Chapter 3
Sediment Properties

3.1. NATURE OF BOTTOM SEDIMENTS

The bottom sediments of Lake Burullus are mainly derived from the suspended load of seston (i.e. the total particulate matter suspended in water), clay and silt. These are carried annually into the lake through the drain water, sea water and wind. Farther away from the effect of the drains, broken calcareous shells and sand are mixed with silt and clay constituting the calcareous sand, silt and clay mixture. The bottom along the northern shores, extending from the lake-sea connection westwards, is mainly clayey-sand, silty sand with some patches formed of molluscan shells. The eastern and western regions of the lake are silty clay (Fig. 3.1: after Zazou as quoted by Darrag 1983). The southern shore sediments, which receive directly the drain discharge, is mainly formed of clay and silt with small areas covered with molluscan shells. The bottom sediments of most southern drains is of the same nature as that of the neighbouring agricultural lands and less mixed with broken shells than the lake bottom sediments.

3.2. SEDIMENTATION RATES

Birks *et al.* (2001) reported that, although Lake Burullus is more saline than Manzala and Edku lakes, there have nonetheless been significant reductions in salinity during the 20th century. The macrofossil record indicates an initial shift towards a freshwater environment at about 24 cm, with further significant changes at 16 cm, and 7 cm. The earliest of these features was probably caused by the initial impact of the first effective Nile barrages, and can be dated to the early 20th century. The later change at 16 cm is a little below the onset of the ^{137}Cs record (dated 1954) and is most likely associated with the impact of later barrages constructed during 1933 – 1951. The most recent change is close to the 1963 depth determined from the ^{137}Cs record, and is probably a response to the essential completion of the Aswan High Dam in 1964 (Appleby *et al.* 2001).

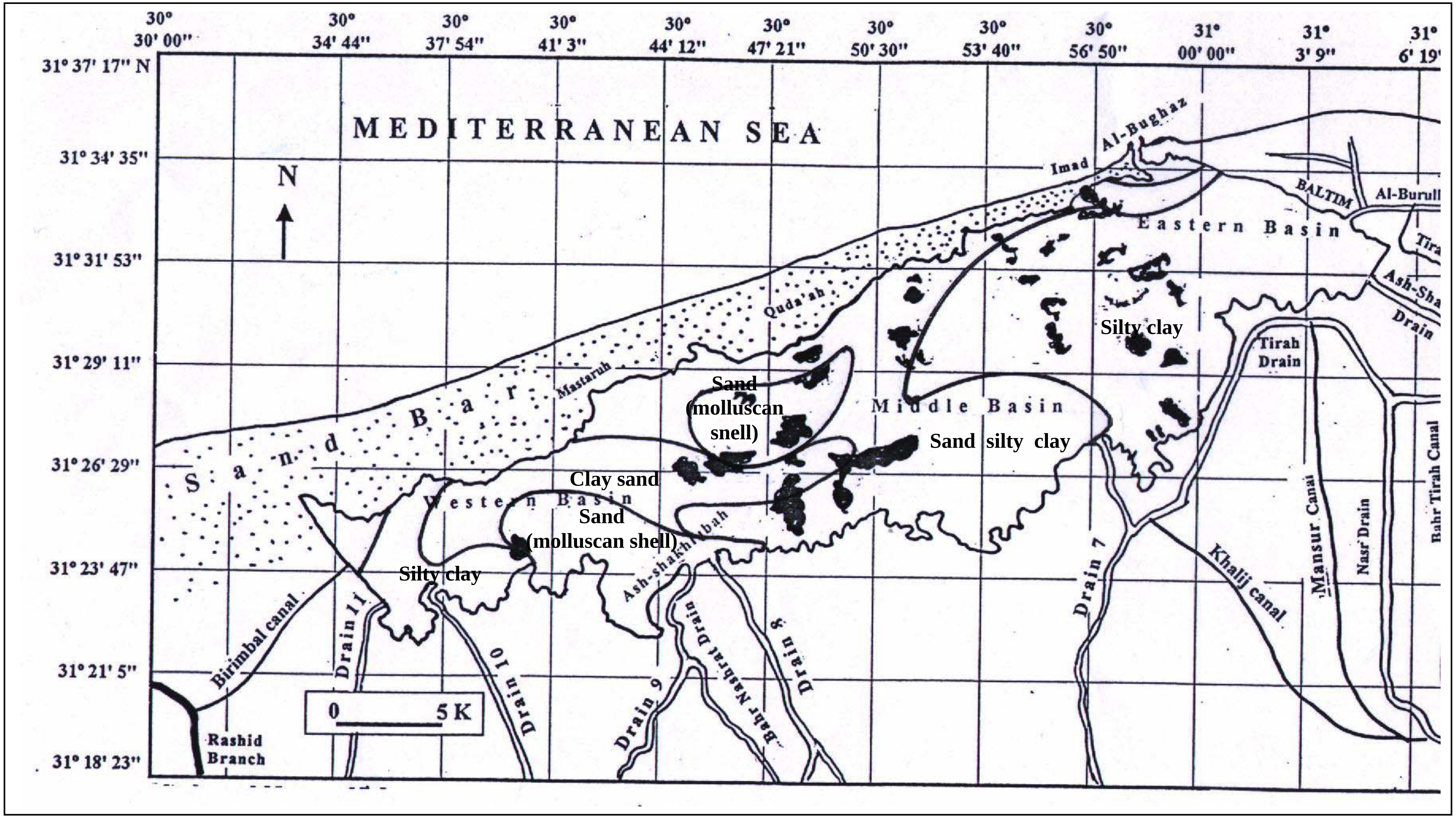

Fig. 3.1. **Bottom nature of Lake Burullus (after Zazou as quoted by Darrag 1983).**

The results of the study of Appleby *et al.* (2001) suggest a significant reduction in sedimentation rates in Lake Burullus after approximately 1960 (Table 3.1). The trend of the pre-1960 biostratigraphic dates suggests that the first significant freshwater changes (ca. 24 cm) can again be dated ca. 1920. The pre-1960 sedimentation rate is calculated to be 0.32 g cm^{-2} yr^{-1} (3.9 mm yr^{-1}), significantly higher than the post-1960 value of 0.075 g cm^{-2} yr^{-1} (2.1 mm yr^{-1}). Sediments in the top 7 cm have a very much lower dry bulk density than those beneath this depth. These results may further indicate reduced minerogenic sediment inputs as a consequence of irrigation - drainage changes, and the end of Nile floods and input of silt following the construction of Aswan High Dam.

Table 3.1. **Chronology and sedimentation rate in Lake Burullus (after Appleby *et al*. 2001).**

Depth	**Chronology**				**Sedimentation rate**		
cm	**g cm^{-2}**	**Date**	**Age (yr)**	**±**	**g cm^{-2} yr^{-1}**	**mm yr^{-1}**	**± (%)**
0	0.00	1998	0	0	-	-	-
1	0.06	1997	1	1	0.077	4.7	20
3	0.49	1992	6	2	0.077	3.2	20
5	1.42	1980	18	5	0.077	3.2	20
7	2.61	1964	34	7	0.077	2.4	20
9	3.80	1958	40	8	0.320	2.4	20
11	5.12	1954	44	9	0.320	2.6	20
13	6.51	1950	48	10	0.320	3.0	20
15	8.11	1945	53	11	0.320	4.2	20
17	9.80	1939	59	12	0.320	3.9	20
19	11.43	1934	64	13	0.320	3.7	20
21	13.25	1929	69	14	0.320	3.6	20
23	15.11	1923	75	15	0.320	3.6	20
25	16.92	1917	81	16	0.320	3.7	20
27	18.63	1912	86	17	0.320	3.8	20
29	20.12	1907	91	18	0.320	3.9	20
31	21.65	1902	96	19	0.320	4.1	20

3.3. SEDIMENT PROPERTIES

The bottom sediments of Lake Burullus were collected from fifteen stations during winter (January) and summer (June) of 2000 and 2001 (Fig. 2.1). The samples were prepared to carry out the following analysis: EC, Cl, pH and the percentage of organic matter, in addition to the heavy metals: Fe, Cu, Zn, Pb, Cd and Ni (Tables 3.2, 3.3). Comparable to the PCA correlation of the 15 stations, based on the water properties, the PCA ordination of the same stations, based on the sediment properties indicates a clear separation between the stations of the eastern, middle and western sectors of the lake (Fig. 3.2). Although there is a heterogeneity between the stations of each sector, some

Table 3.2. **Annual mean of sediment properties in the 15 stations in Lake Burullus. The maximum and minimum values are underlined.**

Variable	Eastern sector							Middle sector					Western sector			Mean±SD
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
EC (mS cm^{-1})	<u>6.4</u>	4.0	2.6	1.7	1.6	1.5	4.2	2.0	1.1	1.0	1.0	1.0	1.1	0.8	<u>0.6</u>	2.0±1.8
Cl (g l^{-1})	<u>2.1</u>	1.1	0.9	0.8	0.8	0.8	1.4	0.6	0.4	0.3	0.4	0.4	0.5	0.3	<u>0.2</u>	0.7±0.6
pH	7.9	<u>7.5</u>	7.6	8.0	8.0	7.9	7.8	8.0	7.7	7.6	8.0	7.8	<u>8.1</u>	7.6	8.0	7.8±0.4
OM (%)	<u>0.8</u>	2.3	2.1	1.9	2.3	3.7	0.9	2.5	3.1	2.7	4.2	2.6	3.2	<u>5.6</u>	3.5	2.8±1.4
Heavy metals (ppm)																
Fe (x 10^{3})	<u>35.1</u>	10.5	15.3	13.1	6.5	17.6	8.4	<u>2.7</u>	22.6	12.0	8.6	4.2	27.3	34.9	23.8	16.2±16.6
Cu	12.3	<u>8.9</u>	16.6	<u>47.3</u>	18.6	32.0	19.2	12.5	37.2	16.8	19.4	12.4	26.9	30.1	34.1	22.9±11.3
Zn	23.7	38.3	49.7	<u>119.7</u>	26.1	66.7	38.1	<u>22.2</u>	86.1	69.3	45.0	31.5	86.2	96.7	84.8	58.9±30.2
Pb	9.9	12.0	16.0	<u>54.8</u>	17.3	31.5	15.7	10.8	13.6	<u>8.7</u>	14.4	16.5	16.7	30.1	11.3	18.6±12.0
Cd	1.1	1.3	6.2	1.6	<u>45.9</u>	2.8	1.0	1.2	4.9	2.2	1.2	<u>0.8</u>	4.2	2.2	2.5	5.3±22.7
Ni	<u>3.3</u>	5.9	9.5	30.0	25.3	32.5	7.8	13.9	45.4	63.6	53.8	40.1	<u>72.5</u>	64.7	42.4	34.0±23.1

Table 3.3. **Annual range, mean and standard deviation (SD) of sediment properties along east-west and north-south axes in Lake Burullus. OM: organic matter.**

a- East-west axis	**East**			**Middle**			**West**		
Character	**Range**	**Mean**	**SD**	**Range**	**Mean**	**SD**	**Range**	**Mean**	**SD**
EC (mS cm^{-1})	0.8 – 9.1	3.1	2.2	0.6 – 3.6	1.2	0.6	0.5 – 1.6	0.8	0.3
Cl (gm l^{-1})	0.5 – 3.0	1.1	0.6	0.0 – 1.2	0.4	0.3	0.0 – 0.8	0.3	0.2
pH	7.0 – 8.0	7.8	0.3	7.0 – 9.0	7.8	0.4	7.0 – 9.0	7.9	0.4
OM (%)	0.6 – 4.1	2.0	1.1	1.0 – 5.3	3.0	1.2	2.7 – 6.1	4.1	1.2
Heavy metals (ppm)									
Fe (x 10^3)	0.0 – 73.5	15.2	17.0	0.0 – 32.5	10.0	10.0	0.0 – 51.2	28.7	18.5
Cu	7.3 – 52.7	22.1	12.8	7.9 – 41.9	19.7	9.9	18.3 – 39.8	30.4	5.9
Zn	18.6 – 126.9	51.7	31.8	18.5 – 91.4	50.8	25.0	71.2 – 105.3	89.2	9.7
Pb	7.9 – 63.5	22.4	15.2	5.1 – 19.7	12.8	3.8	7.8 – 32.8	19.4	8.8
Cd	0.6 – 8.3	2.3	1.9	0.4 – 7.3	2.1	1.8	1.9 – 6.2	3.0	1.2
Ni	1.9 – 37.4	16.3	12.1	11.1 – 67.9	43.4	17.9	30.6 – 88.9	59.8	16.4
b- North-south axis	**North**			**Middle**			**South**		
EC (mS)	0.5 – 9.1	2.0	2.5	0.6 – 6.2	2.8	1.9	0.7 – 3.3	1.5	0.7
Cl (gm l^{-1})	0.1 – 3.0	0.7	0.8	0.0 – 2.1	0.8	0.6	0.0 – 1.3	0.7	0.3
pH	7.0 – 9.0	7.9	0.3	7.0 – 8.0	7.7	0.3	7.0 – 9.0	7.8	0.4
OM (%)	0.6 – 5.3	2.9	1.5	0.7 – 3.8	2.1	1.0	0.9 – 6.1	3.1	1.5
Heavy metals (ppm)									
Fe (x 10^3)	0.0 – 73.5	19.8	21.7	0.0 – 18.3	8.3	6.8	0.0 – 51.2	18.3	15.2
Cu	7.9 – 39.8	21.0	9.4	7.3 – 22.4	14.3	4.5	13.2 – 52.7	30.3	11.4
Zn	18.6 – 92.6	54.2	27.8	18.5 – 77.4	42.0	18.4	21.3 – 126.9	74.2	32.0
Pb	7.8 – 22.5	13.8	3.9	5.1 – 19.2	11.8	3.3	11.3 – 63.5	27.2	14.8
Cd	0.4 – 6.2	2.0	1.5	0.6 – 3.5	1.4	0.7	0.9 – 8.3	3.2	2.0
Ni	1.9 – 88.9	42.4	24.3	3.5 – 67.9	22.8	24.7	6.9 – 73.6	34.6	18.3

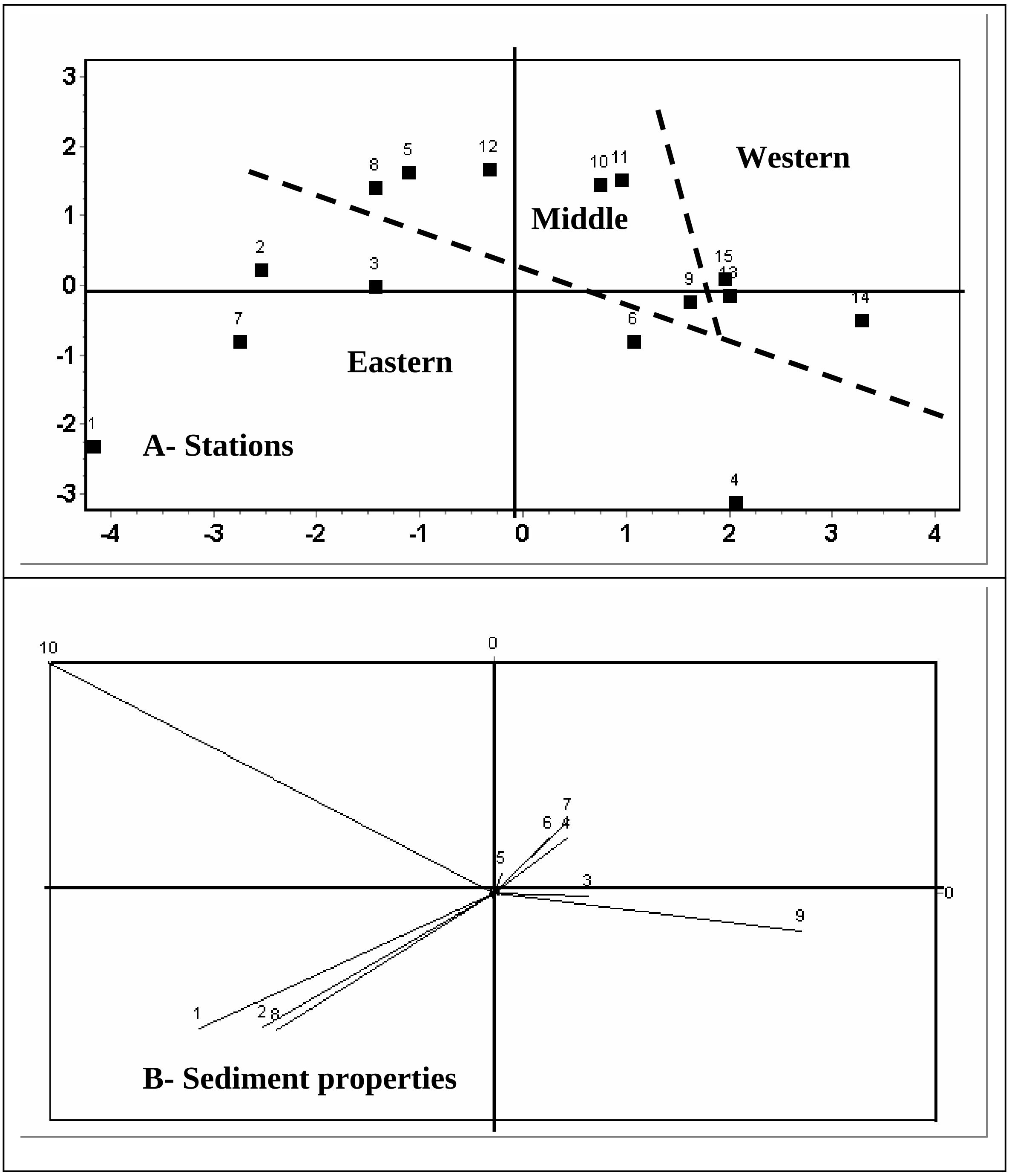

Fig. 3.2. **Principal component analysis (PCA) based on the results of the sediment properties of the 15 sampled stations in Lake Burullus. The sediment properties are: 1: EC, 2: chlorosity, 3: pH, 4: organic matter, 5: Iron, 6: Copper, 7: Zinc, 8: Lead, 9: Cadmium and 10: Nickel.**

stations are very similar to each other (e.g. stations 10 and 11 in the eastern sector, and stations 13 and 15 in the western sector).

3.3.1. Salinity

The sediment salinity of Lake Burullus, as shown by electrical conductivity measurements, depends on the water salinity. The annual mean of water salinity was 2.0 ± 1.8 mS cm^{-1} (Table 3.1), with a minimum of 0.6 mS cm^{-1} at station 15 in the western sector and a maximum of 6.4 mS cm^{-1} at station 1 in the eastern sector (the nearest to the sea outlet). Regarding the spatial variation, the annual mean decreased from east to west (3.1 mS cm^{-1} at east, 1.2 mS cm^{-1} at middle and 0.8 mS cm^{-1} at west). On the other hand, the salinity at the north (2.0 mS cm^{-1}) was higher than the south (1.5 mS cm^{-1}). For both years of sampling (2000 and 2001: Fig. 3.3), the salinity was higher in January (2.5 mS cm^{-1}) than June (1.6 mS cm^{-1}), where the sea water inflows to the lake during this time of the year (El-Shinnawy 2002).

3.3.2. Chlorosity

The chlorosity increases with the increase of salinity. The annual mean was 0.7 ± 0.6 g l^{-1}, with a minimum of 0.2 g l^{-1} at stations 15 (western sector) and a maximum of 2.1 g l^{-1} at station 1 (eastern sector). Regarding the spatial variation, the annual mean was the highest in the eastern sector (1.1 g l^{-1}), and the lowest in the western sector (0.3 g l^{-1}). On the other hand, chlorosity was the same in the north and south (0.7 g l^{-1}). Temporally, chlorosity has the same trend of salinity where it was higher in January (0.8 g l^{-1}) than in June (0.7 g l^{-1}) due to the inflow of sea water during that time of the year (Radwan 1997, El-Shinnawy 2002).

3.3.3. pH

The annual mean of pH was 7.8 ± 0.4, with a minimum of 7.5 at station 2 (eastern sector) and a maximum of 8.1 at station 13 (western sector). The spatial variation indicates that, the annual mean was 7.8 in the eastern and middle sectors and 7.9 in the western sector. On the other hand, pH was 7.9 at the north and 7.8 at the south. For both years of sampling, the mean of pH was higher in January (7.9) than June (7.7).

3.3.4. Organic Matter

The annual mean of organic matter was 2.8 ± 1.4 %, with a minimum of 0.8 % at station 1 (eastern sector) and a maximum of 5.6 % at station 14 (western sector). Regarding the spatial variation, the annual mean of organic matter was 2.0 % in the east, 3.0 % in the middle and 4.1 % in the west. On the other hand, the organic matter was lower in the north (2.9 %) than in the south (3.1 %). This may be due to the accumulation of dead submerged and floating hydrophytes abundant in the west and south of the lake. Generally, the organic matter content in the sediment of Lake Burullus was high near the mouths of the drains. The mean of organic matter is slightly increased during June (2.9 %) than during January (2.6 %), where the submerged and floating hydrophytes grow at that time of the year.

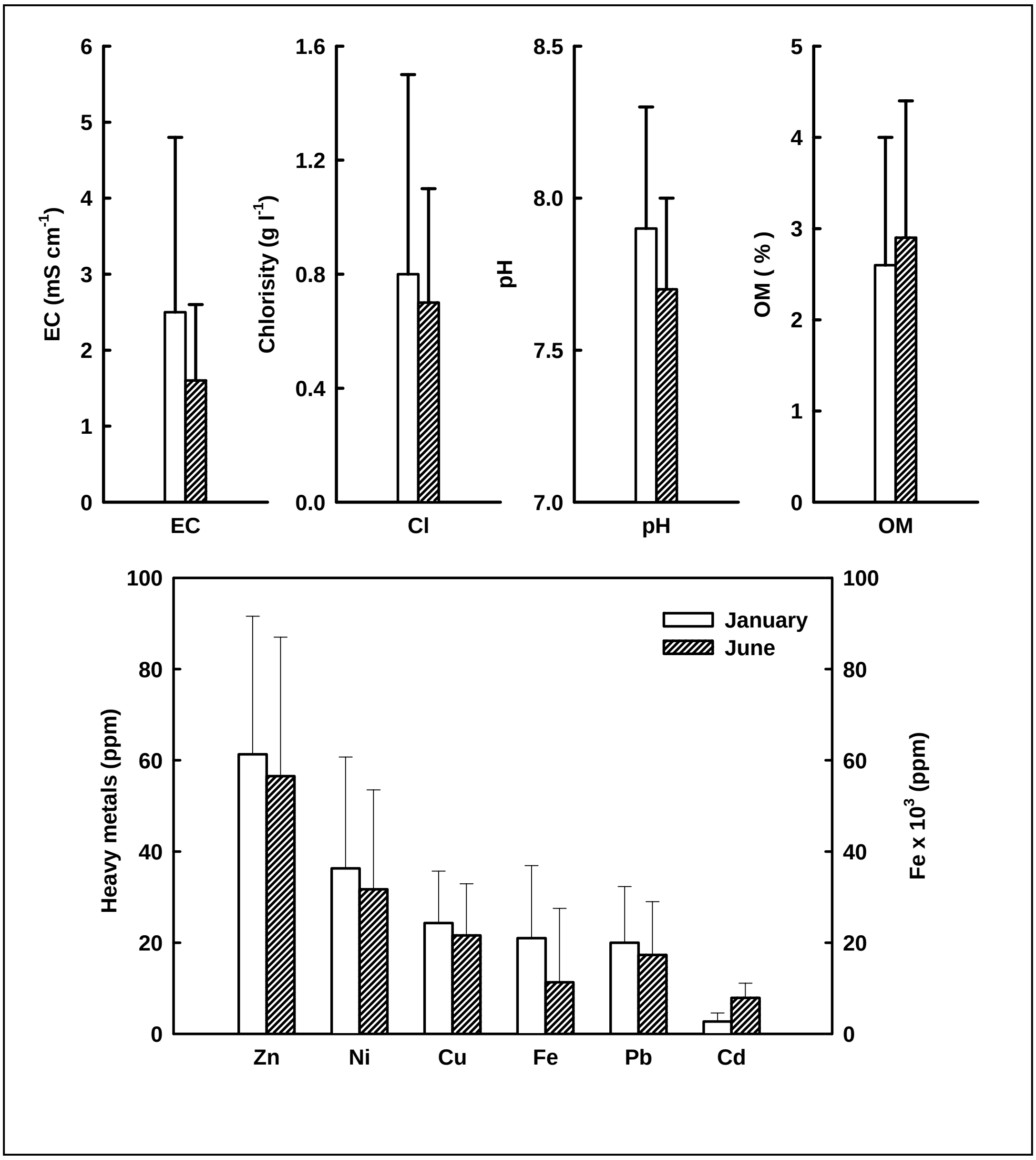

Fig. 3.3. **Temporal variation in the sediment properties in Lake Burullus. The bars at the top of histograms are the standard deviations of the means.**

3.3.5. Heavy Metals

Heavy metals are serious pollutants in natural environment due to their toxicity, persistence and bioaccumulation problems. The impact of anthropogenic perturbation is most strongly felt by estuarine and coastal environments adjacent to urban areas. Heavy metals from incoming drains, tidal and fresh water sources are rapidly removed from water body and deposited onto the sediments (El-Nemr 2003). The concentration of heavy metals in the sediments of Lake Burullus had the following sequence: Fe > Zn > Ni > Cu > Pb > Cd. This trend is dissimilar to that of the lake water (Zn > Fe > Cu > Cd > Pb). Similar to the trend of heavy metals in the water, most of the estimated heavy metals in the sediments were higher in the south than in the north. This trend could be attributed to the effect of sewage effluents from the drains at the south particularly at the stations near to the mouths of drains with increasing levels of organic matter and the clay nature of the sediments. The nature of bottom sediments reflects to a great extent several conditions resulting from water inputs and the kind of pollutants (Radwan 2001). In addition, the trend of variation along east-west axis was: western sector > eastern sector > middle sector for all the estimated heavy metals except Pb (east > west > middle) and Ni (west > middle > east). On the other hand, January was characterized by higher contents of the sediments than June except cadmium.

3.3.5.1. Iron (Fe)

The annual mean of iron was 16.2 x 10^3 ± 16.6 x 10^3 ppm, with a minimum of 2.7 x 10^3 ppm at station 8 (middle sector) and a maximum of 35.1 x 10^3 ppm at station 1 in the eastern sector. Regarding the spatial variation, the mean values were 15.2 x 10^3 ppm in the east, 10.0 x 10^3 ppm in the middle and 28.7 x 10^3 ppm in the west. On the other hand, the iron was higher at the north (19.8 x 10^3 ppm) than at the south (18.3 x 10^3 ppm). In addition, the mean was higher in January (21.0 x 10^3 ppm) than in June (11.3 x 10^3 ppm).

3.3.5.2. Copper (Cu)

The annual mean of copper was 22.9 ± 11.3 ppm, with a minimum of 8.9 ppm at stations 2 (eastern sector) and a maximum of 47.3 ppm at station 4 in the same sector. The spatial variation indicates that the mean values were 22.1 ppm in the east, 19.7 ppm in the middle and 30.4 ppm in the west. On the other hand, the mean was lower in the north (21.0 ppm) than in the south (30.3 ppm). The temporal variation indicated that the mean of copper was higher in January (24.3 ppm) than in June (21.6 ppm).

3.3.5.3. Zinc (Zn)

Zinc has the highest values of heavy metals in the sediments of Lake Burullus, with an annual mean of 58.9 ± 30.2 ppm. It had a minimum of 22.2 ppm at station 8 (middle sector) and a maximum of 119.7 ppm at station 4 (eastern sector). Regarding the variation along east-west axis, the mean value was lower in the east (51.7 ppm) than the west (89.2 ppm). On the other hand, it was lower in the north (54.2 ppm) than the south (74.2 ppm). The content of zinc was higher during January (61.3 ppm) than June (56.5 ppm).

3.3.5.4. Lead (Pb)

The lead had the annual mean of 18.6 ± 12.0 ppm, with a minimum value of 8.7 ppm at station 10 (middle sector) and a maximum of 54.8 ppm at station 4 in the eastern sector. Regarding the spatial variation, the mean value in the east was 22.4 ppm, that of the middle was 12.8 ppm and that of the west was 19.4 ppm. On the other hand, the lead was lower at the north (13.8 ppm) than the south (27.2 ppm). Temporally, the mean was higher in January (20.0 ppm) than June (17.3 ppm).

3.3.5.5. Cadmium (Cd)

The cadmium had the lowest value of all the estimated heavy metals in the sediments of Lake Burullus, with an annual mean of 5.3 ± 22.7 ppm, a minimum of 0.8 ppm at station 12 (middle sector), and a maximum of 45.9 ppm at station 4 (eastern sector). Regarding the variation along east-west axis, the mean value in the east (2.3 ppm) was higher than the middle (2.1 ppm) and west (3.0 ppm). On the other hand, cadmium and similar to the other heavy metals, was lower at the north (2.0 ppm) than the south (3.2 ppm). Temporally, the mean of Cd was lower in January (2.7 ppm) than June (7.9 ppm).

3.3.5.6. Nickel (Ni)

The annual mean of nickel in the sediment was 34.0 ± 23.1 ppm, with a minimum of 3.3 ppm at station 1 (eastern sector) and a maximum of 72.5 ppm at station 13 (western sector). The spatial variation indicated that the mean value was lower at the east (16.3 ppm) than the west (34.0 ppm). On the other hand, the mean value of nickel was 42.4 ppm at the north and 34.6 ppm at the south. In addition, the mean was higher in January (36.3 ppm) than June (31.7 ppm).

3.3.6. Correlation Between the Sediment Properties

Similar to that of water properties, the simple linear correlation coefficient between the salinity and chlorosity of the sediments in Lake Burullus is significant positive ($r = 0.97$, $P < 0.001$). On the other hand, and unlike to the water properties, the correlations between both variables and Zn were negative, although it did not reach the significant level in case of chlorosity with Zn (Table 3.4). In addition to the previous correlations, organic matter had significant negative correlation with salinity ($r = 0.74$, $P < 0.01$) and chlorosity ($r = 0.77$, $P < 0.001$), while the heavy metals Cu, Zn and Pb had significant positive correlation with each other.

***Table 3.4*. Matrix of Pearson simple linear correlation coefficients (r) between sediment properties in Lake Burullus. *: P < 0.05, **: P < 0.01, ***: P < 0.001.**

Variable	EC	Cl	pH	OM	Heavy metal		
					Cu	Zn	Pb
EC	---	0.97***	-0.14	0.74**	-0.47	-0.52*	-0.22
Cl		---	-0.01	-0.77***	-0.34	-0.47	-0.06
pH			---	-0.06	0.29	0.06	0.18
OM				---	0.33	0.45	0.16
Cu					---	0.89***	0.71**
Zn						---	0.63*
Pb							---

3.3.7. Correlation Between Water and Sediment Properties.

As indicated in Fig. 3.5., the similar variables that have significant positive correlations in the water and sediment are EC (r = 0.92, P < 0.001), Cl (r = 0.96, P < 0.001) and Pb (0.59, P < 0.05). Some other variables had positive insignificant correlations (P > 0.05) such as pH (r = 0.21), Cu (r = 0.39), and Fe (r = 0.36); or insignificant negative correlations such as Zn (r = -0.27) and Cd (r = -0.06).

3.3.8. Comparison with the Other Water Bodies

The heavy metals concentrations in the sediments of Lake Burullus, as indicated in the present work, are much lower than those of Danube River (Woitke *et al*. 2003) and Rias Baixas in NW Spain. The exaggerated figures in the study of El-Nemr (2003) on the sediments of Lake Burullus is due to the instantaneous sampling of his study (January 2003) comparing with the all-year average of the present work (monthly samples from January to December 2001). On the other hand, the annual average is less than the effect-range law for all elements except the cadmium (Table 3.5). In case of exceeding the effect – range law, the incidence of biological effects increased to 20 – 30 % for most trace elements. When the values exceed effect-range-median the incidence increased to 60 – 90 % (El-Nemr 2003).

Analysis of the labile (leachable) metal fraction of the sediment may be more useful in terms of discovering its biological significance and the new inputs, than the analysis of the total metal fraction (Lacerda *et al* 1992, Paente *et al*. 1996). Based on the analyses of labile and total fractions in the sediments, the study of El-Nemr (2003) indicated new inputs of the estimated heavy metals (Fe, Ni, Zn, Pb, Cd and Zn) in the sediments of Lake Burullus.

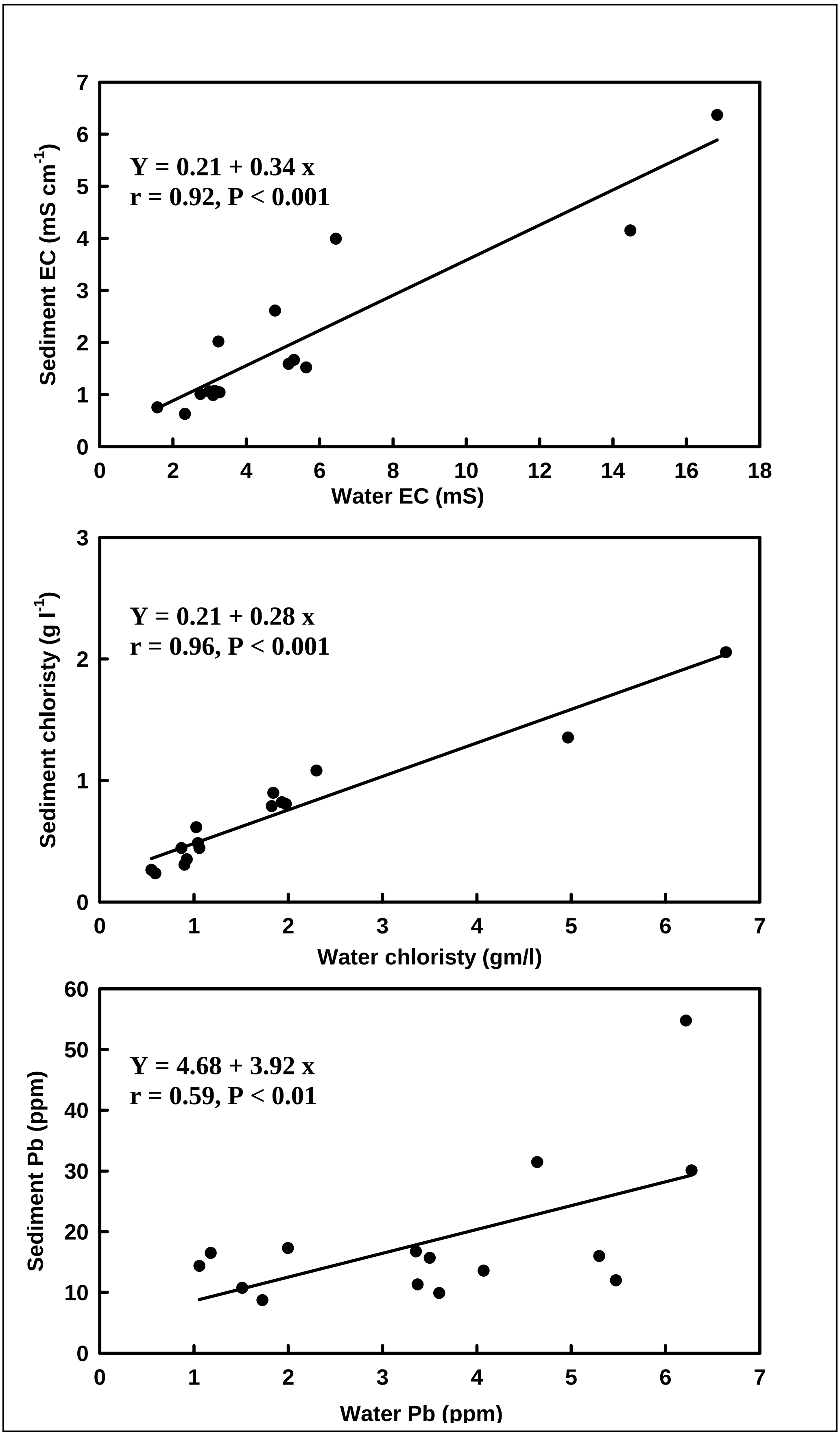

Fig. 3.5. **Simple linear regression between the similar variables in the water and properties of Lake Burullus.**

Table 3.5. **Comparison between the heavy metals in the sediments of Lake Burullus and the sediments of some European water bodies. ERL: effect-range-law, ERM: effect range-medean, NA: not available.**

Heavy metal	Lake Burullus		Danube River	Rias Baixas	ERL	ERM
	The present study	El-Nemr 2003	Woitke *et al.* 2003	Villares *et al*. 2003		
Fe x 10^3	21.6 ± 15.9	25.2 ± 10.4	29.7	23.0	NA	NA
Cu	24.3 ± 11.3	113.1 ± 43.7	65.7 ± 12.3	10.9 ± 15.8	34.0	270
Zn	61.4 ± 30.5	78.4 ± 27.5	187.0± 5.0	41.0 ± 27.1	150	410
Pb	19.7 ± 12.1	60.2 ± 12.5	46.3 ± 6.8	43.3 ± 27.1	46.7	218
Cd	2.9 ± 2.9	9.6 ± 1.5	1.2 ± 0.4	---	1.2	9.6
Ni	35.5 ± 23.8	78.5 ± 13.6	49.6 ± 6.1	---	20.9	51.6

3.4. SUMMARY

The bottom sediments along the northern shores extending from the lake-sea connection westwards, are mainly clayey- and silty-sand with some patches of molluscan shells. The eastern and western sites of the lake are silty-clay. The southern shore sediments, which receive directly the drain discharge, are mainly formed of clay and silt with small areas covered with molluscan shells. A significant reduction in sedimentation rates in Lake Burullus happened after approximately 1960. The trend of the pre-1960 biostratigraphic dates suggests that the first significant freshwater changes can be approximately dated to 1920. The pre-1960 sedimentation rate was calculated to be 0.32 g cm^{-2} yr^{-1} (3.9 mm yr^{-1}), which was significantly higher than the post-1960 value of 0.075 g cm^{-2} yr^{-1} (2.1 mm yr^{-1}).

The bottom sediments of Lake Burullus were collected from fifteen stations during winter (January) and summer (June) of 2000 and 2001. The samples were prepared to estimate the following properties: salinity, chlorisity, acidity, organic matter and heavy metals (Fe, Cu, Zn, Pb, Cd and Ni). Comparable to the PCA ordination of the same 15 stations based on the water properties, the PCA ordination based on sediment properties indicates a clear separation between the stations of the eastern, middle and western sectors of the lake.

The annual mean of sediment salinity was 2.0 mS cm^{-1} with a spatial annual range of 0.6 - 6.4 mS cm^{-1}. For both years of sampling (2000 and 2001), the salinity was higher in January (2.5 mS cm^{-1}) than June (1.6 mS cm^{-1}). The annual mean of chlorosity was 0.7 g l^{-1}, with a spatial range of 0.2 g l^{-1} - 2.1 g l^{-1}. Temporally, chlorosity had the same trend of salinity where it was higher in January (0.8 g l^{-1}) than June (0.7 g l^{-1}) due to the inflow of sea water to the lake winter months. The annual mean of pH was 7.8, with a range of 7.5 - 8.1. For

both years of sampling, the mean of pH was higher in January (7.9) than in June (7.7). Regarding the organic matter, the annual mean was 2.8 %, with a spatial range of 0.8 - 5.6 %. In contrast with the properties, the mean of organic matter was lower in January (2.6 %) than in June (2.9 %).

The concentration of heavy metals in the lake sediments had the following sequence: Fe > Zn > Ni > Cu > Pb > Cd, with annual means of $16.2x10^3$, 58.9, 34.0, 22.9, 18.6 and 5.3 ppm, respectively. This trend is dissimilar to that of lake water (Zn > Fe > Cu > Cd > Pb). In addition, the trend of variation along east-west axis was: western sector > eastern sector > middle sector for all metals except Pb (east > west > middle) and Ni (west > middle > east). The spatial ranges in ppm were 2.7×10^3-35.1×10^3 (Fe), 22.2-119.7 (Zn), 3.3-72.5 (Ni), 8.9- 47.3 (Cu), 8.7- 54.8 (Pb) and 0.8- 45.9 (Cd). On the other hand, the sediments were characterized by higher contents of heavy metals in January than in June except Cd. The January-June ranges in ppm were 11.3×10^3-21.0×10^3 (Fe), 56.5-61.3 (Zn), 31.7-36.3 (Ni), 21.6-24.3 (Cu), 17.3-20.0 (Pb) and 2.7-7.9(Cd).

Similar to the water properties, the simple linear correlation coefficient between the sediment salinity and chlorosity was significant positive. On the other hand, and unlike to the water properties, the correlations between both variables and Zn are negative, although it does not reach the significant level in case of chlorosity with Zn. In addition to the previous correlations, organic matter had significant negative correlation with salinity and chlorosity, while the heavy metals Cu, Zn and Pb have significant positive correlations with each other. The smae water and sediment variables that had significant positive correlations were EC, Cl and Pb.

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