EROS-2000 DANUBE PROGRAMME : STATE OF ECOSYSTEMS WITHIN THE DANUBE DELTA IN 1995

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Abstract. The Danube Delta may be considered a natural filter, which acts as a buffer interface between the Danube River supplies, rich in contaminants collected from a large catchment area, and the western Black Sea. During the 1995 research cruise, sediment, water and biota sampling was carried out in 62 stations, located within the main lakes and channels of the deltaic water system and also, within Razim-Sinoie lacustrine complex. The data obtained point out patterns and trends of the input, dispersal and deposition of the sediments and the pollutants within the main ecosystems. The metallic pollutants in sediments are not exceeding, usually, the normal values, but show increasing trends in areas controlled by Danube River direct supplies (Meşteru-Fortuna, Gorgova-Uzlina depressions and Razim-Sinoie complex). The same areas show high values of the magnetic susceptibility and radioactivity of the sediments. The distribution of the physical-chemical parameters of the Danube Delta waters is influenced mainly by natural factors and subordinately by more or less direct anthropogenic causes. Suspended solid contents are induced both by particulate matter inputs of riverine origin, and by phytoplankton "blooms". The nutrient concentrations in *water* show generally moderate values for nitrites and nitrates, not exceeding the allowable contamination levels. As concerns trace metals in *water*, the main increasing concentration trends have been observed for Hg, Fe, Mn, As, Cd, with accidentally anomalous values mainly for Hg and sometimes Fe. The dispersal of trace metals is influenceded by riverine supplies, hydrological conditions inside the deltaic water system, filtering mechanisms, and subordinately, by atmospheric inputs. The chemical data suggest only moderate to small degradation of the ecosystems, and, taking into account earlier information regarding this subject, a chronical pollution of the delta cannot be proved.

The areas which can be considered under stress, are the Meşteru-Fortuna depression, the Lake Dranov and partly the lakes Goloviţa and Sinoie. A special attention must be paid to the Lake Dranov, where most of the measured parameters show abnormal values as compared with other lakes in the Danube Delta: low Eh, high pH, the highest concentrations of SO_4^{2-}, Al, Hg, Cr, Cd, As, Ni, Se, Co and among the highest Pb, Zn, Mn, Fe abundance. The enrichment mechanism is natural, but the cause is anthropic: the lake was isolated and transformed in a semi-natural fishing pool, where the evaporation-crystallisation prevalence leads to a dangerous salt content increase.

Key words: sediment chemistry, water chemistry, trace elements, physical-chemical parameters, nutrients, environment quality.

INTRODUCTION

The Danube Delta is one of the largest deltas in Europe (the second, after the Volga River delta), covering, together with the Razim (Razelm)-Sinoie lacustrine complex, about 5,800 km^2 of lakes, marshes, channels and meander belt bodies, associated with fluvial levees, lacustrian spits, fossil beach ridges and pre-deltaic relics. A series of interdistributary depressions, with specific hydrographic network, may be outlined principally between the main Danube branches. The delta includes several depositional systems - the ***delta plain***, the ***delta front*** and the ***prodelta*** - to which is to be added the Danube ***deep-sea fan*** (Panin, 1996). The ***delta plain*** contains two important units: an upper (western) one - the "*fluvial delta plain*", and a lower (eastern) one - the "*marine delta plain*", separated by the Jibrieni-Letea-Răducu-Ceamurlia-Caraorman-Sărăturile-Perisor-Lupilor line. This boundary represents an important zone of old accumulative littoral formations belonging to the marine delta plain. The Razim-Sinoie lacustrine complex is a particular unit, originally an old marine bay (Halmyris), in fact a lagoon system, isolated from the Black Sea by juxtaposed beach ridges built up during the last 1,500 years, after the erosion of the fossil secondary Cosna delta.

This study is part of the EROS-2000 Research Project, aimed at assessing the environmental state of the Danube-Danube Delta-Black Sea system. The research was carried out in the framework of the Contract No.95-0339, and financed partly through PHARE Programme-Danube Co-ordination Unit, and partly from the GEOECOMAR own research budget provided by the Ministry of Research and Technology of Romania.

The present paper concerns exclusively with the delta plain area - the delta itself, including the Razim-Sinoie lacustrine complex (Fig.1), and provides a short and general assessment of some tendencies concerning the current status of sediment and water contamination, pointing out the areas under stress. The following hydro-morphological units have been studied (Fig.1):

I - Fluvial delta plain: **Meşteru-Fortuna (1)** and **Matiţa-Merhei (2)** depressions, located between Chilia and Sulina distributaries, **Gorgova-**

Uzlina (3) depression, situated between Sulina and Sf. Gheorghe distributaries, and **Dranov (4)** depression, southward the Sf. Gheorghe distributary;

II - Marine delta plain: **Răducu-Răduculet (5)** depression, located within Chilia-Sulina inter-distributary area, and **Lumina-Roşu (6)** depression, inluded within Sulina-Sf.Gheorghe interdistributary area;

III - Sf. Gheorghe secondary delta (7);

IV - Razim-Sinoie lacustrine-lagoonal complex (8).

METHODS

The cruise, organised between 6-28 July, 1995, took place on board of a small tugboat - "Alumina", and a house-boat. The tugboat was used for sampling activities and towing and the house-boat mainly as laboratory for preparing and analysing samples.The sampling of the water, sediments and biota was carried out in 62 stations, located within the main lakes and channels of various interdistributary depressions, and also, within Razim-Sinoie lacustrine complex., as was stated by the task 3 of the EROS project.

Sediment samples were collected using a hand grab sampler (Van Veen type), and sub-sampled on board for various types of analyses: grain size, magnetic susceptibility, mineralogy, chemistry, total organic carbon etc. A hand plastic corer was used in order to obtain supplementary samples for radioactivity analyses. Surficial and bottom water samples were collected using plastic buckets and Nansen type bottles of 1 l, respectively.

Some phisical/chemical parameters (including nutrient concentrations) of the water were determined in situ, on board, using the portable *HACH DR-2000* equipment for chemical analyses. Metal and pesticide concentrations in water, grain size, mineralogy, magnetic susceptibility, chemistry, radionuclide and pesticide contents of the sediments, were determined in Bucharest laboratories (gamma spectrometry for radionuclide determinations and ICP method for metal analyses).

RESULTS

Sediment quality studies

The Danube Delta water-system contains two general categories of lakes: (1) strongly influenced presently by the River Danube (Meşteru, Lungu, Fortuna, Iacub, Uzlina), and (2) not affected significantly (Cuteţchi, Băclăneşti, Bogdaproste, Matiţa, Trei Ozere, Răducu, Roşu etc.). There are also numerous lakes with intermediate conditions (Tătaru, Puiu, Isacova).

As a result of this differentiation, the lithology of bottom sediments shows variations from clayey-silty muds, rich in mineral material, with high contents of Al_2O_3 and Fe_2O_3, to calcareous-organic muds, characterized by notable levels of **TOC** and **CaO** contents (Table 1). Usually, the mineral muds show higher magnetic susceptibility (**MS**), well correlated with the riverine sediment input (Table 2). All the lacustrine areas evidenced on LANDSAT imagery as receiving elevated amounts of suspended silt have been identified as containing bottom sediments with high **MS**. A special case is represented by the sediments of the Lake Dranov, protected of direct Danubian supplies, where relative high **MS** values may be induced by a certain level of pollution, proved by chemical composition, as well.

The **trace elements** contents show highest concentration in the mineral muds of the Danube influenced lakes (Table 1), and correlate positively with Al_2O_3, Fe_2O_3 and MS, and negatively with CaO and TOC (Table 3), as a consequence of clay minerals and iron oxides and hydroxides abundance, whose retentive properties are very strong. The natural background of the sediments provided by the Danube is not well studied yet, so a preliminary evaluation of trace metal contamination of the Danube Delta sediments is carried out using the average natural concentrations estimated by Turekian and Wedepohl (1961) and French standards for Rhone-Mediterranean-Corse basin (in Naffrechoux, 1992) (Tables 4 and 5). Normalization procedures, using Al_2O_3, TOC and clay contents have been applied, as well, in order to identify anomalous metal concentrations (Van Lexmond and Edelman, 1986; UNEP/IOC/IAEA, 1995).

The concentrations of **Hg** and **Cd**, the only metals included on the *List I ("Black List")* of the Paris Convention and EC Directives (76/464/EEC), are not situated at dangerous levels. The other analysed elements, **As, Ba, Cr, Cu, Mn, Ni, Pb** and **Zn,** classed as *List II ("Grey List")* substances, are not exceeding, usually, the "normal" values, but may show increasing trends in areas controlled by riverine inputs. Therefore, many lakes from Meşteru-Fortuna depressions, or Iacub, Uzlina and other lakes which receive important danubian sediment supplies, show high contents in almost all trace elements. Consequently, the calcareous-organic muds from Matiţa-Merhei depression and from other lakes with more confined conditions, are poor in trace metals.

Some increased values, showing suspect situations, were recorded for As, Cr, Ni, Mn in various sediments (mainly silty-clayey muds).

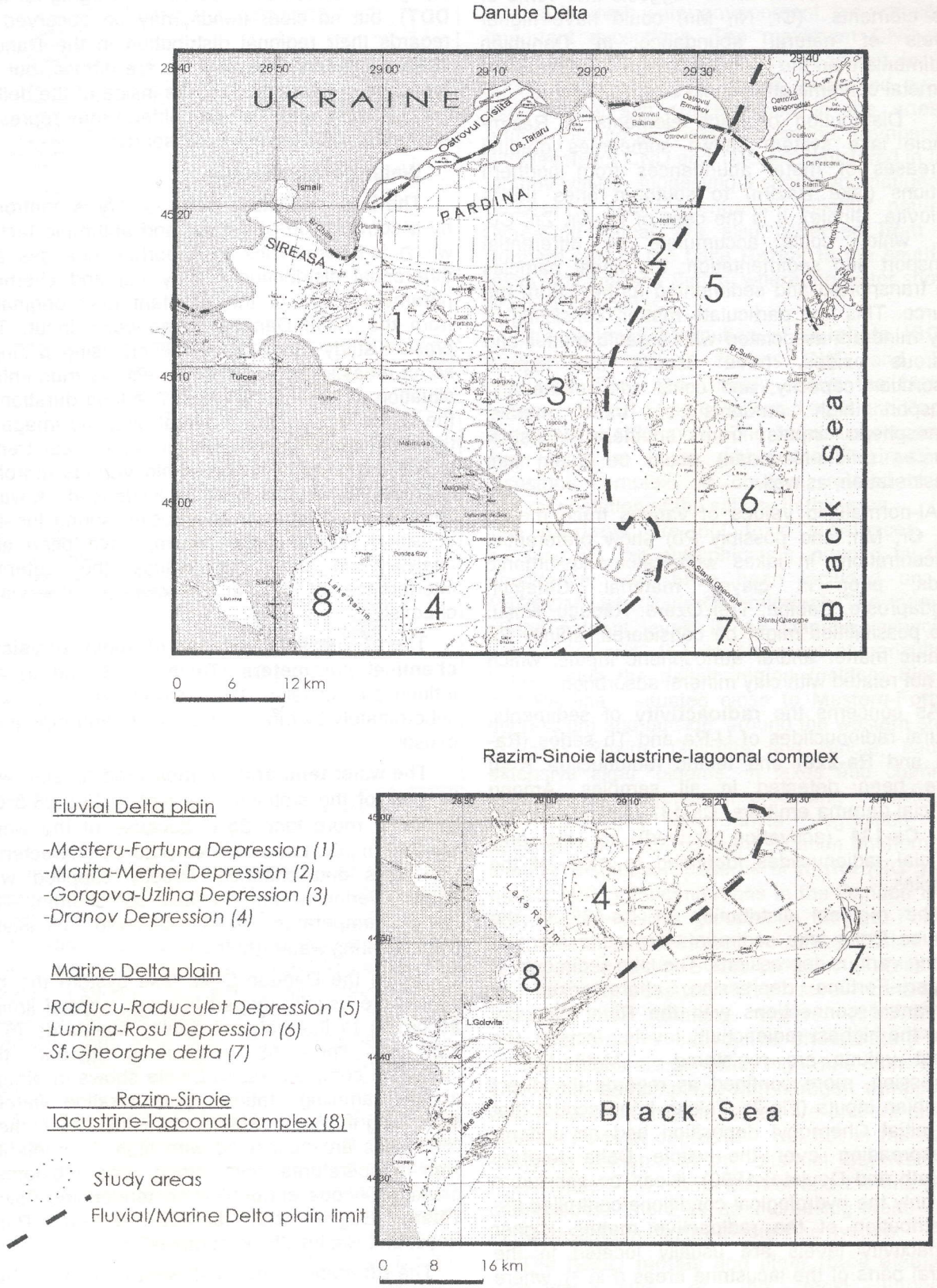

Fig.1 General map of the Danube Delta – Study areas

Instead, the examination of the Al-normalized values for the same areas suggests that some of the elements (Cr, Ni, Mn) could have higher levels of natural abundance in Danubian sediments than the French standards, so the state of metal contamination could be reconsidered.

Distribution of trace elements in Razim-Sinoie lake system shows sometimes gradual increases of metal abundances from northern stations (lake Razim) to southern ones (lakes Golovița, Sinoie). It is the case of Ni, Cr, Zn, Cu, Cd, which could accumulate by differential transport and sedimentation: the finest particles are transported and sedimented furthest from the source. This fine particulate matter, consisting of clay minerals associated with organic matter and hydrous oxides, have usually the highest adsorbtion capacity, and could concentrate and transport high amounts of trace metals. Atmospheric inputs from southern industrial sources (Midia-Navodari) could be taken into consideration, as well.

Al-normalized values of various trace metals (Ni, Cr, Mn, and possibly Pb) show preferential concentrations in lakes with calcareous-organic muds, poor in clayey material: Cutețchi, Bogdaproste, Babina, Trei Ozere, Răducu, Roşu. Two possibilities might be considered: affinity for organic matter and/or atmospheric inputs, which are not related with clay mineral adsorbtion.

As concerns the **radioactivity** of sediments, natural radionuclides of U-Ra and Th series (**Ra-228** and **Ra-226**) and teluric radionuclide **K-40** have been detected in all samples. Among artificial gamma emitters, **Cs-137** (fission derived) and **Cs-134** (activation derived) are the only artificial radionuclides identified in most of the samples.

The regional distribution of Cs-137 in the Danube Delta lake sediments are quite irregular among various depressions. The lake sediments of Meşteru-Fortuna depression, characterized by permanent connections with the River Danube, show the highest radioactivity levels. Instead, the lowest values are registered in Matița-Merhei depression, more confined as regards the direct Danubian inputs (Fig.2). Taking into account that the initial Chernobyl deposition had an uniform widespreading over the whole Delta territory (Osvath and Dovlete, 1990), it can be concluded that only the hydrological conditions controlled the redistribution of the radioactive matter. Higher radioactivity levels are usually located in the central parts of the lacustrine areas (Fig.3), where fine fractions are dominant.

The **organochlorine pesticides**, synthetic organic compounds included on the *List I ("Black list")*, show variable concentrations (0.051-0.098 μg/kg for total **HCH** and up to 0.061 μg/kg for total **DDT**), but no clear trends may be observed as regards their regional distribution in the Danube Delta sediments. The sources are diffuse, but the presence of pesticide deposits inside of the deltaic area (Sireasa and Pardina polders) may represent a potentially dangerous point source.

Water quality studies

The Danube Delta's water quality is controlled by a combination of natural and anthropic factors which led sometimes to important changes and differential distribution of physical and chemical parameters and of the pollutant load originated from the initial Danube River water input. The present study has been achieved using a single set of measurements which reflect the momentary situation of the water quality. The long duration of the cruise did not grant a real synoptic image of the measured parameters, but some clear trends in water quality evolution within various morpho-hydrographycal units could be evidenced. A water sample collected from an artesian spring located in Island Popina (Lake Razim) have been also analysed in order to assess the potential interference of natural sources in lake water chemistry.

The distribution patterns of main **physical-chemical parameters** (Tables 6, 8 and 9) are influenced usually by natural factors, and subordinately by more or less direct anthropogenic causes.

The water **temperature** measured "in situ" was in most of the stations very high (23.8-28.8°C), generally more than 25°C because of the warm weather in july. Lower values (<25°C) characterise the lakes and channels directly supplied with colder riverine waters via "Mile 35" channel. The lowest temperature was registered in Island Popina spring water (22.8°C).

Within the Danube Delta lake system the **pH** values are usually ranged between normal limits, according to international quality standards (6.5-8.5), with some few exceptions. Instead, the lacustrine complex Razim-Sinoie shows in almost all the sampling stations quite alkaline waters, exceeding in many cases 9 pH units. The highest pH values are connected with high O_2 contents, high temperatures and strong algal "blooms", marking serious eutrophication tendencies (lakes Tătaru, Bogdaproste, Isacova, Dranov, Puiu, Roşu, and Razim-Sinoie complex).

The **Eh** measurements showed normal positive values in all samples, with slightly marked decreasing tendency from Danube Delta lake system to Dranov depression and Lake Razim.

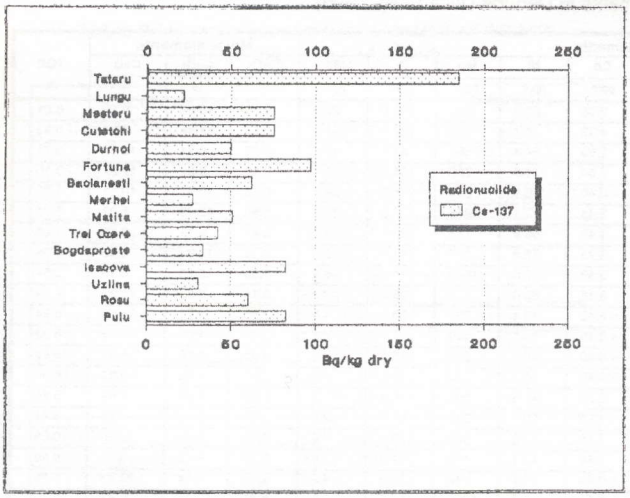

Fig.2 Regional distribution of Cs-137 in Danube Delta lake sediments

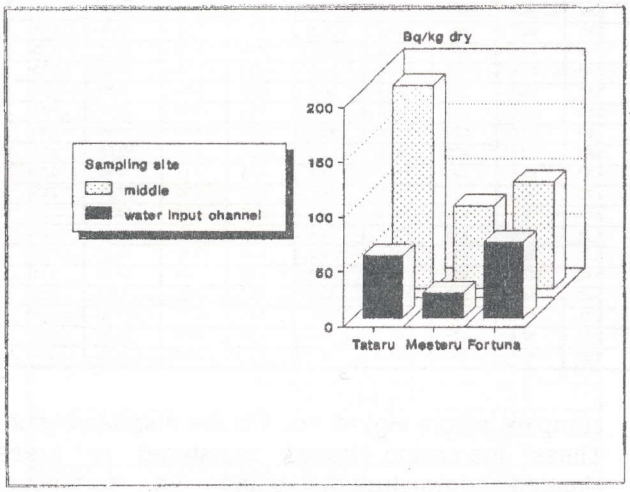

Fig.3 Distribution of Cs-137 in sediments from specific Danube Delta lakes

The **oxygen (O_2)** concentration and saturation reach generally high values in almost all interdistributary depressions and in Razim-Sinoie lake system, with local variations induced by more or less temporary restricted water circulation. The lowest oxygen concentrations have been measured in one lake (Cutețchi) and numerous channels with slow water-flow: Sireasa, Litcov, Nou, Perivolovca, Caraorman and Dunarea Veche branch.

The concentration of **suspended solids** is very variable and controlled by two distinct and even opposite causes. Major concentrations registered in various lakes and channels are explained either by suspended sediment load supply (Meşteru Fortuna depression, Dunavat and Dranov channels), by pytoplankton prolificness (Matița-Merhei depression, Lake Dranov), or by both causes (lakes Razim and Sinoie, sampled in a stormy period).

Conductivity (CND) and total dissolved solids (TDS) show obvious constant levels, normal for fresh water environment, but with some important exceptions. The maximum CND and TDS cocentrations have been measured for the spring water of Popina Island, explained by the high natural salt concentration in the artesian aquifer located in Triassic limestone. Comparable high levels for CND and TDS are registered in lake Dranov waters, suggesting a strong and dangerous process of salt concentration. Slightly naturally increasing values are also observed from the northern part of the Lake Razim, to the south, to lakes Golovița and Sinoie, where the water show a brackish character.

The regional distribution of **sulphate (SO_4^{2-})** concentration values follows CND and TDS evolution. The Lake Dranov shows the highest values (165-167.5 mg/l), followed by Island Popina spring water (130 mg/l). The increasing tendency from north to south within the Razim-Sinoie lacustrine complex is obvious, related to the natural evolution of the salinity in this area.

The **nutrients** are not toxic substances, but because of the eutrophication induced by their abundance, they have been included on the *PARCOM List* (Paris Commission). The increase of the nutrient levels in the Danube, especially after 1980, and the development of agricultural lands inside the deltaic region (polders Sireasa and Pardina, situated close to Meşteru-Fortuna depression) and outside, around the western shore of lakes Razim, Golovița and Sinoie, caused extensive algal "blooms" in lakes and channels with slow water circulation, producing reduction in the submerged macrophyta vegetation and development of strong eutrophication phenomena. General distribution patterns of **nitrite (NO^{2-})** and **nitrate (NO^{3-})** concentrations in the Danube Delta show higher values grouped in Meşteru-Fortuna and Dranov depressions, in lakes Uzlina and Iacub, and in Razim-Sinoie complex (Tables 6, 7 and 9), but ussually, the level considered allowable for drinking waters (80/778/CEE directive) is not exceeded. The **phosphate (PO_4^{3-})** concentrations are generally high, and show some differences as compared with nitrogen compounds distribution. The higher values are present also in Meşteru-Fortuna depression, but not in the same sampling stations, in the channel Dunavat and some lakes from Matița-Merhei and Lumina-Roşu depressions. There is an increasing trend from north to south in Razim-Sinoie lake system.

The **heavy metals** and other **trace elements** represent ones of the most important contaminants for the delta's aquatic environment.

Total concentrations of **Al, As, Cd, Co, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Se** and **Zn** were determined

Table 1 Chemistry of bottom sediments in Danube Delta (July, 1995)

Crt. no.	Sample no.	Location	Trace elements										Major elements			TOC
			Cu	As	Hg	Zn	Pb	Cd	Ni	Mn	Cr	Ba	Fe_2O_3	Al_2O_3	CaO	
			ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	%	%	%
1.	DD 7529	Fortuna Lake	59.1	36.6	< 2.0	159.0	64.1	2.66	69.6	842	121.0	22.9	5.00	10.98	9.10	6.01
2.	DD 7530	Fortuna L.	63.7	218.5	< 2.0	177.0	51.5	4.32	78.1	1290	127.0	42.7	5.55	11.45	7.97	0.93
3.	DD 7531	Băclănești L.	35.0	44.4	< 2.0	110.0	22.2	0.99	64.4	667	81.1	17.2	5.22	6.71	10.57	3.71
4.	DD 7532	Tătaru L.	39.4	108.1	< 2.0	100.0	58.6	2.64	71.6	760	101.0	13.1	5.10	9.92	12.81	3.10
5.	DD 7533	Tătaru L.	23.3	51.4	< 2.0	115.0	3.1	< 0.40	70.9	821	114.0	24.8	5.43	10.71	10.11	1.66
6.	DD 7534	Lungu L.	51.2	58.3	< 2.0	164.0	64.7	3.45	87.1	665	127.0	62.6	5.60	12.56	5.03	3.07
7.	DD 7535	Cutetchi L.	29.7	187.6	< 2.0	104.0	52.9	1.49	68.6	737	106.0	23.6	5.46	9.11	8.68	4.06
8.	DD 7536	Mesteru L.	47.1	71.3	< 2.0	216.0	56.7	3.23	78.6	877	141.0	63.2	6.88	13.84	5.63	0.34
9.	DD 7537	Mesteru L.	74.8	176.0	< 2.0	220.0	93.4	3.53	102.0	1090	141.0	66.5	6.58	13.90	6.15	2.54
10.	DD 7538	Durnoi L.	61.8	110.6	< 2.0	138.0	55.7	3.16	60.8	579	98.0	22.7	5.15	9.52	10.23	4.02
11.	DD 7539	Bogdaproste L.	22.8	62.9	< 2.0	3.67	6.2	< 0.40	36.4	701	33.0	4.6	2.50	2.71	14.00	6.24
12.	DD 7540	Bogdaproste L.	12.1	18.7	< 2.0	23.0	3.0	< 0.40	40.1	890	37.9	7.1	2.61	4.00	14.28	6.33
13.	DD 7541	Trei Ozere L.	29.7	42.1	< 2.0	66.9	23.8	< 0.40	86.8	914	45.6	7.4	3.35	4.36	15.82	5.55
14.	DD 7542	Merhei L.	2.9	39.9	< 2.0	11.6	4.0	< 0.40	21.3	730	39.0	6.8	2.53	3.48	19.04	6.06
15.	DD 7543	Merhei L.	13.9	64.4	< 2.0	20.3	109.4	2.28	41.5	808	76.8	21.3	2.90	7.50	7.62	5.85
16.	DD 7544	Matita L.	20.2	34.5	< 2.0	50.0	27.7	< 0.40	40.4	813	61.2	9.4	3.01	5.46	17.50	4.41
17.	DD 7545	Babina L.	21.7	45.3	< 2.0	32.3	44.3	2.10	33.0	888	49.8	7.9	2.93	4.59	16.66	0.05
18.	DD 7547	Nou Cn.	10.2	29.6	< 2.0	24.9	35.7	1.88	42.4	410	54.0	22.9	2.73	6.12	6.79	6.48
19.	DD 7548	Isacova L.	43.4	59.7	< 2.0	39.4	< 2.0	< 0.40	58.1	740	51.5	4.9	2.97	5.14	20.44	6.25
20.	DD 7550	Uzlina L.	61.6	139.9	< 2.0	252.0	74.1	5.29	92.6	1000	130.0	49.8	6.45	12.38	5.67	3.59
21.	DD 7551	Uzlina Cn.	24.9	107.4	< 2.0	107.0	87.9	3.10	61.0	495	96.9	35.3	3.95	8.52	4.76	2.87
22.	DD 7552	Perivolovca Cn.	33.4	71.5	< 2.0	69.8	37.1	3.30	61.7	634	65.6	6.5	3.45	6.27	15.68	1.00
23.	DD 7554	Iacub L.	57.9	166.0	< 2.0	196.0	19.5	3.28	72.5	980	110.0	15.2	5.45	10.87	10.81	1.89
24.	DD 7555	Răducu L.	14.7	92.1	< 2.0	13.0	10.9	0.57	36.2	672	40.5	7.2	1.74	3.16	20.26	5.34
25.	DD 7557	Puiu L.	14.6	12.6	< 2.0	46.5	48.2	3.05	99.6	698	59.6	5.3	3.13	5.76	19.04	6.38
26.	DD 7559	Rosu L.	< 2.0	92.9	< 2.0	7.7	< 2.0	3.28	48.8	535	76.0	8.5	2.74	5.76	10.47	4.15
27.	DD 7560	Rosu L.	< 2.0	19.7	< 2.0	< 2.0	5.5	< 0.40	61.3	682	19.8	5.3	1.26	1.95	24.08	5.33
28.	DD 7561	Sacalin Bay	< 2.0	79.1	< 2.0	< 2.0	< 2.0	1.57	33.4	397	69.8	20.3	2.12	5.86	5.89	0.10
29.	DD 7562	Dranov Cn.	22.4	118.2	< 2.0	82.3	63.9	3.60	101.0	853	122.0	47.6	6.23	13.19	4.27	1.33
30.	DD 7563	Dranov L.	69.5	17.8	< 2.0	91.6	21.8	4.90	146.0	1090	115.0	45.8	5.88	11.95	7.48	2.82
31.	R 1442	Razim L.	15.5	35.6	< 2.0	91.2	< 2.0	2.90	60.8	402	94.3	8.8	2.60	6.60	13.05	0.67
32.	R 1443	Golovita L.	37.5	117.1	< 2.0	76.2	< 2.0	4.30	81.8	592	114.0	24.4	4.60	10.11	9.45	0.32
33.	R 1444	Golovita L.	29.6	112.5	< 2.0	88.9	7.8	4.70	90.5	603	122.0	36.1	5.20	12.00	7.98	2.09
34.	R 1445	Razim L.	73.8	46.7	< 2.0	74.7	2.7	3.34	73.1	616	103.0	10.5	3.75	8.24	14.42	1.97
35.	R 1446	Razim L.	19.0	74.4	< 2.0	77.4	34.8	1.31	72.6	858	108.0	21.6	5.40	11.03	8.57	2.49
36.	R 1447	Razim L.	7.4	42.4	< 2.0	74.1	28.6	0.72	59.3	834	101.0	19.8	4.50	10.45	10.36	2.08
37.	R 1448	Razim L.	< 2.0	84.6	< 2.0	18.5	19.0	< 0.40	144.0	655	87.5	8.3	3.13	7.56	14.28	1.11
38.	R 1449	Razim L.	< 2.0	46.2	< 2.0	55.9	29.1	1.60	49.4	517	103.0	43.4	3.17	8.58	5.61	0.38
39.	S 188	Sinoe L.	36.3	54.9	< 2.0	144.0	43.7	4.35	81.6	586	119.0	30.4	4.55	10.77	7.33	0.15
40.	S 189	Sinoe L.	58.4	42.8	< 2.0	17.5	5.9	2.48	87.4	275	83.0	11.4	1.40	4.82	10.35	0.53
41.	S 190	Sinoe L.	28.7	88.1	< 2.0	120.0	16.5	5.02	67.8	630	117.0	31.5	3.40	8.98	7.73	0.24

for 30 surficial water samples collected from lakes, channels and the artesian spring located in Popina Island (Lake Razim) (Table 7).

From the *List I ("Black List")*, only Hg shows concentrations which exceed the EC environmental quality standard, for half of the samples. Among the EC *List II ("Grey List")* elements, more or less anomalous values have been recorded only accidentally, for Cu and Zn. The EC Directives for drinking water are sometimes exceeded for Al, Fe, Mn, Co and Se, elements not included on the EC list of dangerous substances (Tables 8 and 9).

The dispersal of trace metals in Danube Delta waters is controlled by various mechanisms. Fe and Al show increased values in areas controlled by riverine inputs, pointing out their lithogenic origin. Mn shows an irregular distribution, suggesting both lithogenic and organic matter influences. Zn and Cu concentrations decrease from the fluvial delta plain (upstream) to the marine delta plain (downstream), suggesting a filtering mechanism. Cd, As, Se and Co are slightly increased in Meşteru-Fortuna depression (riverine influence), and even more enriched in Lumina-Roşu depression and Razim-Sinoie complex, where Hg, Ni and Pb are also increased. These increasing trends registered in areas situated downstream, could be fortuitous, generated by the temporal distance between different measurements, or might reflect atmospheric inputs. The intervention of eolian pathway could be also an explanation for the gradually increasing values registered from north to south in Razim-Sinoie lake system for Fe, Al, Hg, Ni, Pb, Cd, As, Se and Co.

Almost all elements show very high concentrations in Lake Dranov waters and Island Popina spring, but from different reasons: intense evaporation-crystallyzation-concentration processes in the first case, and deep origin of the artesian water in the second case.

The **organochlorine pesticides**, substances included on the EC *List I ("Black List")*, show individual concentration ranges between < 0.002-0.333 μg/l for **HCH** and <0.010-0.083 μg/l for **DDT isomers**, between 0.012-0.369 μg/l **total HCH**, and up to 0.175 **total DDT**.

These values suggest suspect situations in lakes Fortuna (alfa-HCH), Matița (alfa-HCH, beta-HCH), Razim (alfa-HCH) and Sinoie (alfa-HCH). Considering standard limits published in *NRA*

Table 2 Magnetic susceptibility of bottom sediments in Danube Delta (July, 1995)

Location (Lake, Channel)	Sample	Magnetic susceptibility (10^{-6}Slu.)
L.Fortuna	DD 7529	281.1
	DD 7530	269.0
L.Băclănești	DD 7531	7.2
L.Tătaru	DD 7532	71.3
	DD 7533	113.5
L.Lungu	DD 7534	471.2
L.Cutetchi	DD 7535	70.8
L.Mesteru	DD 7536	340.8
	DD 7537	215.1
L.Durnoi	DD 7538	41.6
L.Bogdaproste	DD 7539	-0.9
L.Trei Ozere	DD 7541	6.3
L.Merhei	DD 7542	1.2
	DD 7543	36.9
L.Matita	DD 7544	32.4
L.Babina	DD 7545	6.8
L.Isacova	DD 7548	42.0
L.Uzlina	DD 7550	357.1
Cn.Uzlina	DD 7551	439.7
Cn.Perivolovca	DD 7552	29.3
L.Iacub	DD 7554	147.1
L.Răducu	DD 7555	1.0
L.Puiu	DD 7557	62.6
L.Rosu	DD 7559	104.2
	DD 7560	9.3
Sacalin Bay	DD 7561	229.3
Cn.Dranov	DD 7562	379.5
L.Dranov	DD 7563	150.2
	DD 7564	170.5
L.Golovita	R-1443	120.4
	R-1444	141.3
L.Razim	R-1445	145.9
	R-1446	154.9
	R-1447	154.3
	R-1448	115.3
	R-1449	383.7
L.Sinoe	S-188	107.9
	S-189	124.2
	S-190	191.7

(1995), suspect pollution situations may be added for DDT concentrations in lakes Fortuna, Tătaru, Cutețchi and Matița. As the number of analyses is too reduced to allow an accurate evaluation of pesticide status in Danube Delta, these data must be considered only pre-liminary.

State and trends of contaminant dispersal and deposition

The Danube Delta represents a natural filter for various contaminants transported in solution, or adsorbed on suspended particulate matter. When the filter works, the contaminant concentrations in water and sediments will decrease from the main distributaries to the more distant lakes and channels. The modelling of transport, accumulation and transformation of dissolved and particulate substances in the Danube Delta must take into account a great number of factors: intervention of atmospheric inputs, influence of some polluting sources inside and around the deltaic area, hydrodinamic and physical-chemical conditions, reactivity of particles and natural processes of transfer between water, sediments and biota etc. The data obtained from various analyses of water, sediments and biota samples, collected during the 1995 cruise suggest some conclusions concerning the present status and the main trends in contaminant evolution in different areas of the Delta (Tables 5 and 9). The interdistributary depressions contain usually interrelated systems of lakes and channels, which show frequently common features. The distribution patterns of contaminants and other parameters in the Danube Delta emphasize the particularities of these areas. An overall evaluation of sediment and water quality state and tendencies has been carried out for the main hydro-morphological units contoured on the general map of the Danube Delta in Fig.1.

1. Depression Meşteru-Fortuna. This area became strongly influenced by Danube water supply after the cutting of the channel "Mile 35" between Tulcea and Chilia distributaries, in 1982. Lakes Meşteru, Lungu, and partially Tătaru suffered an intensive process of filling up with sediments and the more distant areas have been influenced by increased suspended solid inputs. In the eastern part of the depression, the Lake Fortuna received large amounts of sediments from River Danube through the channel Crânjală, while the lakes Cutețchi, Durnoi, Băclăneşti had more restricted conditions.

The contaminant inputs in Meşteru-Fortuna depression are dominated by riverine supplies. As a result, the highest metal contents of bottom sediments in Danube Delta are preferentially found in this area. Similar behaviour was noticed for concentrations of some metals in water samples. Environmental conditions could be characterised as follows:

Sediments (Table 5):

- certain pollution with As and secondary with Cr;
- increased levels of Ni, Mn, sometimes Cu, and accidentally Zn contents;
- increased values for the activities of the main artificial radionuclides, Cs-137 and Cs-134); (Fig.2).

Water (Table 9):

- accidentally high pH (lakes Lungu and Tătaru);
- very low oxygen concentrations in several more confined lakes and channels, with restricted circulation (lakes Cutețchi, Tătaru, channels Sireasa, Sontea);

Table 3 Correlation coefficients of chemical and physical parameters of bottom sediments in Danube Delta (n=41, P=0.05, r=0.3078)

Cu	1	0.3728	0.7053	0.3019	0.5641	0.448	0.4462	0.5696	0.393	0.5951	0.5466	-0.2854	-0.158	0.242
As		1	0.5235	0.3519	0.4062	0.1813	0.4016	0.5068	0.393	0.5118	0.4881	-0.3898	-0.2715	0.2645
Zn			1	0.5136	0.5899	0.398	0.7127	0.8011	0.479	0.844	0.8061	-0.5329	-0.2938	0.5395
Pb				1	0.3445	0.1753	0.5538	0.4237	0.344	0.4995	0.5027	-0.4717	0.0516	0.4295
Cd					1	0.446	0.579	0.6924	0.1026	0.5086	0.6444	-0.5693	-0.4486	0.4735
Ni						1	0.4206	0.55	0.2779	0.5147	0.5632	-0.2745	-0.2844	0.2869
Ba							1	0.7879	0.324	0.7377	0.8261	-0.7816	-0.3619	0.7899
Cr								1	0.2559	0.8309	0.9584	-0.773	-0.5702	0.6873
Mn									1	0.5615	0.3935	-0.0238	0.1078	0.0707
Fe_2O_3										1	0.9132	-0.6084	-0.2681	0.4883
Al_2O_3											1	-0.7528	-0.4538	0.6623
CaO												1	0.4418	-0.7441
TOC													1	-0.3921
MS														1
	Cu	As	Zn	Pb	Cd	Ni	Ba	Cr	Mn	Fe_2O_3	Al_2O_3	CaO	TOC	MS

Legend: TOC – Total Organic Carbon MS – Magnetic Susceptibility

Table 4 General sediment quality*. Legend.

Substance	Natural levels	Very good quality	Good quality	Middle quality	Bad quality	Very bad quality
		Normal situation	*Suspect situation*	*Certain pollution*	*Important pollution*	*Excessive pollution*
	ppm	ppm	ppm	ppm	ppm	ppm
	0	1	2	3	4	5
As	13	<20	20 - 60	60 - 180	180 - 540	>540
Ba	580					
Cd	0.3	<4.2	4.2 - 12.6	12.6 - 37.8	37.8 - 113.4	>113.4
Cr	90	<44	44 - 132	132 - 396	396 - 1188	>1188
Cu	45	<52	52 - 156	156 - 468	468 - 1404	>1404
Hg	0.4	<0.52	0.52 - 1.56	1.56 - 4.68	4.68 - 14.04	>14.04
Mn	850	<680	680 - 2040	2040 - 6120	6120 - 18630	>18630
Ni	68	<40	40 - 120	120 - 360	360 - 1080	>1080
Pb	20	<100	100 - 300	300 - 900	900 - 2700	>2700
Zn	95	<188	188 - 564	564 - 1692	1692 - 5076	>5076

* **Column 0** - Average natural concentration of trace metals in shales (Turekian and Wedepohl, *1961*)
Columns 1-5 - Standard levels for the Rhone-Mediterranean-Corse watershed (in Naffrechoux, *1992*)
Ba - data only after Turekian and Wedepohl

- increased levels of concentration for nitrites, and casually nitrates, in sites located close to agricultural polders, or under direct influence of the River Danube;
- important to excessive phosphate pollution (possible accidental contamination);
- increased concentrations of Fe, As, secondary Mn and Zn;
- important anomalous contents of Hg (lakes Lungu, Meşteru and Durnoi).

Within this depression the lakes Meşteru and Fortuna show the highest metal concentrations both in water and in sediments.

2. Depression Matiţa-Merhei. This area is far from the main distributaries of the River Danube, receiving commonly clear waters, poor in mineral suspended solids. The carbonatic-organic sediments prevails and sediment accumulation rate is very low. The atmospheric inputs can be taken into consideration for some substances Environment quality can be considered as follows:

Sediments (Table 5):

Table 5. General sediment quality in Danube Delta water systems.

1. Mesteru - Fortuna Depression

Location	As	Ba	Cd	Cr	Cu	Mn	Ni	Pb	Zn
L. Cutetchi	3	1	1	2	1	2	2	1	1
L. Lungu	2	1	1	2	2	1	2	1	1
L. Mesteru	3	1	1	3	1	2	2	1	2
L. Mesteru	3	1	1	3	2	2	2	1	2
L. Tataru	3	1	1	2	1	2	2	1	1
L. Tataru	2	1	1	2	1	2	2	1	1
L. Durnoi	3	1	1	2	2	1	2	1	1
L. Baclanesti	2	1	1	2	1	1	2	1	1
L. Fortuna	2	1	1	2	2	2	2	1	1
L. Fortuna	4	1	2	2	2	2	2	1	1

2. Matita - Merhei Depression

L. Trei Ozere	2	1	1	2	1	2	2	1	1
L. Bogdaproste	3	1	1	1	1	2	1	1	1
L. Bogdaproste	1	1	1	1	1	2	1	1	1
L. Matita	2	1	1	2	1	2	1	1	1
L. Babina	2	1	1	2	1	2	1	1	1
L. Merhei	2	1	1	1	1	2	1	1	1
L. Merhei	3	1	1	2	1	2	2	2	1

3. Gorgova - Uzlina Depression

Cn. Uzlina	3	1	1	2	1	1	2	1	1
L. Uzlina	3	1	2	2	2	2	2	1	2
L. Isacova	2	1	1	2	1	2	2	1	1
Cn. Nou	2	1	1	2	1	1	2	1	1
Cn. Perivolovca	3	1	1	2	1	1	2	1	1

4. Dranov Depression

L. Dranov	1	1	2	2	2	2	3	1	1
Cn. Dranov	3	1	1	2	1	2	2	1	1

5. Raducu - Raduculet Depression

L. Raducu	3	1	1	1	1	1	1	1	1

6. Lumina - Rosu Depression

L. Iacub	3	1	1	2	2	1	2	1	2
L. Puiu	1	1	1	2	1	1	2	1	1
L. Rosu	3	1	1	2	1	1	2	1	1
L. Rosu	1	1	1	1	1	2	2	1	1

7. Sf. Gheorghe Secondary Delta

Sacalin Bay	3	1	1	2	1	1	1	1	1

8. Razim - Sinoie Lacustrine-Lagoonal Complex

L. Razim	2	1	1	2	1	1	2	1	1
L. Razim	3	1	1	2	1	1	3	1	1
L. Razim	2	1	1	2	1	2	2	1	1
L. Razim	2	1	1	2	1	1	2	1	1
L. Razim	3	1	1	2	1	2	2	1	1
L. Razim	2	1	1	2	1	1	2	1	1
L. Golovita	3	1	2	2	1	1	2	1	1
L. Golovita	3	1	2	2	1	1	2	1	1
L. Sinoie	3	1	2	2	1	1	2	1	1
L. Sinoie	2	1	1	2	2	1	2	1	1
L. Sinoie	2	1	2	2	1	1	2	1	1

Table 6. Chemical and physical analyses of Danube Delta water samples (July, 1995)

Crt no.	Sample no.	Sample locations	O_2 mg/l	O_2 (%)	T°	CND mS/cm	TDS g/l	T°	Eh (mV)	pH	T°	SS mg/l	NO_3^- mg/l	NO_2^- mg/l	SO_4^{2-} mg/l	PO_4^{3-} mg/l
1.	DD 7529	Fortuna L.	8.9	102.2	24.4	0.381	0.190	24.4	242.0	8.20	25.8	2	0.44	0.050	31	0.37
2.	DD 7531	Băclănesti L.	5.75	74.8	25.4	0.386	0.194	24.8	210.0	7.64	24.7	4	1.01	0.100	33	0.20
3.	DD 7532	Tătaru L.	4.45	54.5	23.9	0.355	0.177	23.6	245.7	7.44	23.9	2	0.84	0.076	38	1.62
4.	DD 7533	Tătaru L.	14.25	165.4	24.0	0.349	0.175	24.1	178.6	8.63	24.7	-	-	-	-	-
5.	DD 7534	Lungu L.	9.19	107.5	23.8	0.388	0.195	24.0	186.3	8.88	24.0	15	1.94	0.092	40	0.695
6.	DD 7535	Cutetchi L.	3.63	42.1	25.7	0.391	0.196	23.9	194.6	7.42	26.2	7	2.42	0.175	58	3.395
7.	DD 7536	Mesteru L.	8.36	96.6	24.1	0.391	0.197	24.5	226.7	8.19	25.6	11	-	-	-	-
8.	DD 7537	Mesteru L.	7.49	88.0	24.0	0.391	0.197	24.5	231.2	8.06	25.4	16	-	-	-	-
9.	DD 7538	Durnoi L.	6.80	79.9	24.0	0.390	0.196	24.2	200.2	8.01	24.1	3	3.96	0.069	39	3.62
10.	DD 7538B	Durnoi L.	7.74	91.2	24.1	0.394	0.197	24.2	232.1	8.09	23.6	5	4.29	0.079	38	1.92
11.	DD 7539	Bogdaproste L.	15.28	185.8	26.8	0.355	0.178	27.3	216.4	8.62	28.6	-	-	-	-	-
12.	DD 7540	Bogdaproste L.	11.84	144.0	26.7	0.361	0.182	27.4	223.8	8.26	29.2	6	0.44	0.025	36	0.02
13.	DD 7541	Trei Ozere L.	10.10	123.0	26.4	0.383	0.192	27.0	214.5	7.92	27.4	5	0.22	-		
14.	DD 7542	Merhei L.	8.26	98.6	25.3	0.412	0.207	25.5	349.3	8.10	25.9	12	0.26	0.020	28	1.00
15.	DD 7543	Merhei L.	8.59	101.4	24.9	0.397	0.199	23.3	213.3	8.21	25.8	16	0.31	0.036	32	1.02
16.	DD 7544	Matita L.	10.13	121.9	25.3	0.400	0.200	25.8	195.1	8.06	27.5	18	0.26	0.026	31	0.54
17.	DD 7545	Babina L.	8.10	96.8	25.6	0.403	0.202	26.3	206.6	7.93	27.6	10	0.26	0.020	29	1.82
18.	DD 7546	Litcov Cn.	1.37	15.9	24.9	0.361	0.181	25.3	190.1	7.12	26.4					
19.	DD 7547	Nou Cn.	4.14	49.8	25.7	0.364	0.183	26.3	224.6	7.38	27.6					
20.	DD 7548	Isacova L.	10.12	123.1	26.5	0.368	0.185	27.0	205.9	8.45	28.2	8	0.18	0.010	32	0.72
21.	DD 7548B	Isacova L.	9.68	115.9	26.1	0.376	0.188	26.4	206.9	8.40	27.7					
22.	DD 7549	Uzlina-Isacova Cn.	12.07	147.3	27.2	0.360	0.181	28.0	173.0	8.70	29.5					
23.	DD 7550	Uzlina L.	10.37	123.7	26.5	0.390	0.200	27.2	203.3	8.40	28.5	6	4.62	0.152	64	0.49
24.	DD 7551	Uzlina Cn.	8.61	101.0	23.9	0.392	0.197	24.2	201.5	8.15	24.4					
25.	DD 7552	Perivolovca Cn.	2.31	28.4	25.8	0.364	0.182	26.2	186.9	7.43	26.5					
26.	DD 7553	Panaiotu Cn.	10.50	130.0	26.9	0.362	0.182	27.1	198.9	8.36	27.4					
27.	DD 7554	Iacub L.	4.94	58.5	25.4	0.371	0.189	25.5	207.4	7.47	26.6	10	1.14	0.053	33	0.41
28.	DD 7555	Răducu L.	7.95	88.6	28.0	0.458	0.230	30.3	205.9	8.21	31.0	6	0.44	0.013	34	0.17
29.	DD 7555B	Răducu L.	7.60	90.2	27.9	0.461	0.232	28.4	245.3	8.05	27.8	20	0.40	0.026	26	0.25
30.	DD 7556	Caraorman Cn.	1.42	50.9	26.4	0.377	0.189	27.0	210.0	7.41	27.8					
31.	DD 7557	Puiu L.	11.13	130.0	28.8	0.388	0.195	29.2	222.5	8.51	29.4	5	0.33	0.010	34	3.65
32.	DD 7557B	Puiu L.	5.39	60.6	26.1	0.395	0.198	26.3	226.3	7.68	26.6	63				
33.	DD 7558	Rosu-Puiu Cn.	7.13	82.4	27.3	0.396	0.199	28.0	205.2	7.86	27.7					
34.	DD 7559	Rosu L.	9.05	107.0	28.1	0.400	0.200	28.5	222.1	8.20	28.6					
35.	DD 7560	Rosu L.	13.61	164.8	28.2	0.396	0.199	28.5	160.6	8.78	28.3	13	0.33	0.017	28	1.02
36.	DD 7561	Sacalin Bay	4.96	71.9	26.1	0.432	0.217	26.6	193.7	7.47	27.6	6	0.26	0.020	28	1.82
37.	DD 7562	Dranov Cn.	8.22	92.5	25.4	0.362	0.181	25.5	179.5	8.20	25.8	31	3.85	0.150	36	0.52
38.	DD 7563	Dranov L.	11.81		26.2	2.07	1.03	25.7	152.4	8.68	25.8	39	0.55	0.040	167.5	0.32
39.	DD 7563B	Dranov L.	9.77	122.8	27.3	2.07	1.03	28.6	173.4	8.64	28.2					
40.	DD 7564	Dranov L.	11.78		25.9	2.07	1.04	26.2	177.9	8.86	26.5	28	0.44	0.043	165	0.02
41.	DD 7565	Dranov Cn.	4.45	48.2	25.3	0.402	0.202	25.6	206.9	7.45	26.2	20	2.20	0.076	35	0.12
42.	DD 7565B	Dranov Cn.	6.59		26.0	0.399	0.200	26.6	206.3	7.51	26.0					
43.	DD 7566	Dunavăt Cn.				0.360	0.180	24.3	179.8	7.38	23.6	20	3.85	0.195	36	1.62
44.	DD 7567	Dunavăt Cn.	8.35	88.0	25.5	0.394	0.198	25.7	178.2	8.29	26.3	26	4.84	0.244	37	1.62
45.	R - 1442	Razim L.	8.58	96.4	26.1	0.421	0.214	26.4	169.2	7.83	27.3	21	1.54	0.050	37.5	0.72
46.	R - 1443	Golovita L.	13.28		25.9	0.637	0.319	26.1	165.0	9.19	26.7	63	0.77	0.083	56	2.72
47.	R - 1443B	Golovita L.	10.94		25.6	0.636	0.319	25.9	188.2	8.98	27.3					
48.	R - 1444	Golovita L.	15.29		26.8	0.542	0.273	27.4	134.6	9.12	28.0	58	0.66	0.086	55	0.92
49.	R - 1444B	Golovita L.	9.66		25.9	0.600	0.301	26.4	200.1	8.88	26.8	87	0.77	0.096	65	1.12
50.	R - 1445	Razim L.	10.11	108.3	25.3	0.430	0.215	25.3	142.7	8.90	25.7	20	0.55	0.050	45	1.62
51.	R - 1445B	Razim L.	9.09	92.2	25.5	0.436	0.218	25.6	199.6	6.96	25.7					
52.	R - 1446	Razim L.	13.22		26.6	0.416	0.208	26.9	191.5	9.11	27.5					
53.	R - 1446B	Razim L.	10.51		26.7	0.419	0.210	26.9	209.8	8.95	27.3					
54.	R - 1447	Razim L.				0.422	0.212	25.1	180.4	8.95	26.1	59	0.77	0.092	47	0.62
55.	R - 1447B	Razim L.				0.427	0.215	25.6	223.1	8.89	26.8	84	0.77	0.106	45	0.75
56.	R - 1448	Razim L.				0.423	0.213	25.6	209.0	9.06	27.1					
57.	R - 1449	Razim L.				0.398	0.199	26.8	212.2	7.77	27.5	21	3.74	0.172	37	1.96
58.	R - 1449B	Razim L.				0.398	0.184	25.6	226.4	7.78	26.7	20		0.168	37	3.32
59.	S - 188	Sinoe L.	9.70		25.8	1.641	0.822	26.0	160.2	8.98	27.1	107	0.77	0.119	107.5	2.32
60.	S - 188B	Sinoe L.	8.96		25.9	1.684	0.844	26.3	202.0	8.09	27.9					
61.	S - 189	Sinoe L.	10.85	111.0	26.2	0.758	0.383	26.8	198.6	9.22	27.5	79	0.66	0.086	66	5.52
62.	S -189B	Sinoe L.	10.13	113.1	26.2	0.788	0.395	26.8	201.4	9.21	28.1					
63.	S - 190	Sinoe L.	10.54	112.4	26.0	0.423	0.212	26.2	207.4	9.17	27.8					
64.	E - 1	Sireasa Cn.	4.13	48.5	25.4	0.393	0.197	25.5	195.0	7.44	26.2	2	1.14	0.122	37	2.52
65.	E - 2	Vencova Cn.	8.02	95.1	25.1	0.384	0.195	25.6	233.6	8.22	25.2	29	5.72	0.195	61	0.57
66.	E - 3	Sontea Cn.	5.52	65.5	24.6	0.383	0.192	24.8	232.3	7.64	24.8	4	3.30	0.066	38	2.02
67.	E - 4	Dunărea Veche Br.	3.31	39.3	24.4	0.339	0.170	24.4	184.2	7.37	23.9	5	0.92	0.036	35	0.47
68.	E - 5	Dunărea Veche Br.	3.46	41.5	25.4	0.385	0.193	25.9	219.4	7.38	26.6	5	1.10	0.020	52	0.62
69.	P95	Popina Is.				3.22	1.61	22.8	163.6	7.33	26.4	3	10.824	0.010	130	2.22

B - bottom water

Table 7 Trace element concentrations in Danube Delta water samples (July, 1995)

Crt. no.	Sample no.	Location	Cr µg/l	Al µg/l	Co µg/l	Cu µg/l	As µg/l	Hg µg/l	Se µg/l	Zn µg/l	Pb µg/l	Cd µg/l	Ni µg/l	Mn µg/l	Fe µg/l
1.	DD 7529	Fortuna Lake	0.12	397	1.20	8.6	17.9	< 1.0	33.0	55.7	9.0	0.64	1.42	438	532
2.	DD 7531	Băclănești L.	0.12	177	0.82	2.5	21.3	< 1.0	34.2	13.2	8.5	0.53	1.30	34	140
3.	DD 7532	Tătaru L.	0.17	289	1.25	9.9	18.9	< 1.0	37.4	15.7	10.0	0.71	1.95	64	420
4.	DD 7534	Lungu L.	0.23	327	1.33	5.2	21.7	1.94	44.1	5.7	10.4	0.84	1.91	57	283
5.	DD 7535	Cutetchi L.	0.24	224	1.06	7.0	21.4	< 1.0	36.7	12.0	10.4	0.88	1.81	110	245
6.	DD 7536	Mesteru L.	1.48	745	1.48	9.7	20.4	1.38	39.5	22.4	9.8	0.76	2.14	50	402
7.	DD 7538	Durnoi L.	0.36	177	0.80	3.2	21.2	1.74	34.5	9.2	10.2	0.77	2.19	36	134
8.	DD 7540	Bogdaproste L.	0.24	98	0.97	< 2.0	12.9	< 1.0	28.3	4.3	5.4	< 0.4	0.82	275	62
9.	DD 7541	Trei Ozere L.	0.21	181	1.15	60.1	17.1	< 1.0	32.0	19.2	8.8	0.59	1.53	1120	193
10.	DD 7542	Merhei L.	0.20	209	1.36	4.6	19.3	< 1.0	28.7	19.5	10.1	0.71	1.05	190	206
11.	DD 7543	Merhei L.	0.17	133	0.96	< 2.0	19.4	< 1.0	26.1	5.3	6.8	0.40	0.86	82	62
12.	DD 7544	Matita L.	0.16	105	0.89	< 2.0	22.5	< 1.0	37.2	4.0	9.5	0.43	1.02	93	48
13.	DD 7545	Babina L.	0.12	201	0.98	< 2.0	20.2	< 1.0	35.4	4.8	7.8	0.54	1.14	92	142
14.	DD 7548	Isacova L.	0.35	118	0.57	< 2.0	17.0	< 1.0	27.3	11.0	6.7	< 0.4	0.99	81	80
15.	DD 7550	Uzlina L.	1.17	639	1.50	4.7	20.9	< 1.0	33.1	9.6	7.9	0.73	1.84	105	587
16.	DD 7554	Iacub L.	0.33	166	0.80	2.5	19.8	< 1.0	30.8	< 2.0	10.1	0.64	1.42	76	169
17.	DD 7555	Răducu L.	0.31	125	1.10	< 2.0	21.6	< 1.0	33.0	4.6	8.5	0.60	0.70	64	53
18.	DD 7557	Puiu L.	0.28	176	0.84	2.5	25.2	2.34	34.5	10.9	16.8	1.53	2.92	302	202
19.	DD 7559	Rosu L.	0.23	87	0.95	< 2.0	21.2	2.00	31.6	5.3	15.1	1.35	2.43	71	123
20.	DD 7562	Dranov Cn.	0.69	563	1.42	4.7	24.0	1.00	26.6	8.1	13.3	1.23	3.14	62	598
21.	DD 7563	Dranov L.	4.61	1330	4.80	6.3	65.5	16.5	76.2	48.1	32.6	3.84	7.87	245	1790
22.	DD 7566	Dunavăț Cn.	0.34	205	0.83	2.4	22.9	1.57	28.4	2.5	16.5	1.29	2.38	20	158
23.	R - 1442	Razim L.	0.29	111	0.76	< 2.0	21.6	2.53	29.3	4.2	15.0	1.41	2.53	49	86
24.	R - 1443	Golovita L.	1.93	1230	2.93	3.6	40.4	7.66	58.5	34.7	24.9	1.95	5.58	207	1350
25.	R - 1445	Razim L.	0.33	434	1.42	2.9	27.0	2.92	41.8	6.2	18.9	1.86	3.43	76	490
26.	R - 1448	Razim L.	0.31	238	1.42	2.0	28.4	3.95	38.5	2.1	18.6	1.65	3.63	47	303
27.	R - 1449	Razim L.	0.18	179	0.73	2.1	22.0	1.00	26.8	2.5	15.5	1.46	2.57	27	161
28.	S - 188	Sinoe L.	2.09	1180	4.16	2.3	48.0	13.9	73.2	8.2	35.3	3.17	7.56	286	2110
29.	S - 189	Sinoe L.	0.08	397	2.12	< 2.0	36.1	7.97	44.4	4.2	24.6	2.04	4.41	124	624
30.	P95	Popina Is.	0.49	95	4.48	< 2.0	68.5	22.6	106	< 2.0	46.9	4.75	5.58	< 2	< 10

- increased As, subordinately Mn and accidentally Cr, Ni, Pb contents.

Water (Table 9):

- low oxygen concentration in Dunarea Veche distributary, where the waterflow is very slow;

- medium to important phosphate pollution;

- increased concentrations of Mn, As, Hg, sometimes Fe and Zn, and accidentally Cu.

Within this zone the metal concentrations in the water and in the sediments are usually higher in the lakes Trei Ozere and Merhei .

3. Depression Gorgova-Uzlina. Some of the lakes located within Gorgova-Uzlina depression are influenced by riverine supplies (Uzlina) but, usually, these influences are unimportant (Gorgova, Isacova). The sediments consist predominantly of mineral muds in the first category, and carbonate-organic muds in the second. Environment quality is characterised by the following data:

Sediments (Table 5):

- certain level of pollution with As;

- increased contents of Cr, Ni, subordinately Mn, and accidentally Cd, Cu, Zn.

Water (Table 9):

- very low oxygen concentrations in channels (Litcov, Nou and Perivolovca);

- increased nutrient contents (mainly phosphate);

- increased Mn, Hg, As and possibly Fe and Zn concentrations.

Lake Uzlina shows the most elevated contents for metals in water and sediments.

4. Depression Dranov. This unit is situated between Sf. Gheorghe distributary and Lake Razim. The depression contains an important lake - Dranov, and is cut by two main channels, Dunavăț and Dranov, which represent the principal pathways for the Danube waters towards the Lake Razim. Within the Lake Dranov, which was isolated and transformed in fishing pool 30 years ago, the water supplies from the Danube are insufficient, the evaporation is intense, and the lacustrine environment has been deteriorated. Moreover, around the lake, the land is covered by soils showing moderate to strong salinity, which can contribute with important salt discharges, leached by surface runoff. Environmental quality shows the following features:

Sediments (Table 5)):

- high values for Ni, Mn, Cr, and subordinately As, Cd, Cu.

Water (Table 9):

- high pH in the lake Dranov and oxygen deficit in the channels Dranov and Dunavăț;

- elevated nutrient concentrations, mainly of phosphate, and less of nitrite; the high values is more evident in the Dunavăț channel;

- high sulphate concentration in the Lake Dranov;

- important to excessive pollution in the Lake Dranov with Hg and Fe, and increased levels for all other metal contents;

Table 8 General water quality*. Legend.

Substance		Very good quality	Good quality	Middle quality	Bad quality	Very bad quality
		Normal situation	*Suspect situation*	*Certain pollution*	*Important pollution*	*Excessive pollution*
		1	2	3	4	5
pH		6.5-8.5			5.5 - 6.5 ; 8.5 - 9.5	<5.5; >9.5
O_2	mg/l	>7	5 - 7	3 - 5	<3	
O_2	%	>90	70 - 90	50 - 70	<50	
NO_2^-	mg/l	<0.1	0.1 - 0.3	0.3 - 1	1 - 2	>2
NO_3^-	mg/l	<5	5 - 25	25 - 50	50 - 80	>80
PO_4^{3-}	mg/l	<0.2	0.2 - 0.5	0.5 - 1	1 - 2	>2
SO_4^{2-}	mg/l	<150	150 - 250	250 - 400	>400	
As	µg/l	<10	10 - 50	50 - 100	>100	
Cd	µg/l	<1	1 - 3	3 - 5	>5	
Cr	µg/l	<5	5 - 15	15 - 50	>50	
Cu	µg/l	<20	20 - 40	>40		
Fe	µg/l	<100	100 - 300	300 - 1000	1000 - 2000	>2000
Hg	µg/l	<0.5	0.5 - 1		>1	
Mn	µg/l	<50	50 - 100	100 - 500	500 - 1000	>1000
Ni	µg/l	<50	50 - 100	100 - 300	300 - 1000	>1000
Pb	µg/l	<20	20 - 50		>50	
Zn	µg/l	<10	10 - 125	125 - 300	300 - 1000	>1000

* Data compiled after EEC, French and Romanian directives

- increased values of Hg, Fe, As, Cd, and Mn contents in channels Dranov and Dunavăț.

The Lake Dranov shows the most altered environmental conditions, compared to all the investigated lakes within the Danube Delta, and contains maximal concentrations for almost all metals determined in water.

5. Depression Răducu-Răduculet. This is a small depression located between two main sets of paleo-beach ridges of the Răducu accumulative littoral formation. The Lake Răducu is not very strongly influenced by the riverine inputs and shows restricted environmental conditions. The sediments are calcareous-organic. Environmental conditions are characterised as follows:

Sediments (Table 5):

- certain pollution with As.

Water (Table 9):

- increased concentrations of phosphate, As, Hg, Mn.

6. Depression Lumina-Roşu. The lakes and channels included in this depressions are to some extent influenced by Danubian supplies. The Lake Iacub is most exposed, followed by the Lake Puiu, both undergoing more or less important inputs via the channel Crisan-Caraorman. The Lake Roşu is more isolated, but can be influenced in the western part by supplies from the Lake Puiu and in the eastern part by marine inputs which came through the Lake Roşulet especially in the winter time. Since 1989, the outlet "Canalul Sondei" has been closed, and the marine water income is quite totally suppressed. The sediments are predominantly carbonatic-organic in the Lake Roşu, and more clayey in the lakes Puiu and Iacub. Environment quality is revealed by the following peculiarities:

Sediments (Table 5):

- increased concentrations of As, Ni, Cr and sometimes of Cu, Mn, Zn;

Water (Table 9):

- accidentally high pH values (lakes Puiu, Roşu);
- oxygen deficiency in the lakes Iacub, Puiu and in the channels Caraorman and Roşu/Puiu;
- generally important phosphate contents;
- important levels of Hg concentration in the lakes Roşu and Puiu;
- increased contents of Mn, Fe, As, and subordinately Cd and Zn.

The highest contaminant values in water and sediments are found usually in the lakes Iacub and Puiu, situated closer to the magistral channel Crisan-Caraorman, which brings Danubian water directly from Sulina distributary.

7. Sf. Gheorghe secondary delta. This unit is a relatively recent depositional system built up

Table 9 General water quality in Danube Delta water systems.

1. Mesteru - Fortuna Depression

Location	pH	O_2	O_2'	NO_2^-	NO_3^-	PO_4^{3-}	SO_4^{2-}	As	Cd	Cr	Cu	Fe	Hg	Mn	Ni	Pb	Zn
L. Cutetchi	1	3	4	2	1	5	1	2	1	1	1	2	2	3	1	1	2
Cn. Sireasa	1	3	4	2	1	5	1										
Cn. Vencova	1	1	1	2	2	3	1										
L. Lungu	4	1	1	1	1	3	1	2	1	1	1	2	4	2	1	1	1
L. Mesteru	1	1	1					2	1	1	1	3	4	1	1	1	2
L. Mesteru	1	1	2														
Cn. Sontea	1	2	3	1	1	3	1										
L. Tataru	1	3	3	1	1	4	1	2	1	1	1	3	2	2	1	1	2
L. Tataru	4	1	1														
L. Durnoi	1	2	2	1	1	5	1	2	1	1	1	2	4	1	1	1	1
L. Durnoi	1	1	1	1	1	4	1										
L. Baclanesti	1	2	2	1	1	1	1	2	1	1	1	2	2	1	1	1	2
L. Fortuna	1	1	1	1	1	2	1	2	1	1	1	3	2	3	1	1	2

2. Matita - Merhei Depression

L. Trei Ozere	1	1	1	1	1			2	1	1	3	2	2	5	1	1	2
L. Bogdaproste	4	1	1	1													
L. Bogdaproste	1	1	1	1	1	1	1	2	1	1	1	1	2	3	1	1	1
L. Matita	1	1	1	1	1	3	1	2	1	1	1	1	2	2	1	1	1
L. Babina	1	1	1	1	1	4	1	2	1	1	1	2	2	2	1	1	1
L. Merhei	1	3	1	1	1	3	1	2	1	1	1	1	2	3	1	1	2
L. Merhei	1	1	1	1	1	4	1	2	1	1	1	2	2	2	1	1	1
Cn. Dunarea Veche	1	3	4	1	1	2	1										
Cn. Dunarea Veche	1	3	4	2	1	3	1										

3. Gorgova - Uzlina Depression

Cn. Uzlina	1	1	1														
L. Uzlina	1	1	1	2	1	2	1	2	1	1	1	3	2	3	1	1	1
Cn. Uzlina-Isacova	4	1	1														
L. Isacova	1	1	1	1	1	3	1	2	1	1	1	1	2	2	1	1	2
L. Isacova	1	1	1														
Cn. Litcov	1	4	4														
Cn. Nou	1	3	4														
Cn. Perivolovca	1	4	4														
Cn. Panaiotu	1	1	1														

4. Dranov Depression

L. Dranov	4	1	1	1	1	2	2	3	3	1	1	4	5	3	1	2	2
L. Dranov	4	1	1														
L. Dranov	4	1	1	1	1	1	2										
Cn. Dranov	1	1	1	3	1	3	1	2	2	1	1	3	2	2	1	1	1
Cn. Dranov	1	3	4	1	1	1	1										
Cn. Dranov	1	2	1														
Cn. Dunavat	1	1	2	2	1	4	1										
Cn. Dunavat	1			2	1	4	1	2	2	1	1	2	4	1	1	1	1

5. Raducu - Raduculet Depression

L. Raducu	1	1	2	1	1	1	1	2	1	1	1	1	2	2	1	1	1
L. Raducu	1	1	1	1	1	2	1										

6. Lumina - Rosu Depression

L. Iacub	1	3	3	1	1	2	1	2	1	1	1	2	2	2	1	1	1
Cn. Caraorman	1	4	3														
L. Puiu	4	1	1	1	1	5	1	2	2	1	1	2	4	3	1	1	2
L. Puiu	1	2	3														
Cn. Rosu-Puiu	1	1	2														
L. Rosu	1	1	1					2	2	1	1	2	4	2	1	1	1
L. Rosu	4	1	1	1	1	4	1										

7. Sf. Gheorghe Secondary Delta

Sahalin Bay	1	3	2	1	1	4	1										

8. Razim - Sinoie Lacustrine-Lagoonal Complex

L. Razim	1	1	1	2	1	4	1	2	2	1	1	2	4	1	1	1	1
L. Razim	1	1	1	2		5	1										
L. Razim	4	1	1					2	2	1	1	3	4	1	1	1	1
L. Razim	4	1	1	1	1	3	1										
L. Razim	4	1	1	2	1	3	1										
L. Razim	1	1	1	1	1	3	1	2	2	1	1	1	4	1	1	1	1
L. Razim	4	1	1														
L. Razim	4	1	1														
L. Razim	4	1	1	1	1	4	1	2	2	1	1	3	4	2	1	1	1
L. Razim	1	1	1														
L. Golovita	4	1	1	1	1	3	1										
L. Golovita	4	1	1	1	1	4	1										
L. Golovita	4	1	1	1	1	5	1	2	2	1	1	4	4	3	1	2	2
L. Golovita	4	1	1														
		1	1														
L. Sinoie	4	1	1	2	1	5	1	2	3	1	1	5	5	3	1	2	1
L. Sinoie	1	1	1														
L. Sinoie	4	1	1	1	1	5	1	2	2	1	1	3	4	3	1	2	1
L. Sinoie	4	1	1														
L. Sinoie	4	1	1														

Popina Island Spring	1			1	2	5	1	3	3	1	1	1	5	1	1	2	1

under the direct influence of the Sf. Gheorghe Branch. The Danubian sediment load generated to the south of the distributary mouth a lateral arcuated littoral ridge-Island Sakhalin, which undergoes a continuous process of erosion-deposition, controlled by the riverine sediment input and a very strong southward littoral drift of sediments.

The only sample collected in this area is located in the bay at the back of the Island Sakhalin. The bay is influenced by two secondary distributaries, Seredne and Gârla Turcului, which usually determine mixed brackish to fresh water conditions in this area. The environment quality is suggested by the following analytical data:

Sediments (Table 5):

- As and Cr increased values.

Water (Table 9):

- some oxygen deficiency and high phosphate concentrations.

8. Razim-Sinoie lacustrine-lagoonal complex. The Lake Razim is continuously supplied with River Danube water, mainly through Dunavăţ and Dranov channels. The riverine influences are obvious in the channel mouths zone where depositional processes are more important. The general slow waterflow directed southwards, towards Sinoie, transports water and suspended sediments of Danubian origin. The lakes are not deep (2.5-3.5 m), and during the storms the uppermost part of the bottom sediments is resuspended and transported towards south. Diffuse inputs of more or less polluted water and suspended solids are provided by surficial runoff from the land, around the western border of the lacustrine system. Various human activities (mining, pig-rearing farms, domestic sewage) can constitute point sources, as well. The huge industrial area located southward of the Lake Sinoie may contribute with atmospheric inputs from refineries, fertiliser factories etc.). Environment quality conditions could be characterised by several parameters:

Sediments (Table 5):

- moderate pollution with As, more intense in the southern lakes;
- generally increased concentration levels for Cr and Ni (in all samples), subordinately for Cd (in the southern zone), and accidentally for Mn (in the northern zone).

Water (Table 9):

- pH exceeds 8.5 in almost all the samples;
- nitrites are slightly exceeding the standards in north Razim, and phosphate contents show important to excessive pollution;
- important pollution with Hg in almost all stations;
- certain to important Fe pollution;
- increased values of As and Cd contents in the whole area and for Mn and Pb in the Lake Sinoie.

The sites with the most important anomalous contents are located in the lakes Golovița and Sinoie.

A special attention was paid to the artesian spring from the Island Popina, situated in the northern sector of the Lake Razim. Its water shows very high conductivity (3.22 mS/cm) and TDS (1.61 g/l), high NO_3^- (10.82 mg/l) and phosphate contents (2.22 mg/l) and very high concentration of sulphate (130 mg/l). The metal concentrations exceed the allowable limits for Hg (22.6 μg/l), As (68.5 μg/l), Cd (1.75 μg/l), Pb (46.9 μg/l), or show maximum values for Se (106 μg/l), and Co (4.48 μg/l) (Tables 6, 7 and 9).

CONCLUSIONS

A general overview on the pollution state of the Danube Delta, as results from this data set, shows only moderate to small degradation of the ecosystems. Even if the sampling was performed in single or, some times, in two stations for each investigated lake, the general distribution and the common tendencies put in evidence for various parameters, allow to draw several conclusions concerning the distribution of contaminants in the Danube Delta.

The main **metallic pollutants** in ***sediments*** are As, Cr, Ni, and subordinately Mn, which show somehow increased concentrations in all studied areas, but only accidentally reaching an important pollution level (As content in the Lake Fortuna). There are slight accumulation tendencies for Cu in Meşteru-Fortuna depression and Cd in Razim-Sinoie complex. As it was already mentioned, for the time being, the natural background of the sediments provided by the River Danube watershed is unknown and the present evaluation is only preliminary. Otherwise, the distribution patterns of the Al-normalised values suggest a higher natural level for Cr, Ni and Mn, with tendencies for natural accumulation in environments rich in organic matter, namely Matiţa-Merhei and Lumina-Roşu depressions.

The **physical-chemical** state of the Danube Delta ***water*** shows generally normal values concerning O_2 concentrations, conductivity, dissolved solid contents, Eh and pH. Some differences observed between Danube Delta lakes and channels with locally stagnant and/or confined water bodies are generally not directly connected to the recent anthropic activities. The lowest oxygen levels were measured in slow water flow channels (Sireasa, Litcov, Nou, Perivolovca, Caraorman and Dunarea Veche distributary). The highest pH values characterise the Lake Dranov and the Razim-Sinoie lacustrine complex.

Suspended solid contents are influenced both by mineral particulate matter inputs of riverine origin, and by phytoplankton "blooms". Anomalous concentration of sulphate and consequently very high conductivity and total dissolved solids were found in the Lake Dranov.

The **nutrient** contents of the ***water*** generally consist of low values for nitrites and nitrates and of very high ones for phosphates. The increased levels have been reported within Meşteru-Fortuna depression and in the channels Dranov and Dunavăţ. The eutrophication phenomena observed in numerous areas, including the lakes Razim-Sinoie, show the impact of these nutrient inputs. The nutrient contents are usually higher in lacustrine areas situated near agricultural lands. Moreover, phosphorus may be supplied in larger amounts from point sources. Detergents containing phosphates may be discharged even from the boats. The high values measured in lakes Razim, Goloviţa and Sinoie, far from the direct riverine inputs, could be the effect of such sources (pig-rearing farms, mining industry) located on the western border of the lacustrine complex.

As concerns **trace metals** in ***water***, the main increasing concentration trends have been observed for Hg, Fe, Mn, As, Cd, with anomalous values mainly for Hg and sometimes Fe. The dispersal of trace metals in Danube Delta waters is controlled mainly by riverine supplies, filtering mechanisms, including adsorbtion and desorbtion phenomena, and subordinately, by atmospheric inputs. The intervention of eolian pathway could be an explanation for the gradually increasing values registered from north to south in Razim-Sinoie lake system for Fe, Al, Hg, Ni, Pb, Cd, As, Se and Co.

The areas which cumulate the most anomalous parameters, and could be considered under stress, are the Meşteru-Fortuna depression, the Lake Dranov and partly the lakes Goloviţa and Sinoie. A special attention must be paid to the Lake Dranov, where most of the measured parameters show abnormal values as compared with other lakes in the Danube Delta: low Eh, high pH, the highest concentrations of SO_4^{2-}, Al, Hg, Cr, Cd, As, Ni, Se, Co and among the highest Pb, Zn, Mn, Fe abundance. The enrichment mechanism is natural, but the cause is anthropic: the Lake Dranov was isolated in the sixties and transformed in a semi-natural fishing pool. The evaporation-crystallisation phenomena prevail, or are in equilibrium with the slight riverine inputs, and this prevalence leads to a dangerous salt content increase. Disappearance or diminution of valuable fish species have been observed, yet, in this lake.

As regards the unusual physical and chemical parameters of the Island Popina spring, only a natural cause may be invoked: the deep origin of the water. The artesian springs were encountered in several places on the southern end of the calcareous island and most likely are tectonically controlled. In this case, artesian water emergences could exist in other places under Lake Razim water, contributing, in time, with significant heavy metal loads. In fact, LANDSAT images obtained in the winter time show anomalous temperatures southwards of Island Popina, possibly connected to underwater sources.

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