

Environmental risk assessment of some potentially toxic elements in El-Tabbin region (Cairo, Egypt)

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Abstract As much as 24 soil samples and 6 stream sediments from the River Nile were studied in El-Tabbin region (Great Cairo, Egypt). Twelve chemicals, potentially toxic elements posing potential environmental risk, were the object of concern in this study. Mean contents of analysed elements (in mg kg⁻¹) in soils and the River Nile stream sediments were the following: As_s 3.6/As_{ss} 1.5, Cd_s 0.33/Cd_{ss} 0.12, Cr_s 87.7/Cr_{ss} 141.5, Cu_s 40.3/Cu_{ss} 43.8, Hg_s 0.03/Hg_{ss} 0.13, Pb_s 33.3/Pb_{ss} 20.2, Zn_s 150/Zn_{ss} 109, Se_s 0.24/Se_{ss} 0.05, Ni_s 37.2/Ni_{ss} 48, Sb_s 1.25/Sb_{ss} 1, Ba_s 892/Ba_{ss} 431, V_s 103.3/V_{ss} 167.8. Furthermore, geochemical background values were derived for soil and stream sediment samples. The values are as follows (in mg kg⁻¹): As_s 1.33/As_{ss} 1, Cd_s 0.48/Cd_{ss} 0.05, Cr_s 54.7/Cr_{ss} 106.5, Cu_s 23.8/Cu_{ss} 23, Hg_s 0.025/Hg_{ss} 0.095, Pb_s 15.3/Pb_{ss} 13.5, Zn_s 70/Zn_{ss} 55, Se_s 0.13/Se_{ss} 0.05, Ni_s 19.5/Ni_{ss} 32.5, Sb_s 1/Sb_{ss} 1, Ba_s 266/Ba_{ss} 275, V_s 50.7/V_{ss} 119. More than two-thirds of soil and sediment samples exceeded established (based on literature data) risk limit values for non-polluted environment. Based on environmental risk assessment for potentially toxic elements in soils and sediments in more than 45% of total area disturbed environment ($I_{ER} = 1-3$) was documented and more than 13% of territory was characterised with highly disturbed environment ($I_{ER} > 3$).

Keywords Potentially toxic elements · Soil · Sediment · Contamination · Environmental risk · Egypt

Introduction

Egypt was as Heroditus said “the gift of the Nile”. Everything depended on the River Nile in ancient times as it still does today to a large extent. The alluvial soils of Egypt are formed from disintegration of the eruptive and metamorphic rocks of the Ethiopian Highlands (Blokhuys et al. 1964). The disintegrated materials are carried out by the Nile water to settle in the Nile delta making it very fertile. This process historically occurred during the annual flooding of the Nile in the summer months. However, the construction of the hydro-electric power plant (May 1964) resulted in great modification in the hydro-dynamic regime of the River Nile, with significant changes in physico-chemical and biological properties of downstream water. Also, the rapidly expanding industrialisation and intensive agriculture are other threats to water quality of the River Nile. The Nile receives increasing amount of industrial and agricultural wastes from different point and diffuse sources. Melegy et al. (2002) reviewed the man-made impacts upon water quality of the River Nile in Egypt.

The mega cities of the world are facing serious environmental problems (Molina and Molina 2004). The Greater Cairo area in Egypt is the largest city in Africa and in the Middle East with population of over 15 million people, and it is one of the largest cities in the world. El-Tabbin area is located in southern part of Greater Cairo. Urbanisation and industrialisation have increased very rapidly, particularly in the second half of the last century, causing increased levels of environmental hazards (Robaa 2003).

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One of the most evident unfavourable impacts upon the environment in such areas is the increased level of potentially toxic elements of anthropogenic origin, in soils as well as sediments. Many of European countries, United States, Canada, China and others have created nationwide geochemical datasets and geochemical maps for variety of environmental applications (Garrett et al. 2008; Xie et al. 2008). These kind of maps are rare for African countries, including Egypt.

Therefore, the present study undertaken in El-Tabbin area, near Cairo metropolis, is focussed on determination of the soil and sediment contents of potentially toxic elements, their association with environmental problems and elaboration of baseline geochemical database and maps for study area. The aim of this study was to evaluate the environmental risk for potentially toxic elements based on the total element contents and their comparison with established environmental standards. However, the real risk may be more closely associated to the mobile and bioavailable chemical forms (Anon 2003; Selinus et al. 2005).

The investigated area

The investigated area El-Tabbin is the highly industrialised area in Egypt, (Melegy 2005). El-Tabbin lies on East side of the River Nile with an area about 30 km². It is located in the industrial district south of Greater Cairo (Fig. 1). The industrial activities include ferrous and non-

ferrous metallurgical work, ceramics, fire bricks, cement industry, coke factory, a power plant, chemical industries, etc.

The population of El-Tabbin area, estimated to be 0.1 million of people in 1970, has grown almost to 0.5 million in 2008. Residents are living mainly in small one-family houses and approximately one-fourth of them live in housing estates. The majority of houses are not provided with sewage drains and only small part of them is connected to water-supply network. Although industrialisation was not cause for the early growth, in recent years this has become a contributing factor. A number of environmental and social problems, including traffic congestion, sewerage, water supply as well as lack of appropriate landfill and land use planning arise from the lack of effective planning in the country.

The emissions of the numerous and densely distributed industries are coupled with high temperature, lack of rain and predominant low wind speed. These factors favour the accumulation of air pollutants over the district and supplement the formation of air pollution episodes. The situation temporarily worsens with dust laden winds especially during spring and autumn.

The field mapping of the fluvial and associated sediments of the Nile Valley and the examination of a large number of boreholes, both deep and shallow, show that it is possible to conceive the Nile as having passed through five main episodes since the valley was cut down in the late Miocene time (Said 1981). These are from the oldest to the youngest: Eonile (Late Miocene), Paleonile (Late Pliocene). Proto-, Pre- and Neonile (Pleistocene). They were separated from one another by episodes in which the river declined, ceased to flow or radically changed its regimen probably in response to tectonic activity and/or other climatic changes. The deposits of the last of the rivers, the Neonile which is still extant, are indistinguishable from those of the present-day river.

The most recent of the Nile sediments (Neonile), the valley and delta troughs of the Nile offered the only environment in Egypt which favoured the accumulation and preservation of sediment during the quaternary. The local geology consists of quaternary deposits, floodplain sediments of the Nile River, Yousef (1968) and Said (1990, 1993). Sand, silt and clay are dominating with thickness of about 200 m. From the geochemical point of view, the high content of organic matter, often more than 10%, is very important. These sediments were deposited annually as fluvial deposits of the Nile River. However, after the dam building (May 1964) annual input of the Nile sediments has been interrupted and nowadays land surface form is effected by anthropogenic factors (various dumps, soil displacement during building operations and others).

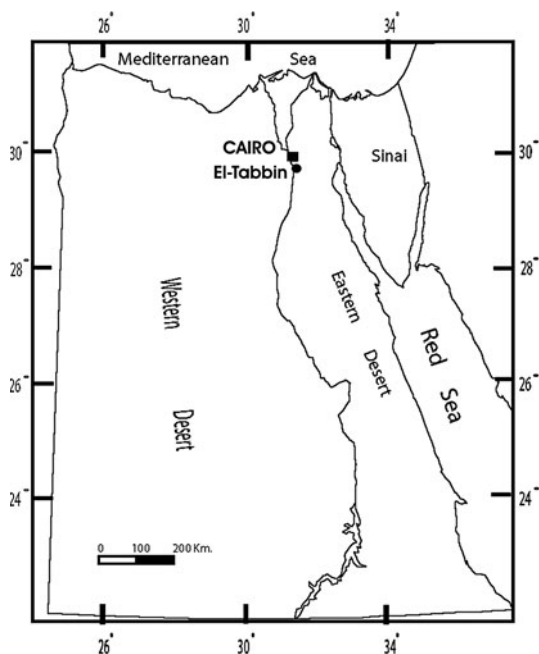


Fig. 1 The location map of the studied area

Materials and methods

Sample collection

For determination of level of pollution, 24 soil samples and 6 stream sediment samples of the River Nile were taken in spring period (May) in 2008 (Fig. 2). The key samples are listed in Table 1.

The sampling density was approximately 1 sample per 1 sq km. Soil samples were collected from the depth of 0 to 15 cm (topsoil). Stream sediments were taken from the bank of the River Nile at points where water flow was slowed-down and the finest fraction of sediment was deposited. Samples were collected in polyethylene bags in total amount of about 1 kg.

Laboratory methods

Collected samples were dried at temperature 40°C on plastic plates. Subsequently, they were pulverised in pottery bowls and screened through a 0.2 mm aperture plastic sieve. After the quartering, samples were treated using non-abrasive mill to 0.09 mm analytical fraction.

Chemical analyses were performed in certified reference laboratory of Geological survey of Slovak Republic. Total contents of Hg, Cd, Se, V, Cr, Ni, Cu, Pb, Zn, As, Sn, Sb and Ba were determined. Soil and stream sediment samples were treated and analysed in the same way. Certified reference materials were used, NIST 2709 for soils and GBW 07309 for stream sediments.

As, Cu, Pb, Zn, V, Cr, Ni, Sn, Sb and Ba were determined by energy-dispersed X-ray fluorescence (XRF) spectrometry on spectrometer X-LAB 2000 fy Spektro. As much as 5 g of sample were homogenised, mixed with 1 g of wax and pressed under a pressure of 250 MPa into a tablet of 40 mm in diameter. Fundamental parameter methods were used to eliminate the interference of major elements on signal of the analyte. The signal was evaluated from the calibration curve. Detection limits for the analysis of these elements (LOQ) were following: for As, Sb and Sn—2 mg kg⁻¹, for Ni—4 mg kg⁻¹, for Cu, Pb, Zn and V—5 mg kg⁻¹ and for Cr and Ba—10 mg kg⁻¹.

Hg was determined directly from solid sample homogenised to analytical grain fraction on mono-purpose built analyzer AMA-254 via atomic absorption spectrometry (AAS). LOQ was 0.01 mg kg⁻¹.

Se was analysed through hydride generation—atomic absorption spectrometry (HG-AAS) after the sample decomposition with acid mixture (HNO₃, HCl). LOQ was 0.1 mg kg⁻¹.

Cd was determined using flame atomic absorption spectrometry (FAAS) after the sample decomposition with acid mixture (HNO₃, HCl). LOQ was 0.1 mg kg⁻¹.

Interpretation of results

Based on geochemical data results, standard single element’s maps of distribution were compiled. These provide a view on spatial distribution of the evaluated elements in El-Tabbin region and basic information about level of contamination in the region by the potentially toxic elements. The soil and stream sediment data were evaluated in the same way.

In the next step, the element contents were compared to existing limit values for chemical contents in soils. In Egypt and even in any of African countries no limit, maximum permissible values, trigger values or clean-up standards for the soil contents of potentially toxic elements, are established. Similarly in Europe no limits have been defined for chemical contaminants in soil and sediments at the legislative level of European Union. These are only available at national levels, like in Slovakia, Italy, Netherlands and others. In the selection of limit values for soils we used the approach introduced by

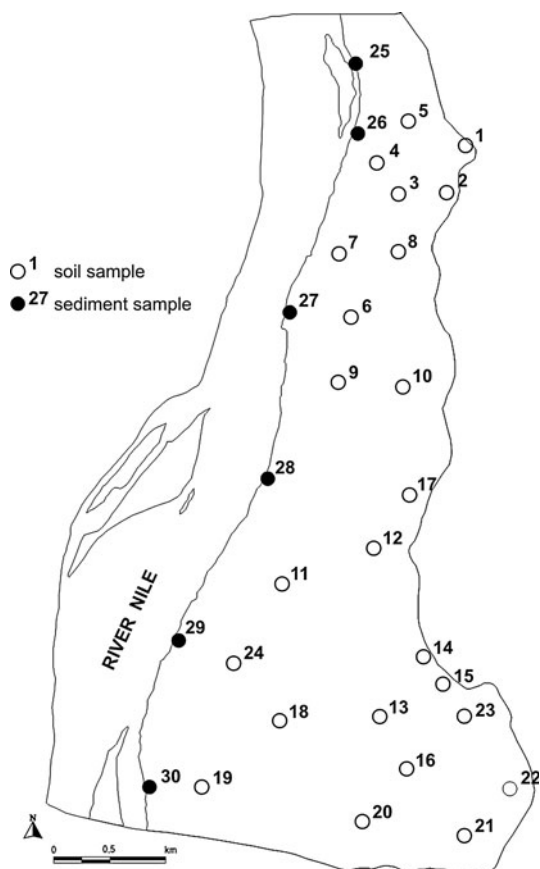


Fig. 2 The sites of soil and sediment samples in El-Tabbin

Table 1 The key of the studied samples collected from El-Tabbin area, Egypt (2008)

| No. of samples | Kind of samples | Investigated sites | Major sources of pollution |
|----------------|--------------------|------------------------------------|--------------------------------------|
| 1 | Soil | Arab Kafr Ei'llw | Cement factory |
| 2 | Soil | Arab Kafr Ei'llw | Cement factory |
| 3 | Soil (school area) | Arab Kafr Ei'llw | Cement factory |
| 4 | Soil (playground) | Arab Kafr Ei'llw | Cement factory |
| 5 | Soil | Es. Naser Egyda | Fired brick industry |
| 6 | Soil | Es. El Tebbin | Asfor Co. of metallurgy and ceramics |
| 7 | Soil | Es. El Tebbin | Somid Co. of pipes |
| 8 | Soil | Es. El Tebbin | ASCO Co. of gases |
| 9 | Soil | El Tebbin | Industrial complexes |
| 10 | Soil (school area) | El Tebbin | Industrial complexes |
| 11 | Soil (arable land) | El Shobak El-Sharqi | Industrial complexes |
| 12 | Stream sediment | El Shobak | Industrial complexes |
| 13 | Soil | El Minya | Coke factory |
| 14 | Soil (school area) | Arab Abu Sa'ad | Non-ferrous metallurgical industry |
| 15 | Soil | Arab Abu Sa'ad | Coke factory |
| 16 | Soil | El Minya, El Shurafa, El-Utaiyat | Coke factory |
| 17 | Soil | Arab El-Fawarsa and El Etwa | Industrial complexes |
| 18 | Soil | El-Utaijat | Industrial complexes |
| 19 | Soil | Es. Arab El-Sabayha | Industrial complexes |
| 20 | Soil | El Minya, El Shurafa and El Utajat | Industrial complexes |
| 21 | Soil | Es Abdel Samie | Industrial complexes |
| 22 | Soil | Arab El Gabibra | Industrial complexes |
| 23 | Soil | Tall El Minya, El Shurafa | Iron and steel company |
| 24 | Soil | El Shobak | Industrial complexes |
| 25 | Sediment | Bank of the River Nile | Industrial complexes |
| 26 | Sediment | Bank of the River Nile | Industrial complexes |
| 27 | Sediment | Bank of the River Nile | Industrial complexes |
| 28 | Sediment | Bank of the River Nile | Industrial complexes |
| 29 | Sediment | Bank of the River Nile | Industrial complexes |
| 30 | Sediment | Bank of the River Nile | Industrial complexes |

Provoost et al. (2006) and determined the 50th percentile (median) of individual national clean-up standard values for residential land use, including guidelines from the following countries: Slovakia, Finland, Belgium, Canada, France, Germany, Italy, the Netherlands, Sweden and Great Britain. In addition to the above guidelines, median of European content chemical level in topsoil from Geochemical atlas of Europe (Salminen et al. 2005) was used in the 50th percentile calculation. Risk (limit) values for potentially toxic elements in soil that we used for the evaluation of soil contamination in El-Tabbin region are summarised in Table 2.

The derived limit (risk) values for contents of potentially toxic elements in soils were used for the calculation of environmental risk index and subsequent compilation of environmental risk map.

Environmental risk calculation and map compilation

The screening level or threshold concentration level of chemical elements in different compartments of the ecosystem (surface water, soils and sediments) has been defined by limits set in specific regulations. These values are based upon current knowledge and are regarded as not posing a threat to human health or to other living organisms of the environment. Exceeding these limits opens the possibility for jeopardising the environment, i.e. *environmental risk*. In these terms, environmental risk means the possibility or probability of jeopardising or damaging single biotic and abiotic environmental components as a consequence of their exposure to the effects of pollutants.

In the terms of the valid European (Anon 1994a) and national (Anon 1998, 2007) protocols, methodological

Table 2 Evaluated chemicals in topsoil, their limit values for environmental risk assessment, European content levels and clean-up standards for residential land use in various countries for comparison (in mg kg⁻¹)

| Parameter | Risk limit value (50th percentile) | European content level ^a | | National clean-up standards for residential land use | | | | | | | | | |
|-----------|------------------------------------|-------------------------------------|-------|--|----------------------|----------------------|---------------------|---------------------|----------------------|--------------------|--------------------------|---------------------|----------------------------|
| | | Median | Mean | Slovakia ^b | Finland ^c | Belgium ^d | Canada ^e | France ^f | Germany ^g | Italy ^h | Netherlands ⁱ | Sweden ^j | Great Britain ^k |
| As | 20 | 7.03 | 11.6 | | | | | | | | | | |
| Ba | 375 | 375 | 400 | 1,000 | | | 500 | 312 | | | 160 | | |
| Cd | 5 | 0.145 | 0.284 | 5 | 10 | 0.8 | 10 | 10 | 20 | 2 | 0.8 | 0.4 | 8 |
| Cr | 125 | 60 | 94.8 | 250 | 200 | 37 ^l | 64 | 65 | 400 | 150 | 100 | 120 | 130 |
| Cu | 95 | 13 | 17.3 | 100 | 150 | 17 | 63 | 95 | | 120 | 36 | 100 | |
| Hg | 2 | 0.037 | 0.061 | 2 | 2 | 0.55 | 6.6 | 3.5 | 20 | 1 | 0.3 | 1 | 8 |
| Ni | 50 | 18 | 37.3 | 100 | 100 | 9 | 50 | 70 | 140 | 120 | 35 | 35 | 50 |
| Pb | 140 | 22.6 | 32.6 | 150 | 200 | 40 | 140 | 200 | 400 | 100 | 85 | 80 | 450 |
| Sb | 3 | 0.6 | 1.04 | 3 | | | | 50 | | | 3 | | |
| Se | 3 | | | 5 | | | 1 | | | | 0.7 | | 35 |
| V | 130 | 60.4 | 68.1 | 200 | 150 | | 130 | 280 | | 90 | | 120 | |
| Zn | 200 | 52 | 68.1 | 500 | 250 | 62 | 200 | 4,500 | | 150 | 140 | 350 | |

n number of samples, % percent of samples

^a Salminen et al. (2005)

^b Anon (1994b) (multifunctional land use)

^c Anon (2007)

^d Anon (1995)

^e Anon (2006)

^f Darmendrail (2001)

^g Anon (1999a)

^h Anon (1999b)

ⁱ Anon (2000) (multifunctional land use)

^j Anon (2002a)

^k Anon (2002b)

^l Chromium(III)

approaches and directives for risk assessment and management, the following definitions have been adopted: environmental risk (ER), which characterises likelihood, or possibility of occurrence of adverse effects as a consequence of the exposure of the environment to single or several stressors. For a single stressor, this represents the ratio between its concentration within the environment (termed the predicted environmental concentration, or PEC) and the concentration presumed to have no negative effect upon organisms or ecological systems (the predicted non-effect concentration, or PNEC). Consequently, environmental risk can be numerically expressed by the environmental risk quotient (Q_{ER}). Its magnitude gives an estimate for the probability of occurrence of ill-effects from the assessed element (metal) upon the environment.

The data from geochemical mapping of soils in El-Tabbin region (sampling density 1 sample/1 sq km) were used as PEC. The correct way to define PNEC value is to apply ecotoxicological monitoring. Unfortunately, we do not have possibility to realise such a research and even no information on similar research from Egypt can be found. That is why we use as PNEC concentrations calculated limit values—risk values for soils derived from limit values from various countries (Table 2). In this case, the environmental risk quotient (Q_{ER}) represents the ratio of measured analytical concentration of an element from geochemical mapping of soils and limit (risk) value established from national limit (risk) concentrations.

The cumulative summary effect of several elements, for which analytical concentration values in more than one case exceed the limits, can be expressed in the form of the risk sum of individual elements as the environmental risk index (I_{ER}). The concentration values of those elements the analytical concentration values of which are below their limit (risk) are excluded from the calculation. Calculation of the environmental risk index value (I_{ER}) for individual analysed water, soil and sediment samples consists of two steps (Rapant and Kordík 2003; Rapant et al. 2008). The first step is the calculation of the environmental risk quotient for each analysed chemical element or compound that exceeds the limit risk values. In the second step, their sum is calculated according to the denoted scheme:

$$I_{ER} = \sum_{i=1}^n Q_{ERi} \quad Q_{ERi} = \frac{AC_i}{RC_i} - 1$$

Q_{ERi} environmental risk quotient of the i -element, which exceeds the limit (PNEC) concentration; AC_i i -element analytical (PEC) concentration; RC_i i -element limit (PNEC) concentration; I_{ER} environmental risk index of the sample tested.

The above Q_{ER} and I_{ER} calculations are derived from the cited regulations for environmental risk assessment and management, namely from the so-called safety coefficient method. It was amended and modified in two ways. Those elements the concentrations of which do not exceed the limit (risk) values and are thus presumed to pose no environmental risk are ignored in the calculation (i.e. $Q_{ER} = 0$). In the calculation of Q_{ER} for individual elements, the number one is subtracted. This avoids the case of a Q_{ER} for several summarised elements that does not reach the limit risk concentration but has a relatively high I_{ER} , although none of the elements exceed the limit risk concentration. In the second case, when subtracting one in the calculation of Q_{ER} , only the element's risk concentration should be considered (the concentration that exceeds the limit risk values). In this way, through I_{ER} for each environmental sample assessed, we will obtain an expression of the potential cumulative risk from all elements the levels of which exceed the limit risk.

Based on the calculated values of I_{ER} for all collected samples, soils and stream sediments, map of environmental risk assessment was compiled. The spatial distribution of I_{ER} was graphically visualised by applying data interpolation and modelling using Arc View GIS 3.2 software. In risk assessment, multi-level scales (5–6 levels) are generally used for characterisation of risk level (Rapant and Kordík 2003). According to our results the following essential scale was developed to estimate the environmental risk level:

| | |
|----------------------|---------------------|
| $I_{ER} = 0$ | negligible risk; |
| $I_{ER} > 0 \leq 1$ | low risk; |
| $I_{ER} > 1 \leq 3$ | medium risk; |
| $I_{ER} > 3 \leq 5$ | high risk; |
| $I_{ER} > 5 \leq 10$ | very high risk; |
| $I_{ER} > 10$ | extremely high risk |

Results

Results of chemical composition analysis of soils and stream sediments of El-Tabbin region are summarised in Table 3. Spatial distribution of selected elements is shown in Fig. 3. The results document general differences between soil samples and River Nile sediment samples. Relatively high inhomogeneity is also observed for all the results, for soils as well as sediments. Generally the soil contents of potentially toxic elements comparing with Nile sediments are higher for Cd, Se, As, Zn, Ba and Pb, similar for Cu, Sb and Sn and lower for Hg, Cr, V and Ni. Although the differences are not distinct.

After the construction of hydro-electric power plant on the River Nile in 1965, yearly floods, which were yielding

Table 3 Chemical composition of soil and stream sediment samples from El-Tabbin region (in mg kg⁻¹)

| No. of samples | Hg | Cd | Se | Cr | Ni | Cu | As | Sb | Ba | Pb | V | Zn | I _{ER} |
|------------------------|-------|------|------|--------|-------|-------|------|------|--------|-------|--------|--------|-----------------|
| 1 | 0.01 | 0.2 | <0.1 | 147 | 61 | 49 | 3 | <2 | 487 | 18 | 193 | 110 | 1.18 |
| 2 | 0.02 | 0.2 | <0.1 | 128 | 65 | 62 | 2 | <2 | 464 | 23 | 187 | 127 | 1.00 |
| 3 | <0.01 | <0.1 | 0.1 | 25 | 8 | 8 | <2 | <2 | 211 | 9 | 26 | 31 | 0.00 |
| 4 | <0.01 | 0.1 | 0.1 | 48 | 12 | 13 | <2 | <2 | 256 | 12 | 40 | 40 | 0.00 |
| 5 | 0.01 | <0.1 | <0.1 | 124 | 63 | 57 | 3 | <2 | 707 | 16 | 177 | 92 | 1.51 |
| 6 | 0.02 | 0.2 | 0.2 | 274 | 57 | 93 | 4 | <2 | 1,661 | 88 | 161 | 140 | 5.00 |
| 7 | 0.02 | 0.2 | 0.1 | 120 | 67 | 82 | 3 | <2 | 673 | 40 | 158 | 264 | 1.67 |
| 8 | 0.06 | 0.3 | 0.2 | 76 | 29 | 49 | 3 | <2 | 312 | 25 | 69 | 140 | 0.00 |
| 9 | 0.01 | 0.2 | 0.1 | 130 | 69 | 60 | 2 | <2 | 473 | 22 | 181 | 123 | 1.07 |
| 10 | 0.01 | 0.2 | 0.2 | 47 | 15 | 37 | 2 | 2 | 1,447 | 79 | 46 | 156 | 2.86 |
| 11 | 0.02 | 0.2 | 0.1 | 97 | 50 | 49 | 3 | <2 | 443 | 29 | 142 | 130 | 0.27 |
| 12 | 0.01 | 0.2 | 0.3 | 52 | 21 | 23 | 3 | <2 | 1,090 | 63 | 60 | 159 | 1.91 |
| 13 | 0.02 | 0.2 | 0.1 | 97 | 53 | 52 | 3 | <2 | 443 | 27 | 138 | 131 | 0.30 |
| 14 | 0.01 | 0.4 | 0.2 | 35 | 13 | 55 | <2 | 3 | 426 | 92 | 30 | 214 | 0.21 |
| 15 | 0.01 | 0.1 | 0.3 | 49 | 18 | 24 | <2 | <2 | 652 | 27 | 57 | 141 | 0.74 |
| 16 | 0.22 | 2 | 2.6 | 109 | 45 | 17 | 43 | 4 | 8,219 | 58 | 153 | 898 | 26.07 |
| 17 | 0.06 | 2.2 | 0.2 | 72 | 15 | 24 | <2 | <2 | 199 | 15 | 39 | 74 | 0.00 |
| 18 | 0.01 | <0.1 | 0.1 | 59 | 31 | 28 | <2 | <2 | 305 | 14 | 73 | 64 | 0.00 |
| 19 | 0.02 | 0.1 | <0.1 | 100 | 50 | 46 | <2 | <2 | 452 | 21 | 136 | 99 | 0.25 |
| 20 | 0.02 | 0.2 | <0.1 | 99 | 55 | 48 | 3 | <2 | 454 | 28 | 148 | 137 | 0.45 |
| 21 | 0.01 | 0.2 | 0.1 | 48 | 18 | 22 | <2 | <2 | 491 | 20 | 55 | 68 | 0.31 |
| 22 | 0.01 | 0.2 | 0.1 | 48 | 22 | 21 | <2 | <2 | 314 | 17 | 57 | 72 | 0.00 |
| 23 | 0.1 | 0.1 | 0.2 | 72 | 33 | 23 | <2 | <2 | 727 | 36 | 88 | 118 | 0.94 |
| 24 | 0.01 | 0.1 | 0.1 | 48 | 22 | 26 | <2 | <2 | 503 | 19 | 66 | 73 | 0.34 |
| 25 | 0.23 | 0.2 | <0.1 | 169 | 61 | 72 | 2 | <2 | 540 | 31 | 215 | 191 | 1.67 |
| 26 | 0.22 | 0.3 | <0.1 | 177 | 58 | 88 | 3 | <2 | 535 | 33 | 204 | 197 | 1.57 |
| 27 | 0.06 | <0.1 | <0.1 | 144 | 52 | 29 | <2 | <2 | 487 | 15 | 179 | 78 | 0.87 |
| 28 | 0.06 | <0.1 | <0.1 | 146 | 52 | 28 | <2 | <2 | 475 | 15 | 171 | 79 | 0.79 |
| 29 | 0.1 | <0.1 | <0.1 | 107 | 32 | 23 | <2 | <2 | 270 | 9 | 122 | 54 | 0.00 |
| 30 | 0.09 | <0.1 | <0.1 | 106 | 33 | 23 | <2 | <2 | 280 | 18 | 116 | 56 | 0.00 |
| X _s 1–24 | 0.03 | 0.33 | 0.24 | 87.67 | 37.17 | 40.33 | 3.67 | 1.25 | 892.04 | 33.25 | 103.33 | 150.04 | 1.92 |
| Me _s 1–24 | 0.01 | 0.2 | 0.1 | 74 | 32 | 41.5 | 2 | 1 | 468.5 | 24 | 80.5 | 125 | 0.40 |
| X _{ss} 25–30 | 0.13 | 0.12 | 0.05 | 141.50 | 48.00 | 43.83 | 1.50 | 1.00 | 431.17 | 20.17 | 167.83 | 109.17 | 0.82 |
| Me _{ss} 25–30 | 0.10 | 0.05 | 0.05 | 145.00 | 52.00 | 28.50 | 1.00 | 1.00 | 481.00 | 16.50 | 175 | 78.5 | 0.83 |

X arithmetic mean, Me median, s soil, ss stream sediment, < below LOQ

flood plain sediments and were forming local soils, including the contents of potentially toxic elements, were interrupted. Thus, during the last 45 years the chemical composition of soils except of natural occurring processes in soil profile (gleying, salinisation) was modified mainly due to anthropogenic activities in El-Tabbin region.

That is why the determined minimal contents of single elements can be considered quasi geochemical background values and all increased contents can be associated with anthropogenic origin of contamination. This presumption is confirmed also by the comparison of our results with the only available literature data from the area of the Nile

Delta (Abdel-Sabour and Abdel-Basset 2002; Abdel-Sabour and Zohny 2004). These authors document in non-polluted area soil contents of Cr in the range 17.6–25.0 mg kg⁻¹ and Zn in the range 74.1–103.8 mg kg⁻¹. The soil contents of these elements in polluted area exceed in the case of Cr 72 mg kg⁻¹ and in the case of Zn 136 mg kg⁻¹. Comparing our data with these results, both are in good agreement.

Our results for El-Tabbin region were also compared with the data from world’s literature, namely with probably one of the most compact data source, the database of Geochemical atlas of Europe (Salminen et al. 2005) and

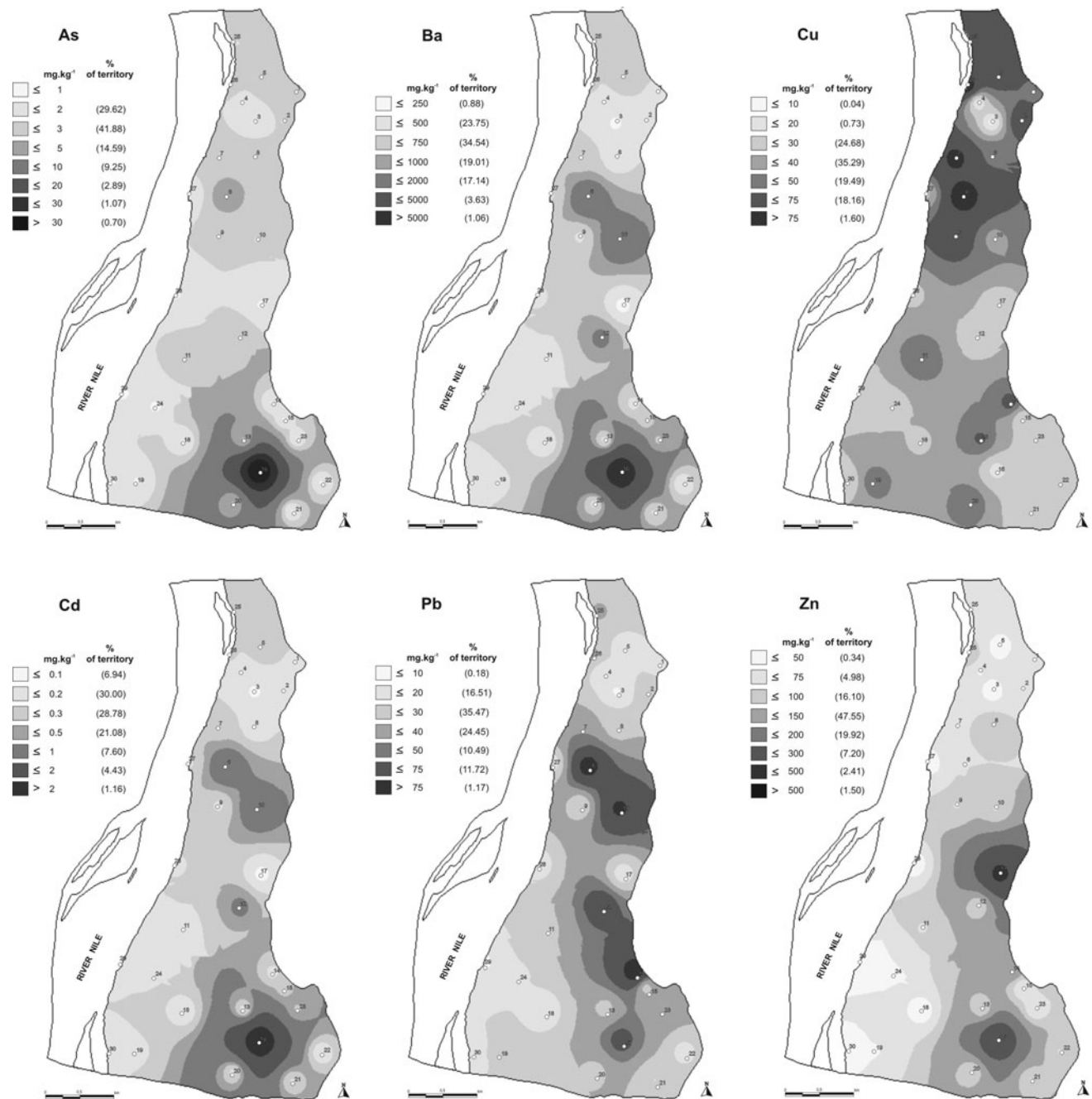


Fig. 3 Distribution of As, Ba, Cd and Pb in soils of El-Tabbin region

also with results summarised in work of Reimann and Caritat (1998). The data comparison revealed higher average contents of potentially toxic elements including Ba, Cd, Cr, Cu, Pb, Sb, Zn, Ni, Se, Sn and similar average contents for Hg and As. Additionally, the soil origin in El-Tabbin region (the River Nile floods with reduced input of potentially toxic elements) causes relatively high anthropogenic loading of study area reflected in the content levels of all analysed potentially toxic elements.

The anthropogenic loading of study area is clearly documented also in the map of environmental risk assessment (Fig. 4). The 50th percentile (median) of individual national clean-up standard values together with European median levels (Table 2) were used as limit (risk) values used in calculation of environmental risk. The negligible risk ($I_{ER} = 0$) present in study area is of very small rate (0.04% of territory). Low risk is documented in about 45% of territory. From the point of view of contents of

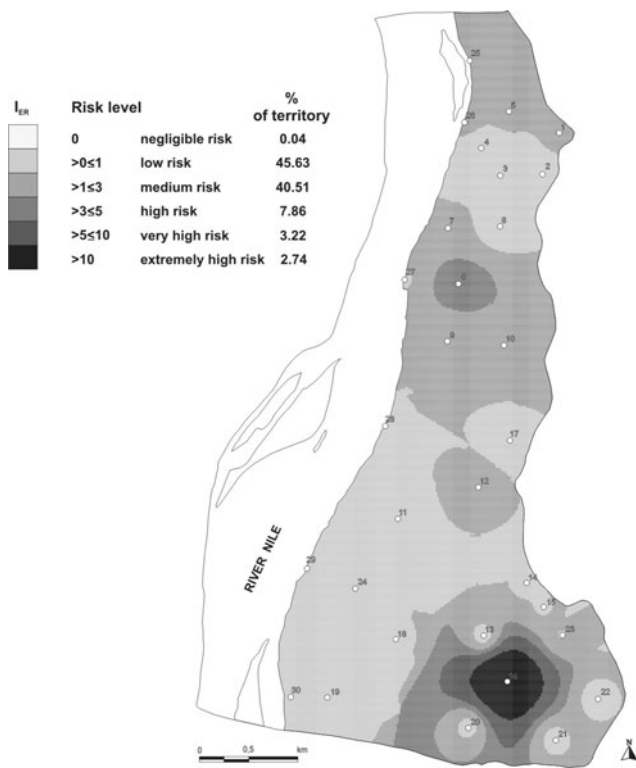


Fig. 4 Environmental risk assessment map of El-Tabbin region

potentially toxic elements, more than 40% of the study area is assessed as territory with partially disturbed level of the environment ($I_{ER} = 1-3$) and about 13% of the study area can be characterised with disturbed to highly disturbed level of the environment ($I_{ER} > 5$). The areas with increased contents of wide group of analysed elements (Hg, Cd, Cr, Cu, Ba, Pb and Zn) include El Minya site (soil sample No. 16, coke factory) and Es. El-Tabbin site (soil sample No. 6, metallurgy and ceramics).

Nowadays, in the area of El-Tabbin and also in the other areas in Egypt no analytical data exist for potentially toxic elements in soil or stream sediments of the River Nile. Also no geochemical background values for El-Tabbin or other region in Egypt that could be used as reference levels are available. Because of relatively small dataset of soil (24) and stream sediment samples (6) in the Nile Delta it was not possible to use any statistical method for the calculation of background or baseline values.

For the determination of background values that characterise non-disturbed natural conditions with no or very low level of anthropogenic origin, so-called geochemical approach was used (Rapant et al. 2009). This approach is based on the elimination of each sample that at least for one element exceeds limit value we have excluded from the dataset. Based on such adjustment of statistical dataset,

Table 4 Geochemical background values for potentially toxic elements in soils and sediments in El-Tabbin region

| Element | Hg | Cd | Se | Cr | Ni | Cu | As | Sb | Ba | Pb | V | Zn |
|----------|-------|------|------|-------|------|-------|------|----|--------|-------|-------|-------|
| Soil | 0.025 | 0.48 | 0.13 | 54.67 | 19.5 | 23.83 | 1.33 | 1 | 266.17 | 15.33 | 50.67 | 70.17 |
| Sediment | 0.095 | 0.05 | 0.05 | 106.5 | 32.5 | 23 | 1 | 1 | 275 | 13.5 | 119 | 55 |

Data in $mg\ kg^{-1}$, values below detection limit were replaced by a half of value

Table 5 Linear correlations for chemical contents in El-Tabbin soils and sediments

| | As | Ba | Cd | Cr | Cu | Hg | Ni | Pb | Sb | Se | Sn | V | Zn |
|----|---------|---------|---------|---------|---------|--------|---------|---------|---------|---------|-------|-------|-------|
| As | 1.000 | | | | | | | | | | | | |
| Ba | 0.980** | 1.000 | | | | | | | | | | | |
| Cd | 0.634** | 0.601** | 1.000 | | | | | | | | | | |
| Cr | 0.107 | 0.122 | -0.035 | 1.000 | | | | | | | | | |
| Cu | -0.106 | -0.108 | -0.145 | 0.712** | 1.000 | | | | | | | | |
| Hg | 0.491* | 0.459 | 0.369 | 0.378 | 0.161 | 1.000 | | | | | | | |
| Ni | 0.127 | 0.081 | -0.126 | 0.785** | 0.711** | 0.245 | 1.000 | | | | | | |
| Pb | 0.274 | 0.391 | 0.157 | 0.150 | 0.364 | 0.043 | -0.068 | 1.000 | | | | | |
| Sb | 0.779** | 0.799** | 0.546* | -0.143 | -0.110 | 0.315 | -0.158 | 0.580** | 1.000 | | | | |
| Se | 0.980** | 0.977** | 0.671** | -0.018 | -0.222 | 0.451 | -0.033 | 0.314 | 0.814** | 1.000 | | | |
| Sn | 0.070 | 0.044 | 0.061 | 0.083 | 0.509* | 0.253 | 0.107 | 0.535* | 0.457 | 0.052 | 1.000 | | |
| V | 0.177 | 0.134 | -0.103 | 0.833** | 0.635** | 0.428 | 0.957** | -0.100 | -0.114 | 0.017 | 0.101 | 1.000 | |
| Zn | 0.953** | 0.944** | 0.609** | 0.129 | 0.069 | 0.536* | 0.182 | 0.434 | 0.825** | 0.938** | 0.266 | 0.212 | 1.000 |

* correlation significant at $p < 0.01$

** correlation significant at $p < 0.001$

background values represent values of arithmetic mean of all samples that we consider as non-influenced by anthropogenic loadings. Such calculated background values for single analysed elements (with regard to low number of samples use of the term “estimate of background value” seems to be more suitable) are reviewed in Table 4.

Mutual relationships between analysed elements were evaluated by correlation analysis including linear correlation as well as Spearman order correlation. Since the results of such statistical analyses were both very similar, only the results of linear correlation are shown (Table 5).

Correlation analysis has documented relatively close relationship between As and Ba, Cd, Sb, Se and Zn; Cr and Ni and V; Cu and Ni and V; Ni and V; Pb and Sb; Sb and Zn; Se and Zn. These correlations are really very high. In many cases they do not correspond to natural and geochemical known associations of metals e.g. Pb, Zn, Cu (correlation between Pb and Zn—0.43; Zn and Cu—0.069; Pb and Cu—0.364) and with regard to nature they are not substantiated (e.g. As and Ba—0.98; Ni and V—0.957; Ba and Se—0.977; Se and Zn—0.938). That is why rather anthropogenic origin could be considered as significant. This fact is reflected also in relatively high anthropogenic rate of majority of potentially toxic elements in study area.

Conclusion

Based on presented results we can conclude that El-Tabbin region is characterised with relatively high level of anthropogenic contamination of soils and stream sediments by potentially toxic elements. More than two-thirds of soil and sediment samples from this region exceed, many times very significantly, established limit values (derived from literature dataset) for non-polluted environment. From the point of view of environmental risk, assessment more than 40% of the territory is characterised with highly disturbed environment due to increased levels of potentially toxic elements. This disturbance is unambiguously linked with anthropogenic activities, mainly various industrial manufacture that was initiated and developed during the last 30–40 years. In the case that no effective environmental measurements will be taken there is high presumption of further increase of content levels of potentially toxic elements in soils of study area.

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