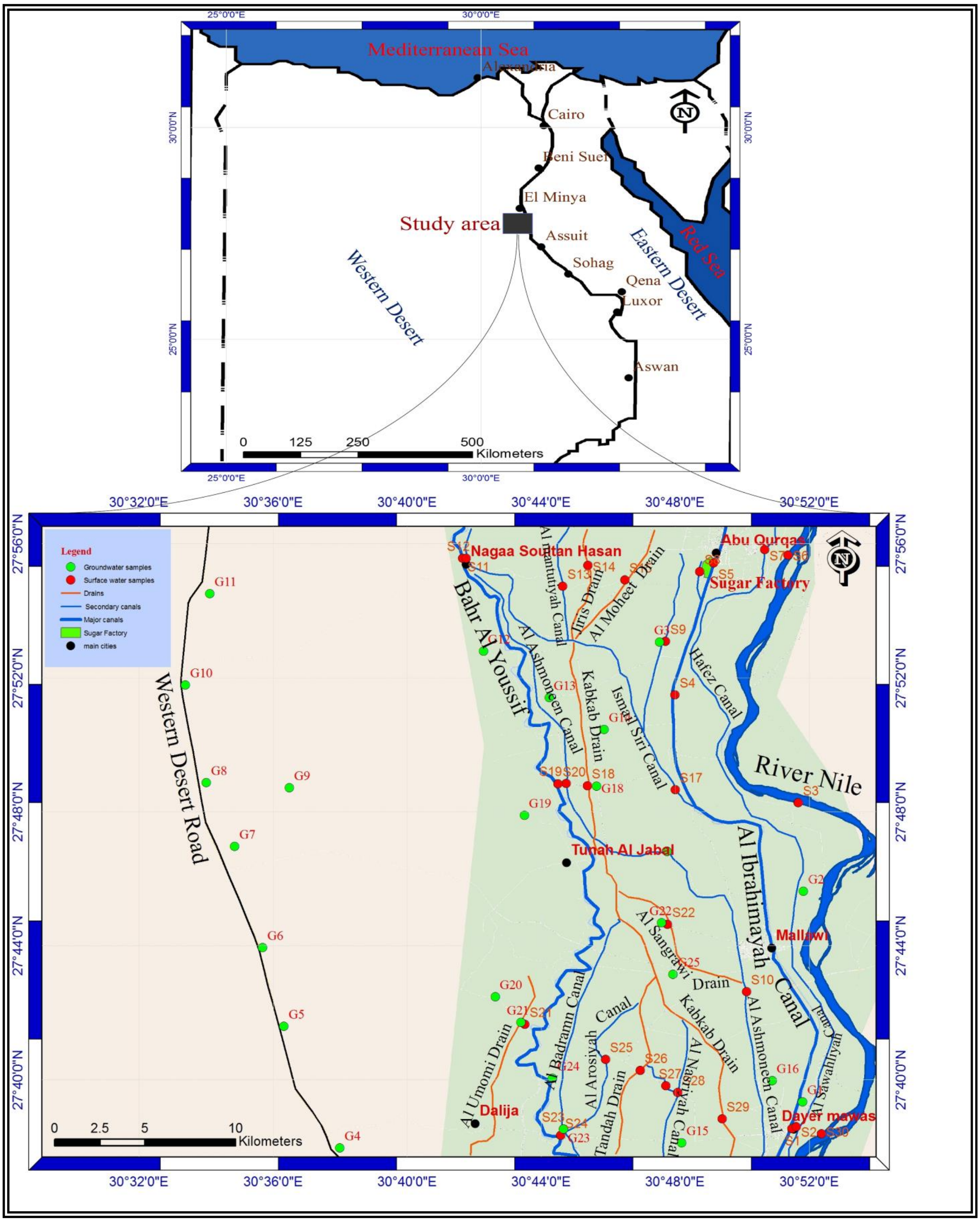

Figure 1: Location map of the study area.

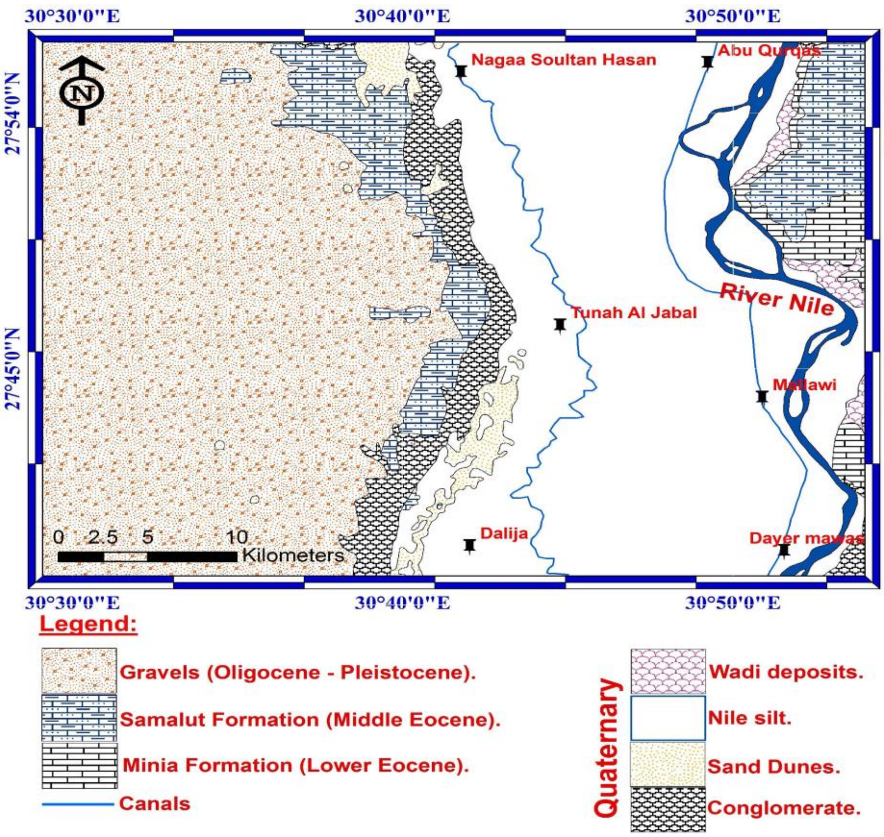

Figure 2: Geologic map of the study area.

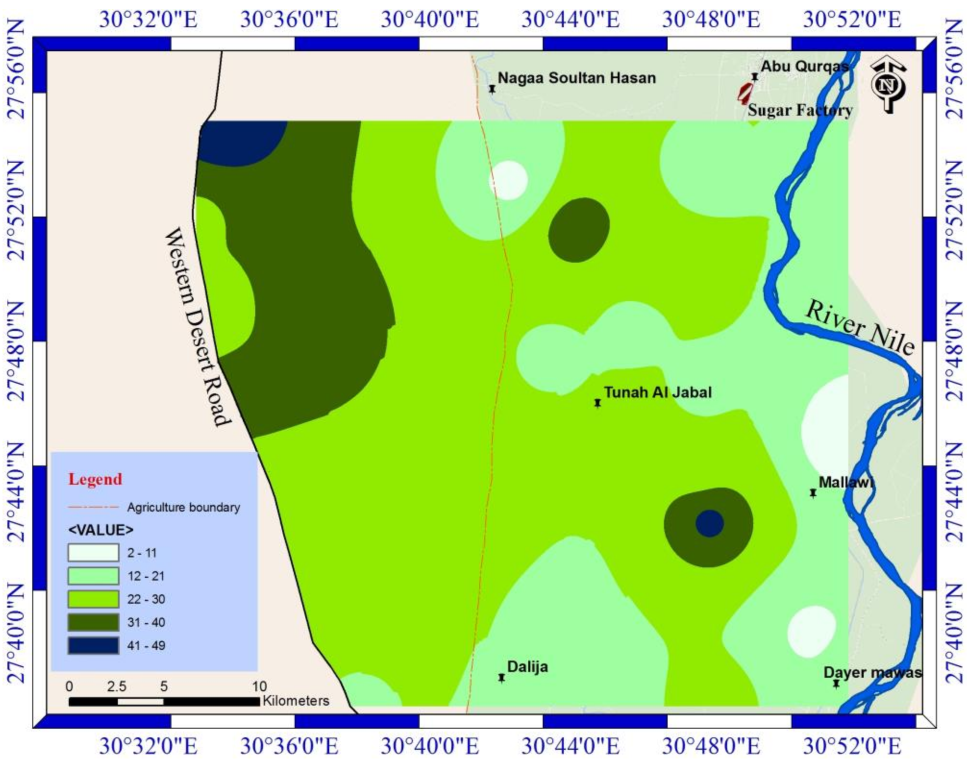

Figure 3: Spatial distribution map of Cd in the studied groundwater samples.

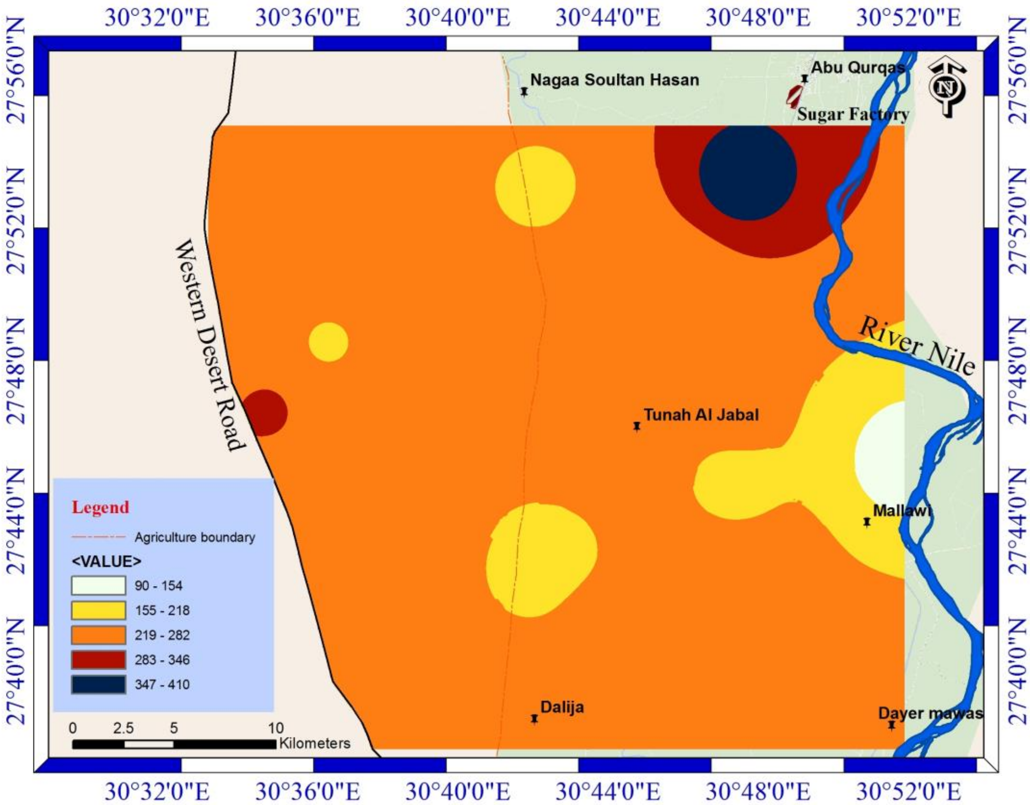

Figure 4: Spatial distribution map of Pb in the studied groundwater samples.

Table 1: Surface water samples and localities.

Sample No.	**Water stream name**	**Sample No.**	**Water stream name**
S_3, S_6, S_{30}	River Nile	S_{28}	Al Nasriyah canal
S_1, S_5	Al Ibrahimayah canal	S_9	Branch from Ismail Siri canal
S_{11}, S_{20}, S_{24}	Bahr Youssef	S_{27}	Branch from Al Nasriyah canal
S_2	Al Sawahliyah canal	S_4	Al Sellic Drain
S_7	Hafez canal	S_{14}	Jiris Drain
S_8	Al ShiekhSharf canal	S_{15}	Al Moheet Drain
S_{10}, S_{16}, S_{19}	Al Ashmoneen canal	S_{18}, S_{29}	Kabkab Drain
S_{12}, S_{17}	Ismail Siri canal	S_{21}	Al umomi Drain
S_{13}	Al Mantutiyah canal	S_{22}	Al Sangrawi Drain
S_{23}	Al Badraman canal	S_{26}	Tandah Drain
S_{25}	Al Arosiyah canal		

Table 2: Cd and Pb concentrations in the surface water samples (µg/l).

Sample No.	Nile & Canals		Drains		Sample No.	Nile & Canals		Drains	
	Cd	Pb	Cd	Pb		Cd	Pb	Cd	Pb
S_1	39	184	-	-	S_{18}	-	-	17	216
S_2	37	210	-	-	S_{19}	15	208	-	-
S_3	22	270	-	-	S_{20}	15	208	-	-
S_4	-	-	22	222	S_{21}	-	-	28	183
S_5	19	241	-	-	S_{22}	-	-	21	260
S_6	1	54	-	-	S_{23}	33	275	-	-
S_7	19	96	-	-	S_{24}	21	250	-	-
S_8	48	288	-	-	S_{25}	7	272	-	-
S_9	9	209	-	-	S_{26}	-	-	22	273
S_{10}	20	222	-	-	S_{27}	16	298	-	-
S_{11}	19	268	-	-	S_{28}	35	329	-	-
S_{12}	43	262	-	-	S_{29}	-	-	23	198
S_{13}	28	303	-	-	S_{30}	28	192	-	-
S_{14}	-	-	42	234	Mean	24	233	23	224
S_{15}	-	-	12	213	Median	21	245	22	219
S_{16}	32	225	-	-	Min.	1	54	12	183
S_{17}	22	261	-	-	Max.	48	329	42	273

Table 3: Cd and Pb concentrations (μg/l) in the study groundwater samples.

Sample No.	Cd	Pb	Sample No.	Cd	Pb
G_1	15	249	G_{15}	24	274
G_2	2	90	G_{16}	8	242
G_3	19	410	G_{17}	19	228
G_4	20	224	G_{18}	19	228
G_5	26	252	G_{19}	19	243
G_6	23	242	G_{20}	28	162
G_7	36	296	G_{21}	14	266
G_8	25	230	G_{22}	27	193
G_9	39	213	G_{23}	17	275
G_{10}	29	229	G_{24}	19	264
G_{11}	49	254	G_{25}	42	276
G_{12}	9	197	Mean	24	242
G_{13}	38	270	Minimum	2	90
G_{14}	23	242	Maximum	49	410

Table 4: Statistical parameters of non-carcinogenic and carcinogenic health risks for surface water samples.

Parameter	HQ_{nc} for Adults		HQ_{nc} for Children	
	Cd	Pb	Cd	Pb
Minimum	0.05	0.03	0.08	0.04
Maximum	2.06	0.16	3.95	0.25
Average	1.30	0.11	1.96	0.17
Parameter	**HQ_c for Adults**		**HQ_c for Children**	
	Cd	**Pb**	**Cd**	**Pb**
Minimum	$0.17*10^{-4}$	$6.2*10^{-3}$	$0.1*10^{-5}$	$3.7*10^{-2}$
Maximum	$7.9*10^{-4}$	$37*10^{-3}$	$4.8*10^{-3}$	$22*10^{-2}$
Average	$3.9*10^{-4}$	$26*10^{-3}$	$2.3*10^{-3}$	$15*10^{-2}$

Table 5: Statistical parameters of non-carcinogenic and carcinogenic health risks for groundwater samples.

Parameter	HQ_{nc} for Adults		HQ_{nc} for Children	
	Cd	**Pb**	**Cd**	**Pb**
Minimum	0.11	0.04	0.16	0.07
Maximum	2.68	0.20	4.03	0.31
Average	1.29	0.12	1.94	0.18
Parameter	**HQ_c for Adults**		**HQ_c for Children**	
	Cd	**Pb**	**Cd**	**Pb**
Minimum	$4.8*10^{-6}$	$3.13*10^{-5}$	$2.9*10^{-5}$	$1.67*10^{-9}$
Maximum	$1.2*10^{-4}$	$14.3*10^{-5}$	$7.11*10^{-4}$	$86.1*10^{-5}$
Average	$5.66*10^{-5}$	$8.41*10^{-5}$	$3.42*10^{-4}$	$48.5*10^{-5}$