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Soil Mapping as A Base to Survey the Heavy Metals Content of Bahr El-Bakar Area, East Delta, Egypt

W.A.M. Abdel Kawy and R. M. M. El-Kilani
Soils Science Department, Faculty of Agriculture, Cairo University, Cairo, Egypt.

THE AIMS of this study are: 1) producing a geometrically corrected physiographic-soil map scale 1:50.000 reduced to the attached map scale 1: 250.000 for the studied area as a base to survey the heavy metals content; 2) To check the sustainability of the agricultural ecosystem through checking for the possible consequences of using drainage water which have high heavy metal content due to pollution effects.

To fulfill the first aim, eight soil profiles were chosen from 22 profiles to represent the different mapping units. Morphological description was carried out and soil samples were collected for physical and chemical analysis. Based on the aerial photo-interpretation and the geographic information system, coupled with the field work and laboratory analysis data, the physiographic soil map was produced.

The following main landscape units can be identified:
1-Coastal plain (the Fluvio Marine deposits) which contain clay flats, clay swamps, hills and old sandy deposits remnants.
2-Young sub-deltaic deposits.

With respect to the second aim, the drainage water dissolved heavy metal analysis was determined. The analysis show that using this water as the sole source of irrigation, which is actually the case, with a cadmium dissolved content of 0.02 ppm will lead to an incremental increase of 80 grams cadmium per acre per year, and since the warning value for cadmium concentration in the surface layer of the soil is 5 µg/kg. *i.e.*, 5 kg/acre. The warning value amount will accumulate in the soil during a period of 62 years. So, there are very strong doubts about the sustainability of this system. There are already signs of the buildup of heavy metal accumulation in the surface layer due to the use of drainage water (Bahr El-Bakr drain) in irrigating the studied area.

Keywords: Soil mapping, Heavy metals, Bahr El-Bakar area, East Delta, Sustainability.

Egypt is in urgent need to increase both the productivity of the existing land and to expand the cultivated area, therefore, locating new areas having potential for program, special consideration has been focused on the projects of soil reclamation. One of the problems, which are facing the land reclamation policy is heavy textured salt affected soil and the sustainability of the land resources in the reclaimed areas. The studied area which is located at the fringe of the east Nile Delta is one of these areas. The study area is mainly irrigated by Bahr El-Bakar drain, accordingly soil pollution must be monitored to ensure that there is no pollution possibility hazard.

Description of the studied area

Location

The studied area incorporates an area of approximately 80192.19 feddans. It is bounded by longitudes 32° 00` W and 32° 15` E and latitudes 30° 45` and 31°00` N (Fig. 1).

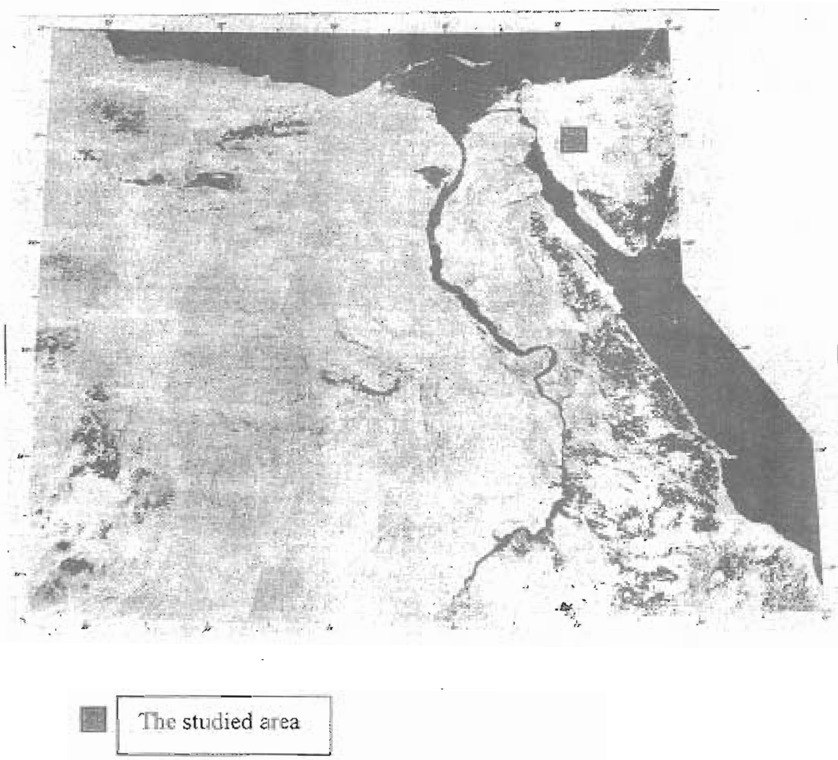


Fig.1. Location of the studied area.

Climate

Using Egyptian Meteorological Authority (1996) and Soil Taxonomy system (1999), the soil temperature regime of the studied area could be defined as thermic and soil moisture regime as torric.

Geology

According to Said (1993), the studied area is composed of Quaternary deposits late Pleistocene to Holocene.

Holocene deposits include

Young fluvio-marine deposits, which were originally transported and deposited by both the river and the sea, and which are composed of clay and silty clay inter-layered with lenses of quartz sand, and highly enriched with salts.

Young aeolian deposits, which are distributed as sand sheets developed into hummocks or sand dunes of variable size.

Gypsiferous deposits, which occur at El-Ballah and composed of nearly pure gypsum crystals.

Pleistocene deposits include

Sub-deltaic deposits, which are composed of medium and fine quartz sand, resting either directly on the old fluvio-marine deposits or on their equivalent fluviatile deposits. They are called locally "Turtle Backs"

Material and Methods

Aerial photo-interpretation

Panchromatic aerial photographs scale 1: 40,000 which were taken during the year (1991), consisting of 25 aerial photographs, have been used for the present study. All photographs were analyzed stereoscopically and further division was made using "the physiographic analysis" as detailed by Bulter (1959); Vink (1963); Goosen (1967); Ligterink (1968); Bennema & Gelens (1969) and Zink & Valenzuala (1990). The main elements used were slope, relief, greytone, in addition to parceling and natural vegetation. Thus, the physiographic map has been obtained.

Field Work

To fulfill the objective of this study, eight soil profiles were chosen from 22 localities to represent the different soil units. Morphological description was carried out following the guidelines, edited by FAO (1990) and abbreviated as

Texture:		**Structure**		**Consistency**		**Stickiness**		**Boundary**	
S	Sandy	SG	Single grained	VFI	Very firm	ST	sticky	C	Clear
SCL	Sandy clay loam	MW	Massive, weakly coherent	EFI	Extremely firm	VST	Very sticky	G	Gradual
C	Clay	MM	Massive, mod. coherent	Carbonates		Plasticity		Slope	
		MG	Massive strongly coherent	SL	Slightly calcareous	PL	plastic	F	Flat
		Cementation		MO	Mod.	VPL	Very plastic	A	Almost flat
		Y	Compacted	ST	strong			G`	Gently undulating
		W	Weakly cemented	EX	Extremely			U	Undulating
		M	Mod. cemented						

Laboratory analysis

Soil

Disturbed soil samples were collected for laboratory analyses, which include the following :

Mechanical analysis (Piper , 1950 and Klut, 1986).

$CaCO_3$, O.M & EC (Jakson, 1967 and U.S.D.A, 1991).

Soil reaction pH (Richard, 1954).

Cation exchange capacity after Piper (1950), as modified by Gohar (1954).

Exchangeable sodium according to Tucker modified method (1971).

Available N.P.K., after Jackson (1967) and Page *et al.* (1982).

Soil color by Munsell color .

Heavy metal content in the soil was determined by the use of *aqua regia* method (Cottenie *et al.*,1982)

Available Fe, Mn, Zn and Cu were determined by DTPA method after Lindsay & Norvell (1978) and measured by AAS.

Water

The dissolved heavy metals in the water were determined, after filteration and acidification by HNO_3 and the use of AAS.

Data integration and soil map production

Soil Taxonomy (1999), was used to classify the different soil profiles. The soil correlations between the physiographic and taxonomic units, were designed in order to identify the major soil sets of the studied area, after Elberson & Catalan (1987).

ARC-info program has been used as the main GIS software for this study.

Soil and water contamination status

The obtained results were compared with the guide values and quality standards for assessing soil and water contamination by heavy metals after Moen *et al.* (1986) as shown in Table 1.

TABLE 1. Guide values and quality standards used for assessing soil and water contamination.

metals	soil (mg/kg.) [a]				Surface waters (μg/l) [b]				Groundwater (mg/l) c
	A	B	C	STV	TotTV	TotLV	DisTV	DisLV	
As	20	30	50	29	5	10	4	8.6	10
Ba	200	400	2000	200	-	-	-	-	50
Cd	1	5	20	0.8	0.05	0.2	0.003	0.005	1.5
Co	20	50	300	10	-	-	-	-	10
Cr	100	250	800	100	5	20	0.5	2	1
Cu	50	100	500	36	3	3	1	1.3	15
Hg	0.5	2	10	0.3	0.02	0.03	0.003	0.005	0.05
Mo	10	40	200	10	-	-	-	-	5
Ni	50	100	500	35	9	10	7	7	15
Pb	50	150	600	85	4	25	0.2	1.3	15
Sn	20	50	300	20	-	-	-	-	10
Zn	200	500	3000	140	9	10	2	2	150

[a] A, reference value; B, test requirements; C, intervention value & STV, target value for soils. TotTV: total content target value; TotLV: total content limit value; DisTV:dissolved content target value; DisLV:dissolved content limit value, Groundwater dissolved content target value .

Results and Discussion

Visual interpretation of conventional aerial photographs

The most important elements used and which played the decisive role in the photo-interpretation of the studied area were relief, slope and gray tone elements. Geomorphology was assumed to be one of the driving soil forming factors. Soil mapping criteria concepts provided by geomorphology can conveniently be used for soil data structuring.

The combination of the geomorphic approach, as a hierarchical classification system of geoforms, using the existing body of knowledge in geomorphology, with the photo-interpretation map and field observations improved the results and allowed us to use the computer-assistance procedures.

The soil map legend of the investigated area is shown in Table 2 and the physiography and soil map is shown in Map 1.

Soil classification

According to the Recent American Soil Taxonomy (1999), the studied soils could be classified as :

C_{11}, Vertic Torrifluvents (cons.) – C_{12}, Vertic Torrifluvent (cons.).
C_2, Typic Aqusalids (cons.) – C_{31}, Typic Torripsamments (cons.).
C_{32}, Typic Torripsamments (cons.) – D_1, Typic Torrifluvents (cons.).
D_{21}, Typic Torrifluvents (cons.) – D_{22}, Typic Torrifluvents (cons.).
The physiographic-soil sets are shown in Table 2.

Soil characterization

The present geomorphic–pedomorphological study, which was based on aerial photographs interpretation, field observation and analytical data is shown in Tables 3 and 4.

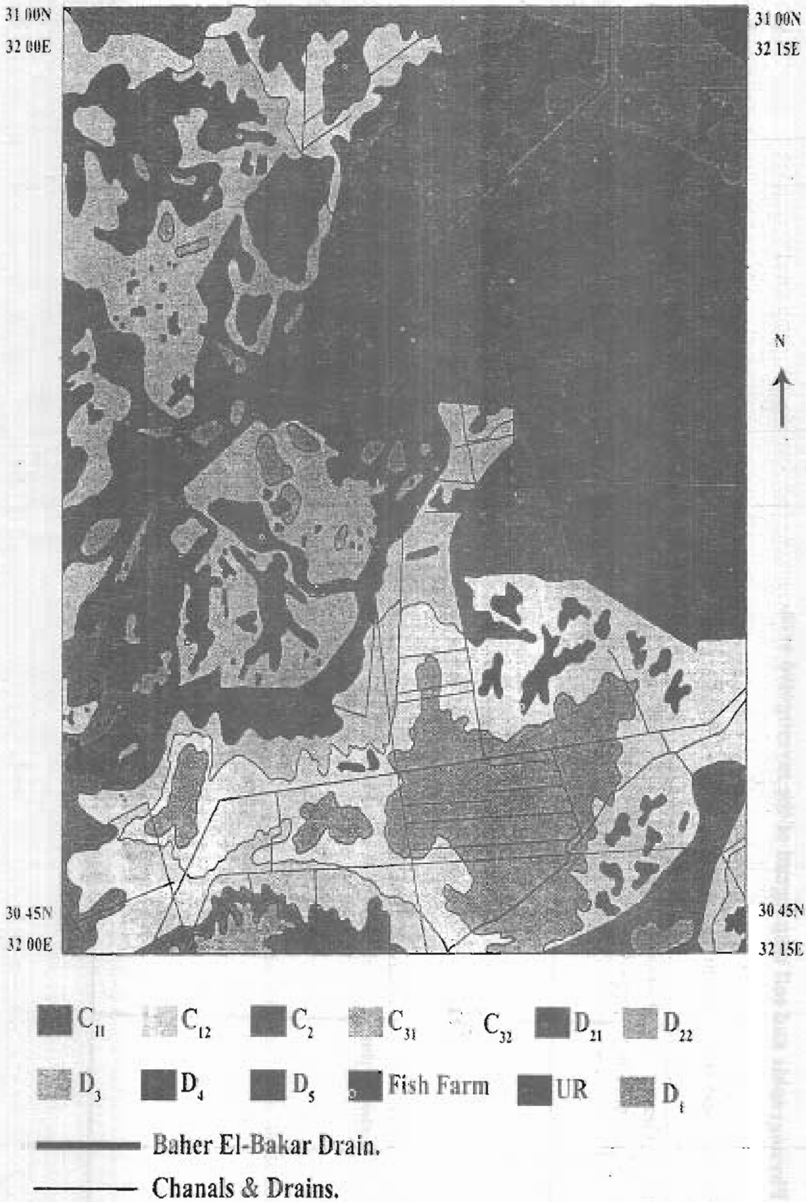
The obtained results indicate the following:

Coastal plain:-(Fluvio- marine deposits)

This plain is low lying, almost flat. It was originally affected by the Nile then the sea and later by the wind as soil forming factors. Soils of this landscape mainly occur on three main sub-land types, *i.e.* clay flats, clay swamps and old sand deposits. These soils are found in mapping units (c_{11}, c_{12}, c_2, c_{31} & c_{32}) and are represented by profiles 1,5 & 9. The particle size distribution is characterized by alternative pattern of sedimentation as the texture is clayey for the different layers of profiles (1 & 5) and sandy clay loam in the upper layer, sandy in the second layer of profile 9. The structure is massive. The consistence is extremely firm, very sticky, very plastic. There are few to many shells along the profile depths. The compaction in the second horizon is slight to high. There are common fine to medium pores. The effervescence with HCl is slight to moderate, the natural of boundary is clear. $EC_{soil\ paste}$ varies between 15.3 and 19 dS/m; pH value is 8.6–8.8; Organic matter content ranges between 1.2 and 1.9 %, the high values of O.M. content may be due to the common humified and fresh residuals of organic materials (fish ponds) and irrigation water of Bahr El-Bakar drain which is very rich in decomposed organic residuals. Calcium carbonate varies between 6.8 and 11.7 %, the high percentage of $CaCO_3$ is due to shells fragments. CEC ranges between 2.2 and 68.9 meq./100 gm soil, ESP ranges between 16.4 and 20.2 %. The macro nutrients analysis indicates that; available Nitrogen is 21.3 – 91.1 ppm ; available Phosphors is 24.6 – 31.4 ppm and available Potassium is 100.2 – 290.2 ppm.

Soil of recent sub-deltaic deposits (Alluvial deposits)

These soils represent the recent sub-deltaic plain, which is of recent age. Throughout the successive periods of the river terraces formation, immense quantities of gravel and sand have been carried by the Nile into the sea, where they spreads out around the river's mouth in the form of Delta. As the relative level of the sea fell, the less compacted sandy and gravelly deposits were disintegrated by water action and the materials were again redistributed, where the more resistant portions remained in situ and formed Islands, these soils are called "Turtle backs" or "Hummocks".



Map. 1. Physiographic-soil map of the studied area.

TABLE 2. Physiographic and soil map legend of the investigated area.

Landscape	Relief	Lithology/origin	Land form	Mapping unit	Rep. Profiles	Soil sets	Type of Soil sets
Coastal plain	Gently undulating	Fluvio-marine deposits.	* clay flats				Cons
			Relatively high	C_{11}	1	Vertic Torrifluvents	Cons
			Relatively low	C_{12}	2	Vertic Torrifluvents	
			* clay swamps	C_2	5	Typic Aquisalids	Cons.
			* old sandy deposits.				Cons.
			Remnants.				Cons
			Relatively high	C_{31}	6	Typic Torripsamments	
			Relatively law	C_{32}	9	Typic Torripsamments	
Young sub-deltaic deposits	Flat to almost flat	Alluvial deposits	* scattered small hills (Hummocks)	D_1	12	Typic Torrifluvents	Cons .
			* flat plains.				Cons.
			Relatively high	D_{21}	14	Typic Torrifluvents	
			Relatively law	D_{22}	22	Typic Torrifluvents	
			* marches	D_3	-	-	-
			* intermittent wet land.	D_4	-	-	-
			* Gypsiferous deposits.	D_5	-	-	-

TABLE 3. Soil morphological features abbreviations of the studied area.

Mapping unit	Rep. Profile No.	Depth in cm	Slope	Color		Texture class	Structure	consistency	stickiness	Plasticity	Carbonates	Boundary	Cementation	Other
				Dry	moist									
C_1	1	0-35	A	10YR5/3	10Y R2/2	C	MG	EFI	VST	VPL	MO	C	M	Shells
		35-110		5Y R5/3	5Y R3/2	C	MG	EFI	VST	VPL	SL	C	M	shells
		Water table level												
C2	5	0-20	A	10YR5/2	10YR2/2	C	MM	EFI	VST	VPL	SL	C	M	Shells
		20-45		5YR3/2	5YR2/1	C	MM	EFI	VST	VPL	SL	C	M	shells
		Water table level												
C_3	9	0-45	G	5YR5/2	5YR3/2	SCL	MG	VFI	ST	PL	MO	C	W	Shells
		45-80		5YR3/2	5YR2/1	S	MG	VFI	ST	PL	MO	C	W	shells
		Water table level												
D_1	12	0-40	A	10YR5/3	10YR2/2	C	MM	VFI	ST	PL	MO	G	W	shells
		40-100		10YR5/3	10YR2/2	C	MM	VFI	ST	PL	MO	G	W	Shells
		Water table level												
D_2	22	0-30	A	5YR3/2	5YR 1/1	C	MM	VFI	ST	PL	MO	C	W	Shells
		30-75		10YR 5/2	10 YR 2/2	C	MM	VFI	ST	PL	MO	C	W	Shells
		Water table level												

All abbreviation according to FAO (1990) & ISRIC (1991) .

TABLE 4. Main physical & chemical characteristics of the representative soil profiles .

Mapping unit	Rep. Profile No.	Depth in cm.	Particle size distribution %					Texture class	pH	O.M %	$CaCO_3$ %	EC dS/m	CEC meq./ 100 gm soil	ESP %	Available macro Nutrients (ppm)		
			Gravel	C. sand	F. sand	Silt	Clay								N	P	K
C_1	1	0-35 .	0 0	0 64	2.17	25.56	71 63	Clay	8.6	1.8	10 2	17.6	68.2	16.4	91 1	31.4	290.2
		35-110	0.0	0.79	3 24	22.36	73.61	clay	8.7	1 5	9.6	15 3	68.9	17 6	-	-	-
		Water table level															
C_2	5	0-20	0.0	0.71	1.86	30.02	67 41	clay	8.8	1.9	9.7	19.1	60.3	20.2	83 3	30.2	245 8
		20-45	0.0	0.43	2.19	25 56	71.82	Clay	8.7	1.4	6.8	16 2	60 8	18 7	-	-	-
		Water table level															
C_3	9	0-45	0 0	4.83	55 55	16.31	23 31	SCL	8.7	1 7	11.7	18.2	13 1	18 3	21 3	24.6	100.2
		45-80	0.0	11.72	78.40	3.72	6.16	Sandy	8.6	1.2	10.3	15.4	2.2	16.9	-	-	-
		Water table level															
D_1	12	0-40	0.0	0.57	3 31	42 38	53.92	clay	8 5	1.6	12.6	10.6	47.8	15.8	81.6	27.8	210.4
		40-100	0.0	0 16	2 68	37 25	59.64	clay	8.5	1 2	10 4	9.2	51.1	16 3	-	-	-
		Water table level															
D_2	22	0-30	0.0	0.18	2.36	37.25	60.21	clay	8.8	1.8	13.5	11.3	54 2	16.4	91 4	26.7	208.6
		30-75	0.0	0 27	2.11	32 7	64 92	clay	8 6	1.1	11.2	8 7	56 3	15.5	-	-	-
		Water table level															

These soils are found in mapping units (D_1, D_{21}, D_{22}, D_3, D_4 & D_5) and represented by profiles 12 & 22. The texture is clayey for different layers. The structure is massive. The consistence is extremely firm, very sticky, very plastic. There are few to many shells along the profiles. The compaction in the second horizon is slightly to highly compacted. There are common fine to medium pores. The effervescence with HCl is slight to moderate, the natural of boundary is gradual to clear. $EC_{(soil\ paste)}$ varies between 8.7 and 11 dS/m; pH value ranges between 8.5 and 8.6 Organic matter content ranges between 1.1 and 1.6 % and calcium carbonate varies between 10.4 and 13.5 %. CEC ranges between 47.8 and 56.3 meq./100gm soil, ESP ranges between 15.5 and 16.3 %. The macro nutrients analysis indicate that; available Nitrogen content is 81.6- 91.9 ppm; available Phosphorus is 26.7 –27.80 ppm. and available Potassium is 208.4- 210.4 ppm.

Soil and water contamination status

The obtained results reveal that the available Fe ranges between 8.6 and 14.9 ppm, available Mn ranges between 11.3 and 22.4 ppm, available Zn ranges between 1.2 and 2.9 ppm, available Cu ranges between 2.9 and 9.6 ppm, available Co ranges between 0.1 and 0.4 ppm, available Pb ranges between 0.2 and 0.8 ppm, available Ni ranges between 0.2 and 0.7 ppm, available Cd ranges between 0.03 and 0.08 and available Cr ranges between 0.03 and 0.09 ppm. The DTPA- extractable heavy metals content (ppm) in the surface, subsurface soil are shown in Table 5 .

The heavy metal content, as determined by the use of *aqua regia* method, show that, Fe content ranges between 303.2 and 1102 ppm, Mn content ranges between 11.29 and 57.96, Zn content ranges between 6.21 and 24.13 ppm, Cu content ranges between 8.82 and 30.63 ppm, Co content ranges between 0.11 and 1.32, Pb content ranges between 0.46 and 7.68 ppm, Ni content ranges between 0.3 and 4.68 ppm, Cd content ranges between 0.03 and 0.42 ppm and Cr content ranges between 0.03 and 0.36 ppm. The heavy metals content, extracted by the use of aqua regia, is shown in Table 6.

The obtained results from Bahr El-Bakr irrigation water analysis indicated that dissolved Fe is 0.4 ppm, dissolved Mn is 0.31 ppm, dissolved Zn is 0.09 ppm, dissolved Cu is 0.1 ppm, dissolved Co is ±0.05 ppm, dissolved Pb is ±0.05 ppm, dissolved Ni is ±0.06 ppm, dissolved Cd is 0.02 ppm, and dissolved Cr is ±0.08 ppm. The values of the dissolved heavy metals in irrigation water are given in the last row of Table 5. The obtained values of the dissolved Co, Pb, Ni and Cr lie close to the detection limits of atomic absorption spectrophotometer (AAS) for those elements, that is why the symbol ± was used.

The heavy metals content of the soil , as determined by the use of *aqua regia* show no problem in the current level of heavy metals in the soil, as compared to the reference values (column A) given in table 1. In fact, it shows low values for the elements Zn, Cu, Co, Pb and Ni. On the other hand, the value of Cadmium in some of the profiles show a value about half of the reference value. Cadmium is very highly toxic to humans and easily absorbed by plants. That is why the very low warning value for it in column B of Table 1.

TABLE 5. DTPA-Extractable heavy metals content (ppm) of the surface, subsurface soils and irrigation water samples.

Mapping unit	Rep: profile No.	Depth in cm	Fe	Mn	Zn	Cu	Co	Pb	Ni	Cd	Cr
C_1	1	0-35	14.60	21.80	2.50	9.60	0.40	0.80	0.60	0.07	0.09
		35-110	9.10	11.30	1.00	4.20	0.10	0.30	0.20	0.03	0.04
C_2	5	0-20	15.10	21.40	2.60	9.30	0.30	0.80	0.50	0.06	0.08
		20-45	8.60	12.40	1.20	3.80	0.10	0.30	0.20	0.03	0.04
C_3	9	0-45	15.60	22.40	2.80	8.60	0.40	0.80	0.60	0.07	0.08
		45.80	10.80	12.80	1.40	3.50	0.10	0.20	0.20	0.03	0.03
D_1	12	0-40	14.90	21.80	2.70	8.30	0.30	0.80	0.60	0.07	0.08
		40-100	9.20	12.60	1.30	3.10	0.10	0.30	0.20	0.03	0.02
D_2	20	0-30	14.80	20.60	2.90	8.20	0.40	0.70	0.70	0.08	0.09
		30-75	10.00	12.30	1.20	2.90	0.10	0.30	0.20	0.03	0.03
Bahr El-Bakar irrigation water			0.40	0.31	0.09	0.10	0.05	0.05	0.06	0.02	0.08

TABLE 6. Heavy metals content (ppm) of the surface, subsurface soils as determined by the use of aqua regia .

Mapping unit	Rep: profile No.	Depth in cm	Fe	Mn	Zn	Cu	Co	Pb	Ni	Cd	Cr
C_1	1	0-35	949.8	57.96	18.92	28.86	1.32	7.68	3.93	0.42	0.29
		35-110	691.5	20.11	8.31	11.82	0.21	1.10	0.64	0.10	0.08
C_2	5	0-20	1102.3	62.11	19.13	30.41	1.05	7.00	4.11	0.40	0.32
		20-45	679.4	19.08	6.21	10.36	0.20	1.00	0.60	0.08	0.06
C_3	9	0-45	665.6	31.14	16.6	19.31	0.80	3.41	2.24	0.20	0.16
		45.80	303.2	11.29	9.14	9.68	0.11	0.92	0.33	0.03	0.03
D_1	12	0-40	715.2	41.18	24.13	26.60	1.16	6.82	4.68	0.46	0.33
		40-100	450.8	16.22	12.14	8.82	0.21	0.71	0.61	0.10	0.10
D_2	20	0-30	1043.6	51.33	21.66	30.63	1.10	8.93	3.00	0.42	0.36
		30-75	620.0	12.13	6.65	9.00	0.18	0.46	0.30	0.11	0.08

The problem comes from comparing the dissolved heavy metal content of the Bahr El-Bakar drain water, which form the sole source of irrigation water for most of the soils in this region, to the total cadmium content per acre as determined in column B in Table 1. The dissolved Cadmium content is 0.02 ppm, which represents a 0.02 gram per cubic meter of the water used for irrigation. Depending on the fractional use of drain water in the irrigation which is one for most of the studied area, the use of 4000 m^3 per acre per year for irrigation, will increment the cadmium content of the surface layer by 80 grams per year per acre. The critical ceiling, according to the test value as given in column B in Table 1, of 5 µg/kg dry soil, *i.e.*, 5 kg/acre for the upper layer of soil, assuming an initial content of 0.0 ppm, will be reached in 63 years. Four surface soil layers, out of five have already exceeded the 0.4 ppm value. The current contribution of pollution to incrementing the Cadmium level can be shown from comparing the values of Cadmium content in the surface layers of the profiles to those of the lower layers. This enrichment ratio ranges from 4 to 6 for the different profiles. Cadmium will probably precipitate as carbonates due to the high pH of the soil. Dissolved Cadmium is not as immobile as lead which is very immobile (El-Kilani & Belal, 2005). This could be a factor in decreasing the ratio of enrichment for cadmium with respect to that of lead. The lead enrichment ratio ranges from to 3 to 16. The difference in the enrichment ratio could also be due to the ratio of the pollutants in incoming air deposition or irrigation water with respect to the initial cadmium content of the soil. Very little of the cadmium could move through the soil to the lower layers of the soil and this may lengthen the time span required to reach the warning value. Another point which is worth mentioning, is that the determined value of cadmium concentration in drain water was that of the dissolved and not the total, which is higher due to the cadmium adsorbed to the suspended particles and which will shorten the time span even further.

From the above discussion, a study on the dynamics of Cadmium movement in this soil and Cadmium fluxes to this ecosystem is urgently required.

Conclusion

On comparing the measured heavy metals concentrations, with the Guide values and quality standards for assessing soil and water contamination by heavy metals after Moen *et al.* (1986), it is shown that all obtained values are below the reference value (column A in Table 1). But comparing the values of the dissolved Cadmium for the Bahr EL-Bakar drain water, which is used as the main source of irrigation for the studied area, show that there will be a problem of exceeding the warning value (column B) for Cadmium in less than 60 years. This sheds strong doubts on the sustainability of these ecosystems. An evaluation of the Cadmium dynamics *i.e.* its flux and transport through the soil should be undertaken.

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عمل خــرائط التربة كأساس لحصر المحتوى من المعادن الثقيلة بمنطقة بحر البقر – شرق الدلتا – مصر

وائل أحمد محمد عبد القوي و رشدي الكيلاني
قسم الأراضي – كلية الزراعة – جامعة القاهرة – القاهرة – مصر.

إن الأهداف الرئيسية لتلك الدراسة هي:-

١.إنتاج خريطة فيزوجرافية أرضية مصححة مقياس ١: ٥٠,٠٠٠ تصغر إلى الخريطة الملحقة بمقياس ١: ٢٥٠,٠٠٠ لمنطقة الدراسة كأساس للتعرف على محتوى التربة من المعادن الثقيلة.

٢. التحقق من إستدامة النظام البيئي الزراعي من خلال فحص النتائج الممكنة لإستخدام مياه صرف ذات محتوى عالي من المعادن الثقيلة نتيجة تأثير التلــــوث.

وللوصول للهدف الأول تم اختيار ٨ قطاعات من إجمالي ٢٢قطاع لتمثل مختلف الوحدات الأرضية وتم وصفها مورفولوجيا. كما تم جمع عينات التربة للتحليل الطبيعي والكيماوي وبالاعتماد على تفسير الصور الجوية ونظم المعلومات الجغرافية بجانب النتائج الحقلية والمعملية تم إنتاج الخريطة الفيزوجرافية الأرضية. وأمكن تحديد وحدتان رئيسيتان:

١.السهل الساحلي (ترسيبات بحرية فيضية) والتي تشمل على السهول الطينية والمستنقعات الطينية والتلال والترسيبات الرملية القديمة المتبقية.

٢.الترسيبات تحت الدلتاوية الحديثة.

وفيما يختص بالهدف الثاني فلقد تم تقدير محتوى ماء الصرف من المعادن الثقيلة وأظهرت التحاليل أنه بإستخدام ذلك الماء (ماء مصرف بحر البقر) كمصدر وحيد للري وهو ما يمثل الواقع بمنطقة الدراسة ، بمحتوى كادميوم ذائب قدره ٠,٠٢ جزء في المليون سوف يؤدي إلى زيادة تدريجية قدرها ٨٠ جرام كادميوم لكل فدان سنوياً ونظراً لأن القيمة التحذيرية لتركيز الكادميوم في الطبقة السطحية للتربة يصل إلى ٥ ميكرو جرام / لكل كجم تربة أي ٥ كجم / فدان فإن تلك القيمة سوف تتراكم في التربة خلال فترة قدرها ٦٢ سنة ولذلك فإن هناك شكوك قوية حول إستدامة ذلك النظام وهناك بالفعل مؤشرات على تراكم المعادن الثقيلة في الطبقة السطحية نتيجة لإستخدام ماء الصرف (مصرف بحر البقر) في ري منطقة الدراسة.