Determination of Some Heavy Metals in Water and Fish Flesh of Common Species in Bardawil Lagoon, Egypt

M.H. Abdo[1] and A.M. Yacoub[2]

National Institute of Oceanography and Fisheries.

101 Kasr Al Eini St., Cairo, Egypt

Summary The aim of this study is to gather detailed information on the distribution of some heavy metals (Fe, Mn, Zn, Cu, Pb and Cd) in the water ecosystem of the Bardawil lagoon, as well as, accumulation of these metals in fish flesh of common species in the lake (*Solea vulgaris, Mugil cephalus and Liza ramada*). The results revealed that, the levels of studied heavy metals were in the permissible limits in the aquatic ecosystem except for iron, cadmium and lead. The arrangement of these metals from the high to low concentrations were in the following order: Fe > Zn > Mn > Pb > Cu > Cd in water. The concentrations of heavy metals in the fish flesh (muscles and skin) were in the permissible limits except for iron, zinc and copper. The order of heavy metals concentration in the fish flesh was: Cu > Fe > Zn > Mn > Pb > Cd.

Introduction

Our lakes are considered as important sources for fish production in Egypt that contribute to our economical foundation in an effective way. Comparing with other lakes, Bardawil lagoon has the advantage by producing luxurious, high quality fish that are exported to European countries.

The lagoon is a natural depression separated from the Mediterranean Sea by a sedimentary bar with maximum width (2 km). It is connected to the sea by artificial openings in the west (Boughazes I and II) and an eastern natural opening, the Zaranique. The lake is situated in the north of Sinai 30 km east of Port Said to 20 km west of town El-Arish between E: 32˚ – 40′ and E: 33˚ – 30′ and N: 31˚ – 03′ and N: 31˚ – 14′. Bardawil Lagoon covers an estimated area of 90 km^2 and a maximum width of 22 Km(1). The water depth ranges from 0.5 m to a rather rare

3m. Water salinity ranged from 38.5 ‰ in winter and 69 ‰ during summer[2]. The effect of heavy metals (Fe, Mn, Zn, Cu, Pb and Cd) and the macronutrients (Na, K, Ca and Mg) on the liver and gills tissues of four common fish species (*Mugil cephalus*, *Liza ramada*, *Solea vulgaris* and *Sparus aurata*)[3, 4].

Some studies were carried out on the water quality and physico-chemical characteristics of Bardawil lagoon[5-8]. Also, Lotfy (2003)[9] determined (Fe, Zn, Mn, Cu, Pb and Cd) in the recent sediment of the lagoon.

Heavy metals have a great ecological consideration due to their toxicity and accumulative behavior[10]. Fish may accumulate significant concentrations of metals even in water in which those metals are below the limit of detection in routine water samples[11]. The impact of heavy metals on aquatic environment affects directly or indirectly human health (NWQCU)[12].

The present study aims to determine the concentrations of (Fe, Mn, Zn, Cu, Pb and Cd) in water and their accumulation in fish muscles and skin of three common fish species (*Liza ramada*, *Mugil cephalus* and *Solea vulgaris*) in Bardawil Lagoon.

Experimental

The sampling stations were chosen to cover the western and eastern arms of the lake (Fig. 1), twelve stations were classified, coded and named as follows:

Eastern Arm		**Western Arm**	
Name	**Station Code**	**Name**	**Station Code**
Karn Samda	Station No. 1	El-Rwakk	Station No. 7
Boughaz II	Station No. 2	Boughaz I	Station No. 8
El-Kalss	Station No. 3	Al-Romih	Station No. 9
Matt Ebliss	Station No. 4	Al-Nasser	Station No. 10
Messfek	Station No. 5	Al-Neghila	Station No. 11
El-Telol	Station No. 6	Rabaa	Station No. 12

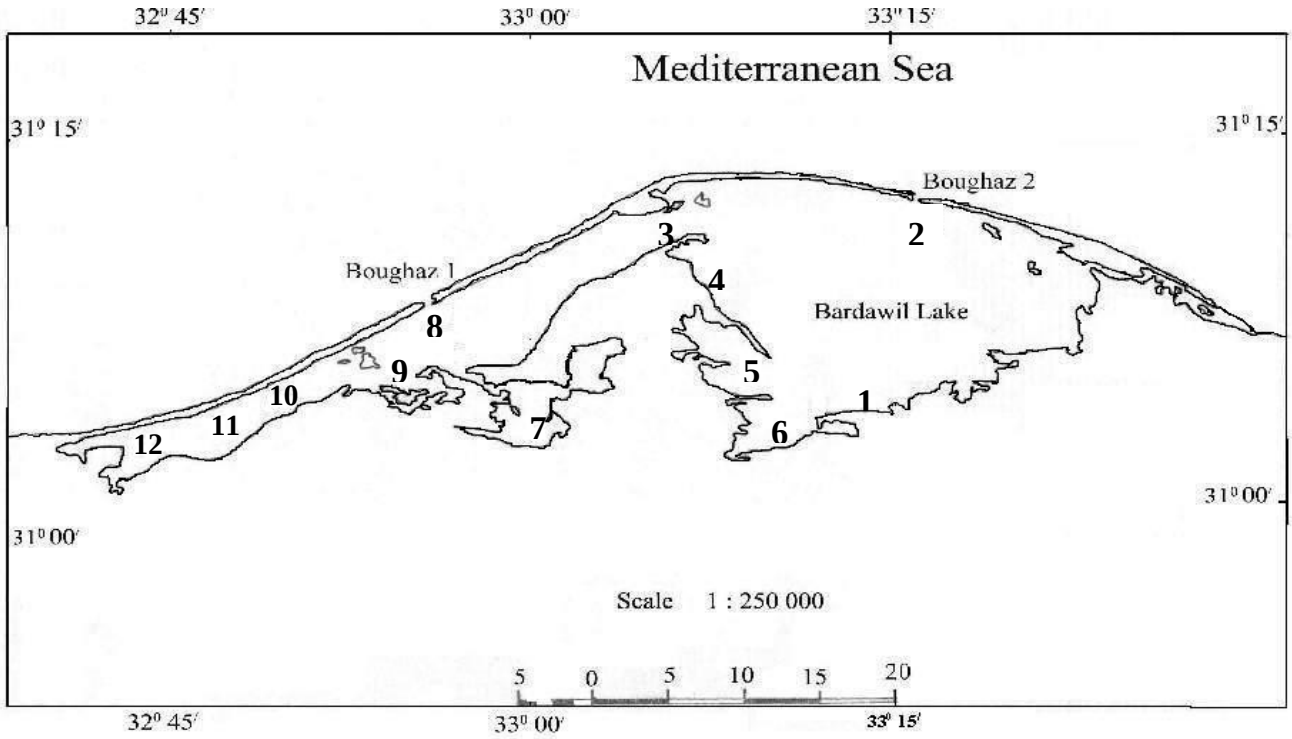

Figure (1): Map showing the sampling sites in Bardawil Lagoon.

The present study was extended from autumn 2001 to summer 2002. Water samples were collected from subsurface layer by using polyvinyl chloride Van Dorn plastic bottle (2 L). Samples were preserved immediately after collection by acidifying with concentrated nitric acid to pH < 2; by using 5 ml HNO_3 for 1 liter water sample. Heavy metals were extracted from water samples using nitric acid digestion method according to (APHA, 1995)[13].

Fish samples of *Solea vulgaris*, *Mugil cephalus* and *Liza ramada* were collected in winter 2001 and summer 2002 from El-Telol location in Bardawil lagoon. The lengths of specimens ranged between 20-23.8, 22.6-26.4 and 24-27.5 cm for *Solea vulgaris*, *Mugil cephalus* and *Liza ramada*, respectively. The corresponding weights of specimens ranged between 69.5-139.6, 110-168.8 and 115.4-140 g for the aforementioned fish species, respectively. The samples were digested according to the method described by (Goldberg *et. al*. 1993)[14].

The concentrations of Fe, Mn, Zn, Cu, Pb and Cd in both water and fish muscles and skin samples were measured by using ICP-400 spectrometer Perkin Elmer, USA. The concentrations of Fe, Mn, Zn, Cu, Pb and Cd expressed in mg/kg dry weight and µg/l in fish muscles and skin and water samples respectively.

Results and Discussion

(A) Heavy metals in water

Because of the very important role of heavy metals pollution, the determination and speciation of heavy metal is a primary target in environmental research[15].

1- Iron:

The obtained results of iron in Table (1) revealed that, the highest values were recorded during winter. This is mainly attributed to the decrease of pH during this season and the increased mobilization of iron from sediment to water[16]. A maximum value of 1540 µg/l for iron was observed at station 6 (El-Telol). This can be attributed to the high amount of suspended solids and wastes at this station produced from the human activities of fishermen which may contain high amount of suspended solids[17].

2- Manganese:

The obtained results of manganese concentrations presented in Table (1) showed that, the concentrations of manganese were higher during hot seasons than cold seasons. This was mainly attributed to the mobilization of manganese from the sediment to the overlaying water due to the decomposition of organic debris by microbial activity[18] which agreed with the finding by (Goher, 2002)[19].

3- Zinc:

Seasonal variations of zinc concentrations at different selected stations presented in Table (1) indicated that, the high values of zinc content during winter and autumn seasons may be attributed to the decrease of sorption of zinc with the lowering of temperature[15]. The lower values recorded during hot period especially summer can be attributed to the elevation in air and water temperatures which would facilitate the precipitation of zinc to sediment[20].

Zinc concentrations reached to the maximum values of 760 and 860 µg/l at El-Telol station. This is strongly attributed to anthropogenic sources since contamination from ships is most obvious in dock and harbours, where lead, zinc and chromium are used in preservative paints. These results agreed with the findings by (Hassaan & Nadia, 2000)[21].

4-Copper:

The distributions of copper concentrations at different selected stations of Bardawil lagoon presented in Table (1) showed low levels are during winter, spring and summer seasons and not detected at most stations during autumn. This is mainly attributed to devoid of pollution sources of this element in the lake[22].

5- Lead:

The present results of lead, Table (1) show that the relative decrease of lead during autumn season may be related to the increase in salinity and carbonate content during this season[23]. On the other side, the relative increase of lead content during winter, may be due to the decrease in the precipitation of lead salts under low pH and temperature values.

6- Cadmium:

Cadmium may present in the lake water as a result of industrial discharge or deterioration of galvanized pipes[13]. Cadmium concentrations in Bardawil lagoon were not detected at most stations except that stations (2,3,8,10 and 11) reached to 10 µg/l through the investigation period. The low levels of cadmium in lake water were strongly attributed to the devoid of pollution sources (industrial or agricultural) discharged in the lake. Also, the increase in salinity may decrease the sorption of this metal to solid phase[19, 24].

Generally, a comparison of the present results with the standard values cited by WHO (World Health Organization) and EEC (European Economic Community)[25] is fruitful. The concentration values of iron and lead in the present study are higher than the permissible limits of (0.3 mg/l), (0.2 mg/l) and (50 µg/l) of WHO and EEC respectively. On the other the values of Mn, Zn, Cu and Cd are lower than the permissible limits of WHO and EEC (100 µg/l), (20-50 µg/l), (5 mg/l), (50 µg/l) and (5 µg/l) respectively.

Also, comparing the present results of heavy metals with other Egyptian lakes e.g. Qarun[19], Manzala[24, 26] and Burullos[22]. The concentration values of Fe, Zn and Pb are higher than these lakes, but the concentration levels of Cu and Cd are lower than measured in the same lakes. The concentrations of manganese present are in the same ranges of these lakes.

Table (1): Seasonal variations of studied heavy metals (µg/l) at selected stations of Bardawil lake water during 2001-2002

Heavy metals	Seasons / Stations	Autumn	Winter	Spring	Summer
Iron	Karn Samda (1)	230	540	270	750
	Boughaz (II) (2)	240	700	450	310
	El-Kalss (3)	200	570	540	630
	Matt Ebliss (4)	100	570	220	640
	Messfek (5)	140	1080	390	230
	El-Telol (6)	190	1540	190	290
	El-Rwakk (7)	170	1040	190	220
	Boughaz (I) (8)	250	510	430	290
	Al-Romih (9)	220	480	260	550
	Al-Nasser (10)	130	880	270	190
	Al-Neghila (11)	280	450	170	170
	Rabaa (12)	130	270	110	420
Manganese	Karn Samda (1)	20	30	140	150
	Boughaz (II) (2)	50	20	50	20
	El-Kalss (3)	30	20	50	20
	Matt Ebliss (4)	20	20	90	20
	Messfek (5)	20	30	110	30
	El-Telol (6)	60	20	120	20
	El-Rwakk (7)	70	20	130	40
	Boughaz (I) (8)	20	40	60	30
	Al-Romih (9)	30	20	150	30
	Al-Nasser (10)	40	30	140	30
	Al-Neghila (11)	20	30	80	30
	Rabaa (12)	90	10	100	20
Zinc	Karn Samda (1)	70	280	190	30
	Boughaz (II) (2)	120	140	60	30
	El-Kalss (3)	20	60	110	20
	Matt Ebliss (4)	130	100	50	30
	Messfek (5)	650	200	80	50
	El-Telol (6)	860	760	80	50
	El-Rwakk (7)	50	680	540	30
	Boughaz (I) (8)	60	110	60	30
	Al-Romih (9)	20	130	80	40
	Al-Nasser (10)	50	700	50	50
	Al-Neghila (11)	40	100	90	20
	Rabaa (12)	70	280	190	30
Copper	Karn Samda (1)	10	30	20	10
	Boughaz (II) (2)	10	*	10	30
	El-Kalss (3)	10	10	10	30
	Matt Ebliss (4)	*	30	20	30
	Messfek (5)	10	20	40	*
	El-Telol (6)	*	50	30	20
	El-Rwakk (7)	*	20	20	*
	Boughaz (I) (8)	*	20	10	10
	Al-Romih (9)	10	20	10	20
	Al-Nasser (10)	*	80	20	20
	Al-Neghila (11)	*	20	30	20
	Rabaa (12)	*	10	20	10

Table (1) Cont.

Lead	Karn Samda (1)	50	30	50	50
	Boughaz (II) (2)	30	60	50	40
	El-Kalss (3)	30	30	60	60
	Matt Ebliss (4)	40	60	30	20
	Messfek (5)	10	40	40	80
	El-Telol (6)	40	70	70	30
	El-Rwakk (7)	40	20	50	10
	Boughaz (I) (8)	20	50	50	40
	Al-Romih (9)	20	70	60	40
	Al-Nasser (10)	40	60	40	40
	Al-Neghila (11)	30	40	30	30
	Rabaa (12)	60	70	30	50
Cadmium	Karn Samda (1)	*	*	*	*
	Boughaz (II) (2)	*	*	10	*
	El-Kalss (3)	*	*	10	*
	Matt Ebliss (4)	*	10	*	*
	Messfek (5)	*	*	*	10
	El-Telol (6)	*	*	10	*
	El-Rwakk (7)	*	*	*	*
	Boughaz (I) (8)	*	*	*	*
	Al-Romih (9)	*	*	*	*
	Al-Nasser (10)	*	*	10	*
	Al-Neghila (11)	*	*	10	*
	Rabaa (12)	*	*	*	*

* not detected

(B) Heavy metals in fish muscles and skin

Table (2): The concentration levels of heavy metals in the muscles and skin of the studied fish species in Bardawil lagoon during winter 2001 and summer 2002 (mg/kg dry weight).

Seasons	Species / Elements	*Solea vulgaris*	*Mugil cephalus*	*Liza ramada*
Winter	Fe	11.64	9.52	9.60
	Mn	10.95	1.72	0.98
	Zn	11.07	4.37	9.75
	Cu	197.58	250.98	120.97
	Cd	0.21	0.09	0.31
	Pb	2.25	1.78	0.11
Summer	Fe	15.36	16.64	15.69
	Mn	2.42	1.81	1.53
	Zn	13.72	6.24	8.12
	Cu	216.76	192.90	177.00
	Cd	0.20	0.44	0.16
	Pb	0.97	0.54	0.44

1- Iron:

The values of iron in the muscles and skin of the studied fishes ranged from 9.52 mg/kg to 11.64 mg/kg in winter and from 15.36 to 16.64 mg/kg dry weight in summer. The values of iron ranged from 37.64 mg/kg in the gills of the same fishes[4] and from 48.68 to 97.15 mg/kg in their livers[3]. Thus, the values of iron in the muscles and skin were significantly lower than that of the liver and gills.

Food and Drug Administration (F.D.A.) recommended 0.5 mg daily dietary allowance supplied by 100 g serving of fish muscles[27]. The iron concentration levels in the present study were slightly higher than the allowed levels in all fish species.

2- Manganese:

The concentrations of manganese in the muscles and skin ranged from 10.95 to 0.98 mg/kg in winter and from 2.42 to 1.53 mg/kg in summer. In comparison with the values of manganese in the liver and gills of the same fish species. The values of manganese in muscles and skin were significantly lower than those of liver and in the same range of the gills concentrations in all fish species except for *Solea vulgaris* which had higher value in winter[3, 4]. Manganese level reached the highest value of 10.95 mg/kg in winter, this may be due to the increase in metabolic rate during winter which leads to decrease of manganese concentrations in water in this season (Table 1).

3- Zinc:

The levels of zinc concentration ranged between (11.07 – 4.37 mg/kg) in winter and between (13.72 – 6.24 mg/kg) in summer. The concentrations of zinc and iron in summer were higher than those in winter. The increase of zinc and iron in summer may be attributed to the increase in metabolic rates, which result in increased heavy metals uptake as previously indicated that as water temperature rises, water born toxicants become lethal to fish at lower concentration[28]. It was that zinc concentrations in muscle tissue of fish species from non- polluted areas, were less than 1 ppm[29]. In the studied fish species, zinc levels were higher than in non-polluted areas.

4- Copper:

The values of copper ranged between (120.96 - 250.98 mg/kg) in winter and between (177.00 - 216.76 mg/kg) in summer. The concentrations of copper in fish muscles and skin followed the increase and decrease of the concentrations of copper in water at El-Telol station (Table 1) where the fish samples were collected. National Health and Medical Research Council, recommended that the standard concentration of copper for human consumption is 30.0 mg/kg[30].

5- Lead:

The concentrations of lead in the muscles and skin of the studied fish species ranged between (2.25 - 0.11 mg/kg) in winter and between (0.97 - 0.44 mg/kg) in summer. USFDA (Food and Drug Administration) maximum permissible level for lead is 2.0 mg/kg in fish muscles[31]. The concentration of lead in *Solea vulgaris* fish was slightly higher than the permissible limit (PL) in winter but the concentrations of lead were lower than (PL) it in other fish species. All fish species contain allowed levels of lead in summer.

6- Cadmium:

The concentrations of cadmium in the muscles and skin ranged between (0.31 - 0.09 mg/kg) in winter and between (0.44 - 0.16 mg/kg) in summer. The values of cadmium were lower than the permissible limit (0.5 mg/kg) of National Academy of Science[31] in all fish species.

It is concluded that, the concentrations of zinc and copper in water were in the permissible limits but the fish flesh of the studied species accumulated these elements to a great extent, indicating high tendency of the fish to accumulate these elements. The concentrations of the toxic nonessential elements (cadmium and lead) in the fish flesh were in the permissible limit with one exception (the relatively high concentration of lead in *Solea vulgaris* in winter). So, the muscles and skin (the edible part of fish) is suitable as food in the common fish species in Bardawil lagoon (*Solea vulgaris, Mugil cephalus* and *Liza ramada*).

References

1. S.M. Aboul-Ezz, *Bull. Inst. Oceanogr. & Fish. ARE*, 14 (1), 159-174 (1988).
2. E.A., Ibrahim, M.M. Hussein, S.M. Aboul-Ezz, and T.A. Selim, The second report, *Nat. Inst. Ocean. Fish. (Egypt).* (1987).
3. A.M. Yacoub, and A.M. Abdel-Satar, *Egypt. J. Aquat. Biol. & Fish*., 7 (4), 403-422 (2003).
4. A.M. Yacoub, *J. Egypt. Acad. Soc. Environ. Develop*., 5 (1), 119-143 (2004).
5. L. Yitzhak, *Limnol. & Oceanogr*., 16 (6), 983-987 (1971).
6. T.A.E. Siliem, *Bull. Nat. Inst. of Oceanogr and Fish.* 14 (1), 123-140 (1988).
7. T.A.E. Siliem, *Bull. Nat. Inst. of Oceanogr. and Fish.* 15 (1), 21-33 (1989).
8. E.E. Shabana, Limnological studies on Lake Bardawil, M. Sc. Thesis, Fac. Sci., Suez Canal Univ. (1999).
9. F.M. Lotfy, *J. Egypt. Acad. Soc. Environ. Develop., (D-Environmental studies)*, 4 (2), 179-197 (2003).
10. D. Purves, "Trace elements contamination of the environment". El-Servier, Amsterdam (1985).
11. C.F. Mason, *Chemosphere*, 16 (4), 901-906 (1987).
12. NWQCU (National Water Quality Conservation Unit) Assessment of water quality hazards in Egypt. 2nd Advisory Committee Workshop, National Water Quality Conservation Program, 24-25 March (1995).
13. American Public Health Association (APHA), "Standard methods of the examination of water and wastewater". New York, *1193* (1995).
14. E.D. Goldberg, M. Koide, V. Hodge, A.R. Flegal, and J. Martin, *Estuar. Coastal Shelf Sci*., 16, 69-93 (1993).
15. L.A. Warren, and A.P. Zimmerman, *Wat. Res*., 28 (9), 1921-1931 (1994).
16. A.M. Abdel-Satar, Distribution of some elements in River Nile environment at great Cairo Region. Ph. D. Thesis, Fac. Sci., Cairo Unv., Egypt. (1998).
17. C.H. Vander Weijden, and J.J. Middelburg, *Wat. Res*., 23, 1247-1266 (1989).
18. W. Sung, and J.J. Morgan, Geochem. Cosmochim. Acta, 45, 2377-2383 (1981).

19. M.E.M. Goher, Chemical studies on the precipitation and dissolution of some chemical elements in Lake Qarun, Ph.D. thesis, Fac., of Sci., Al-Azhar Univ. (2002).
20. M.H. Abdo, *Egypt, J. Aquat. Biol.& Fish.*, 8 (4), 195-211 (2004).
21. M.H.H. Hassaan, and A.A. Nadia, *Bull. Nat. Inst. of Oceanogr. & Fish., A.R.E*, 26, 339-353 (2000).
22. A.M.R. Radwan, *Bull. Nat. Inst. Oceanogr. & fish. A. R. E.* (26), 355-364. (2000).
23. D.R. Turner, M. Whitefield, and A.G. Diekson, *Geochem. Chosmochim. Acta*, 45, 855-881 (1981).
24. A.M. Abdel-Satar, *Egypt. J. Aquat. Biol. & fish.*, 5 (3), 17-30 (2001).
25. World Health Organization for inorganic constituents of health significance and European Economic Community Standards for parameters Water Quality Standards and Goalls, New York *1271* (1992).
26. A.M. Ibrahim, M.Y. Bahnasawy, S.E. Mansy, R.I. El-Fayomy, *J. Egypt. Ger. Soc. Zool.* Vol. *29*(*B*) vertebrat Amafomy & Embryology, *43-58*. *9*th Int. conf. Al Arish *2-6* April (1999).
27. E.I. Adeyeye, *Pak. J. Sci. Res.*, 36, 333-337 (1993a).
28. A.M. Hilmy, N.A. El-Domiaty, A.Y. Daabees, and H. Abdel-Latif, *Comp. Biochem. Physical*., 82 (C), 297-301 (1987).
29. A.K. Koli, S.S. Sandhu, W.T. Canty, K.L. Felix, R.G. Read, and R. Whitemore, *Bull. Environ. Contam. Toxicol*., 20 (3), 328-331 (1978).
30. M. Bernard, Levels of trace metals in the Mediterranean. VI fournee Etud. Pollutions. Cannes. GIESM 1982 (1982).
31. E.I. Adeyeye, *Ghana J. Chem.*, 1, 377-384 (1993b).