ENVIRONMENTAL STATE OF THE DANUBE RIVER IN 1996

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Abstract: The Danube River has the biggest water and sediment discharge into the Black Sea. The main anthropic objectives are represented by Portile de Fier I and II dams, that induced a dramatically decrease of the water and sediment discharges into the Black Sea. The measured discharges for June 1996 were higher than the multiannual mean values. Nine left tributaries of the Danube River transport important quantities of pollutants, thus representing local pollution hot spots. The bottom sediments grain size analysis shows that most of them are sands, excepting the sediments from dam lakes areas (muds and silts in the Portile de Fier I dam lake and gravels, with a thin cover of silt and mud, in Portile de Fier II lake) and the mouths of the Danube Delta distributaries (silt, mud). Heavy metals contents in bottom sediments vary along the river. The contents are higher in fine sediments. Therefore, the highest concentrations were measured in the samples collected from the Portile de Fier I and II dam lakes. Mining activities represent the most important anthropic factor that generates high pollutants contents. Other important values were measured downstream the town ports and the junctions with the main Romanian tributaries. Water samples were also analysed. According to the pH - E_{H2} diagram the water quality is classified as "aerobic septic water". Nutrient fluxes (detergents, phenols, etc.) also have important values. Samples collected at the mouths of the main Romanian tributaries show high values for almost all the analysed pollutants. Diatoms assemblages, another important pollution index, show a low pollution level for Portile de Fier I dam lake. The high resolution gamma spectrometry analyses were performed on two cores in the Portile de Fier I lake, thus obtaining the values of sedimentation rates, considering the basis of measurements the maximal concentration of artificial radionuclides represented by the moment of the Chernobyl accident. The comparison between the pollutants contents measured in 1995 and 1996 show than the environmental state of the Danube River has improved in 1996. Several results are presented at the end of the paper.

Key words: water discharge, sediment discharge, bottom sediments, water quality, bottom sediments grain size, heavy metals contents, diatoms assemblages, gamma spectrometry, main Romanian tributaries, Danube River.

INTRODUCTION

The Danube River (Fig.1) is the largest river to discharge into the Black Sea, with a total length of about 2850 Kilometres and a drainage basin of 817 000 Km^2 (Kristiansen et al. in Stanners and Bourdeau, 1995). The Romanian Danube watershed has 1075 Kilometres in length and represents the lower course of the river. The multiannual mean water discharge was of about 6047 m^3s^{-1} and 51.7 million t/year for transported sediments (Bondar, 1991), these values being the average till the building of the Portile de Fier I Dam. After the building of the Portile de Fier I Dam at Km 942.9 (in 1970), the sediment flux decreased as an important process of sedimentation began to take place in the Portile de Fier I dam lake (about 30-32 million tons/year). Downstream the Portile de Fier II Dam (that was built between 1982-1985 at Km 864) the sediment discharge is not higher than 20-30 million tons/year (Panin et al., 1996). Therefore, it can be said that these two dams represent the most important anthropic factor for the Danube River - Black Sea environmental system.

The following important tributaries are situated along the Romanian territory, on the left bank of the Danube: Jiu (90 m^3/s multiannual mean water discharge), Olt (160 m^3/s), Vedea (12 m^3/s), Arges (65 m^3/s), Ialomita (40 m^3/s), Siret (210 m^3/s), Prut (86 m^3/s) (Waters Cadastral Atlas from Romania, 1992).

This paper deals with a brief presentation of the results regarding the nutrients and heavy metals in sediments (grabs and cores) and surface waters.

The longitudinal study of the river was completed on 42 cross-sections (Fig.2) that were grouped in the following sectors: Portile de Fier I and II dam lakes, the river between Portile de Fier II dam and Mile 44 (entrance on the Danube Delta territory) and the main Danube Delta distributaries - Chilia, Tulcea, Sulina and Sf. Gheorghe. Studies were also made at nine confluences with the main Romanian tributaries: Cerna, Topolnita, Jiu, Olt, Vedea, Arges, Ialomita, Siret and Prut.

During the cruise (June-July, 1996) the measured values of water and sediment discharges were: 8580 m^3/s at Km 1072.4-Bazias (entrance of the river on the Romanian territory), 8740 m^3/s at the beginning of the Danube Delta (Mile 44-Ceatal Izmail). The measured discharge values during the cruise were higher than the multiannual mean level. The transported suspended sediment was 400 Kg/s at Km 1047-Moldova Nouă and 287 Kg/s at Mile 44-Ceatal Izmail, upstream Danube Delta territory.

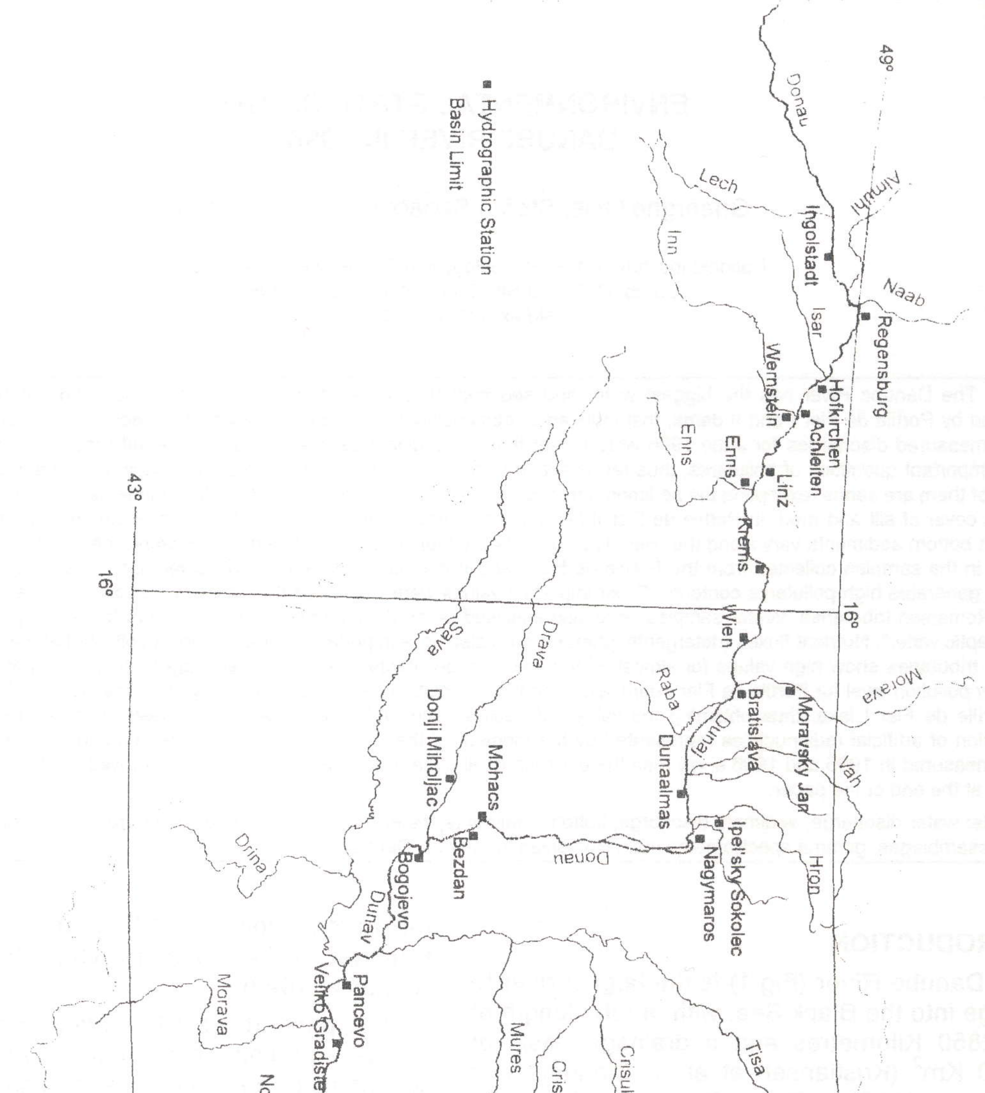


Fig.1 Hydrographic basin of the River Danube

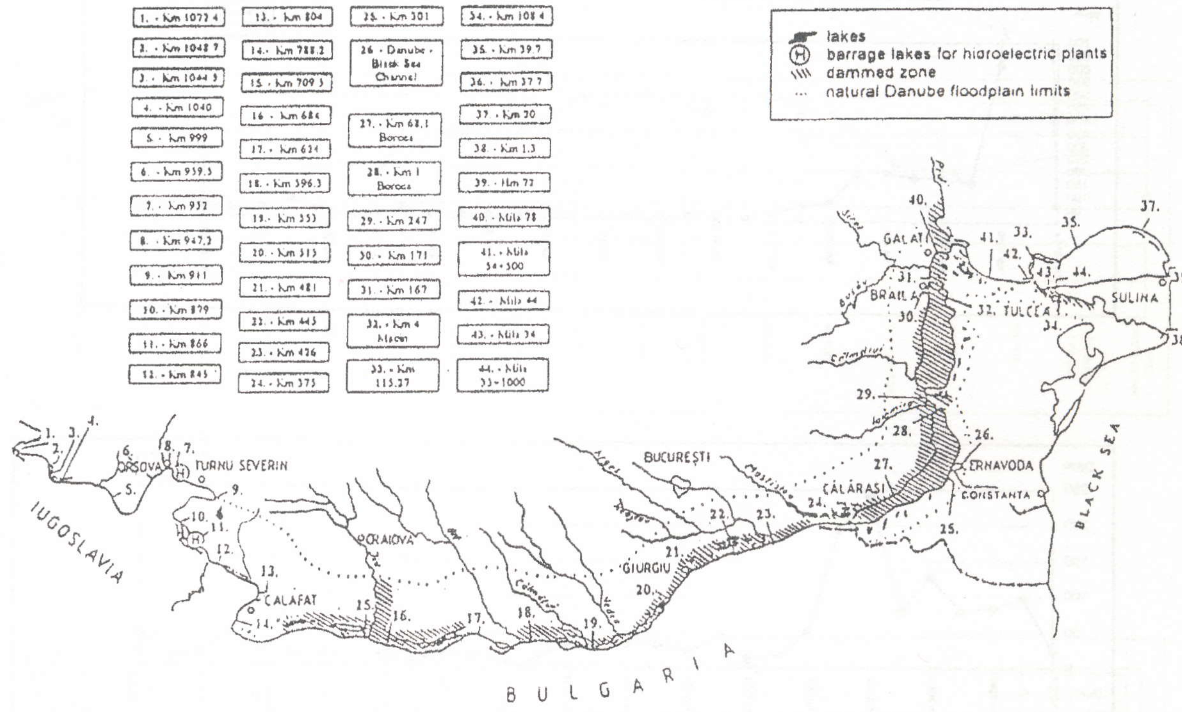


Fig.2 Location of the profiles along the Romanian section of the Danube

RESULTS

Bottom sediments distribution is different along the Romanian watershed of the Danube River. The different sectors have various sediment grain sizes, according to the dynamic regimes: mostly silts for the dam lakes (sands or gravels between km 1075 and 1000), sands and pebbly sands for the natural braided course (between Portile de Fier II dam and Mile 44) and fine sands for the deltaic main distributaries. Portile de Fier I dam lake represents a complex environment: the upper part (Km 1075-Km 1000), has a natural flowing regime, while the lower part (Km 1000-Km 943) is a lacustrine *sensu stricto* environment. There is just a thin cover (1-2 cm) of fine sediments near the dam in the Portile de Fier II dam lake. At the mouths of the main deltaic distributaries (Km 20-Chilia; Hm. 72-Sulina; Km 1.3-Sf. Gheorghe) the bottom sediments are fine grained (silt, mud).

The contents of **heavy metals in bottom sediments** vary along the river. The highest values were located in the areas with fine sediments such as Portile de Fier I and II dam lakes: Cu-3690 ppm, Zn-1500 ppm, Fe-17.9 %, Pb-126 ppm, Cr-246 ppm between km 1048.7 and 1044.5; Ni-107 ppm at km 999, V-120 ppm at km 947.2, Mn-1520 ppm at km 866. Along the river, between Portile de Fier II (km 864) and the begining of the Danube Delta (Mile 44) there are important values for: Cd-12 ppm at km 481 (downstream Giurgiu - Russe town ports) and As-111.9 ppm at km 375 (the border between Romanian and Bulgarian territories). Very important values were measured along Sulina distributary for Cu-38 ppm, Pb-67.8 ppm, Mn-1070 ppm and V-61.6 ppm.

Areas with high anthropic activities are real "hot spots" for heavy metals pollution of sediments (e.g. Moldova Nouă - Cozla mining area) (Fig.3).

According to the pH - E_{H2} diagram the **water quality** can be classified in the "aerobic septic water" category. The nutrients fluxes have significant values: NO_3^- 21.03-0.27 mg/l from the main distributaries of the Danube Delta and at km 1072.4; PO_4^{3-} 1.86-1.28 mg/l at km 426 and from Braila area; SO_4^{2-} 75-68 mg/l from Cernavoda area and at km 1048.7; detergents 0.320-0.210 μg/l at km 445 and downstream Olt river (km 596). Some heavy metals contents in surface water present high distributions in the samples collected from the dam lakes and the Danube Delta and lower for the rest of the watershed, such as Zn, Fe, As and Hg (Fig.4). The latter element exceeds the Romanian standard value (1ppb) along all Romanian territory (4 ppb-km 1072.4; 6 ppb-Hm 72 Sulina distributary).

The **main Romanian tributaries** have a very important local contribution to the pollution of the

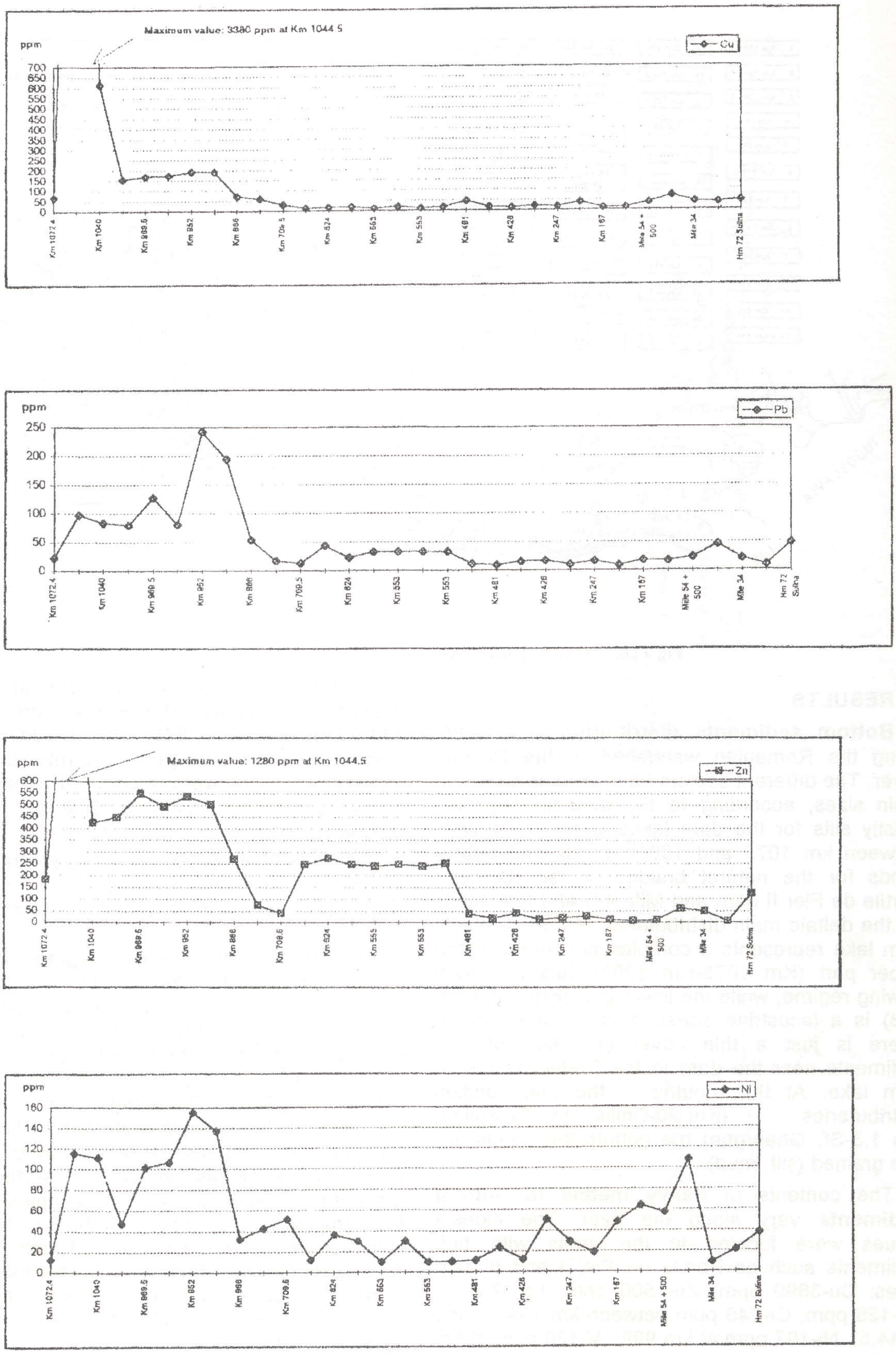
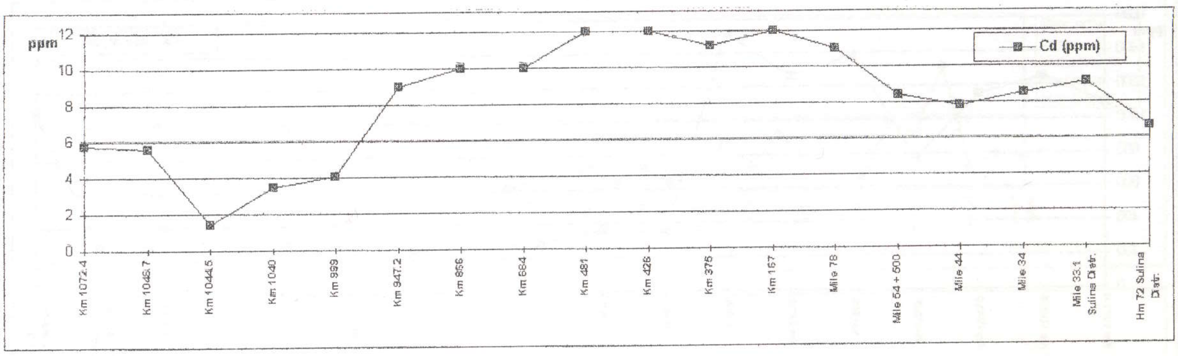
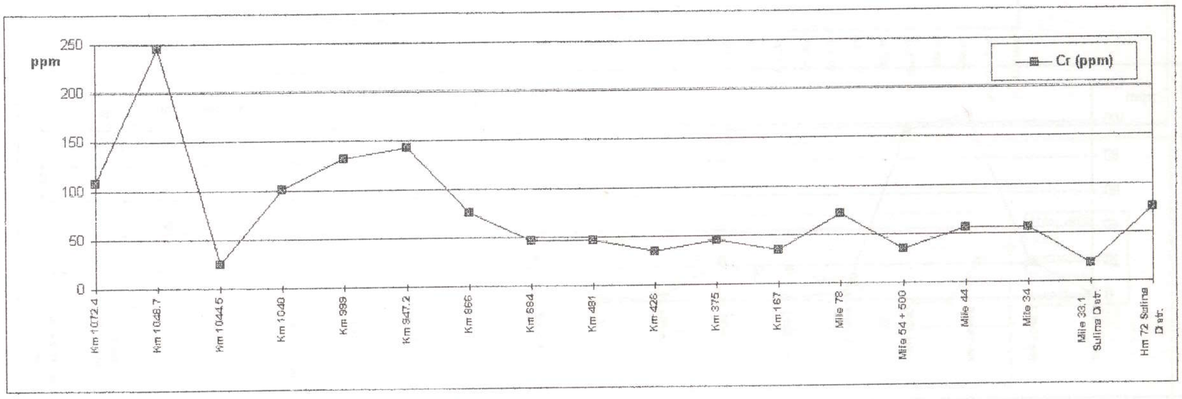


Fig.3 Heavy metal contents in bottom sediments of the River Danube

Fig.3 – continuation





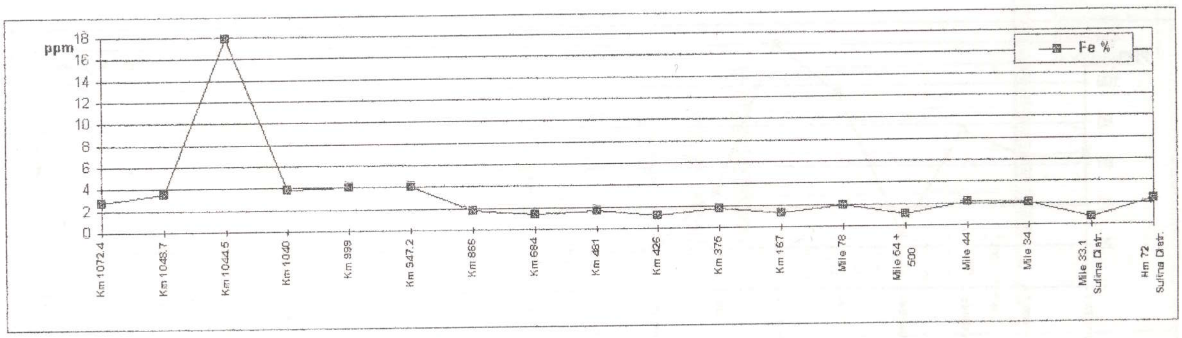
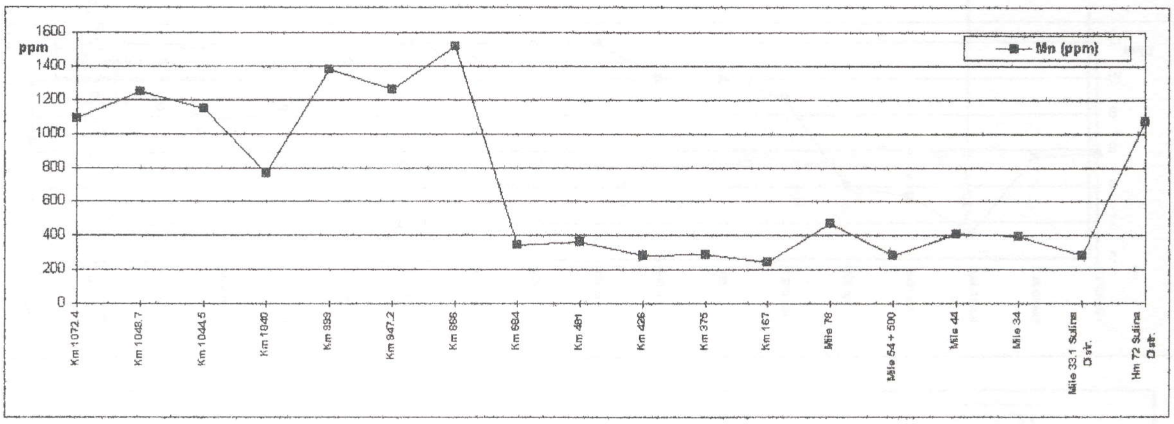
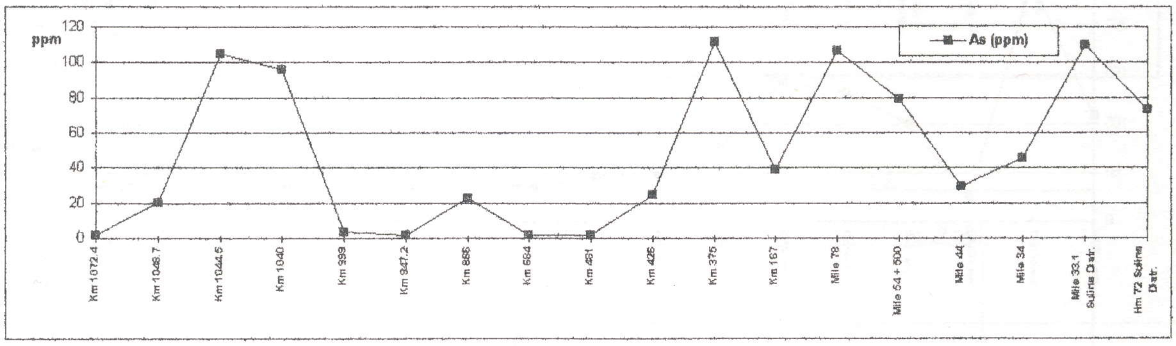
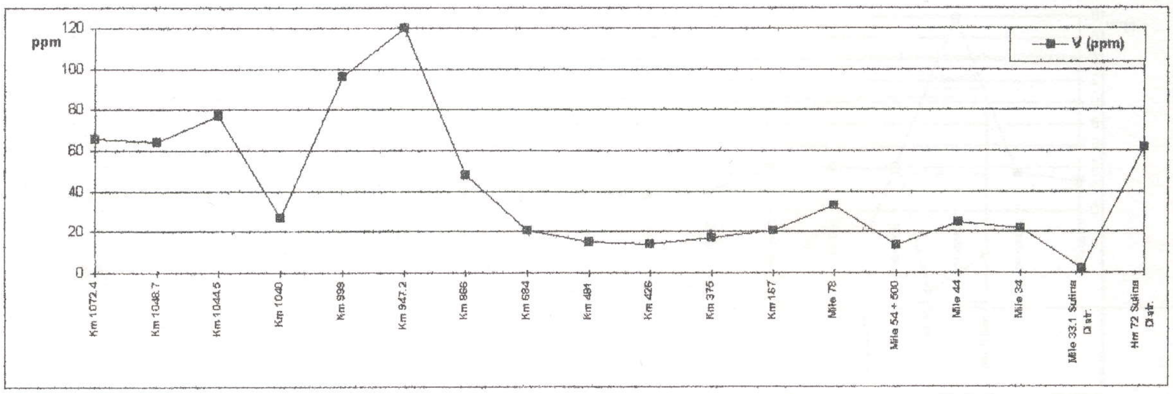


Fig.3 – continuation







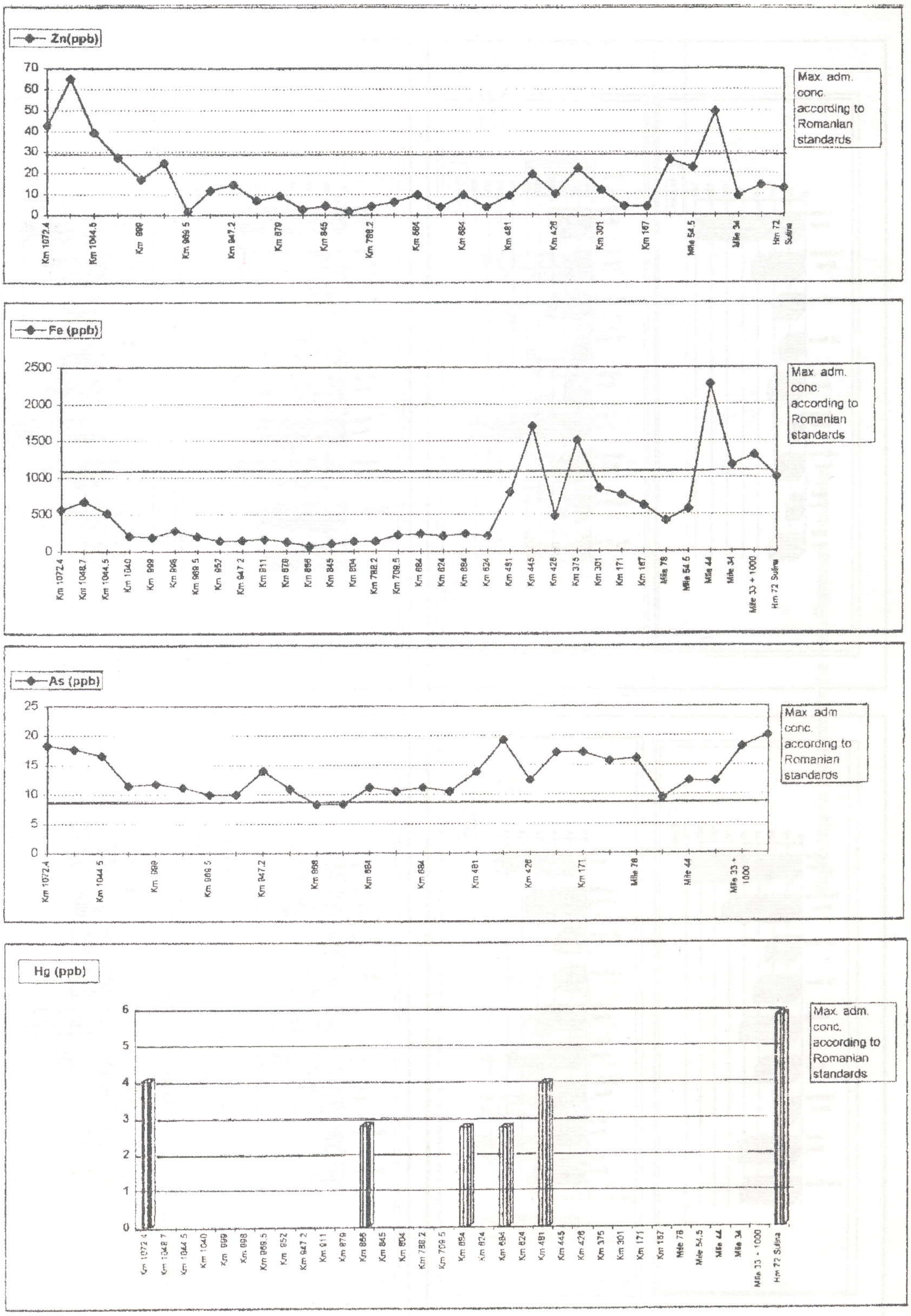


Fig.4 Heavy metals from surface waters of the River

Fig.5 Heavy metal contents in bottom sediments of the main Romanian tributaries

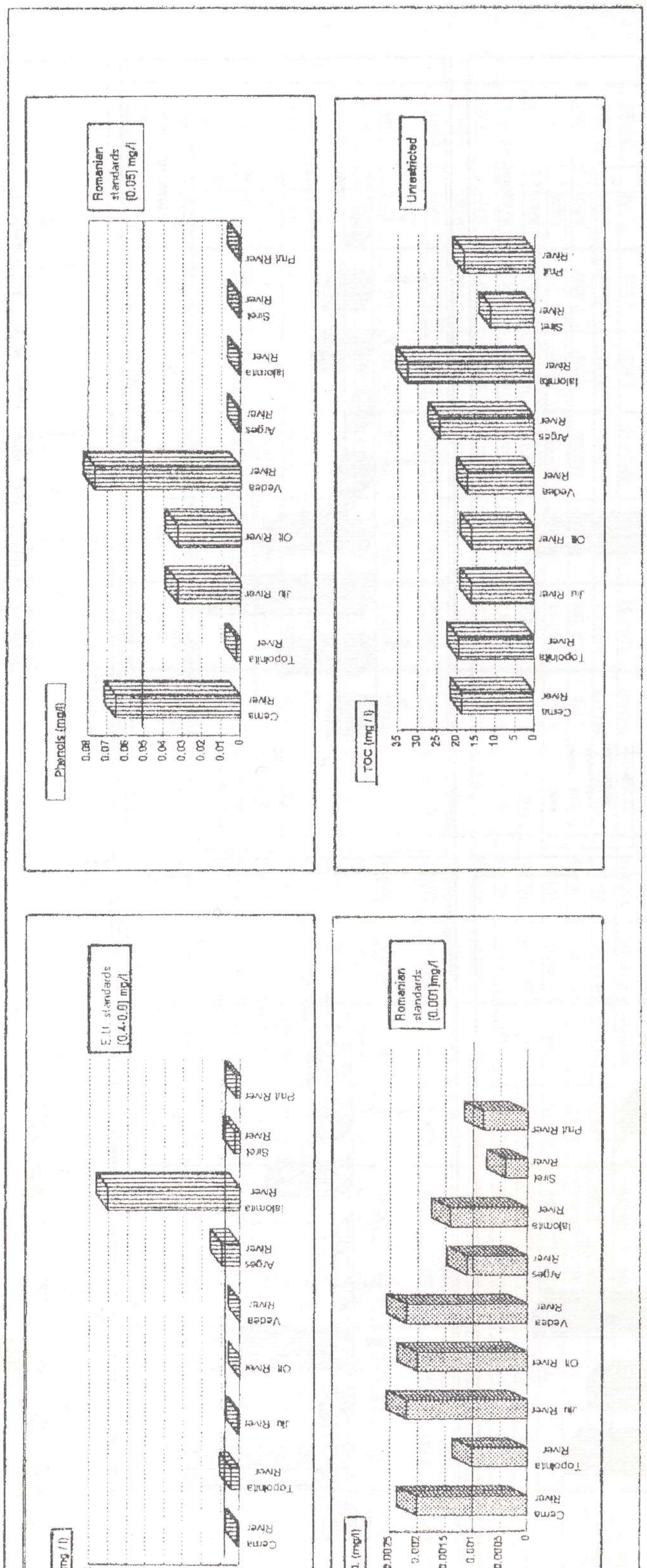


Fig.6 Organic pollutants for the main Romanian tributaries

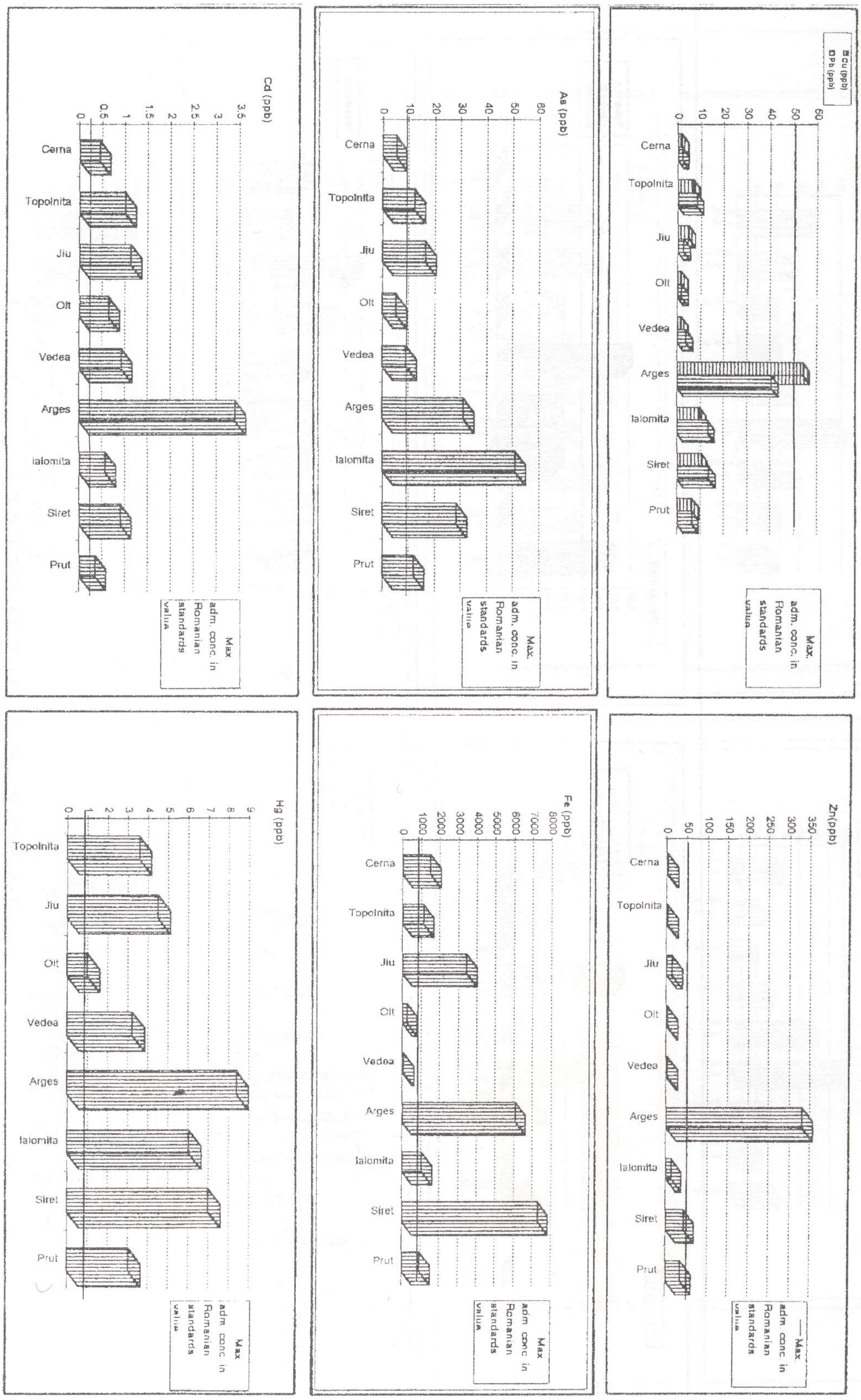


Fig.7 Heavy metal from surface water of the main Romanian tributaries

Table 1 Organic pollutant fluxes for the surface water of the River Danube (comparative results 1995/1996)

Station	Km / Mile	Q 1995 m^3/s	Q 1996 m^3/s	F_{NH4} 1995 (t/day)	F_{NH4} 1996 (t/day)	F_{NO2} 1995 (t/day)	F_{NO2} 1996 (t/day)	F_{NO3} 1995 (t/day)	F_{NO3} 1996 (t/day)	F_{PO4} 19965 (t/day)	F_{PO4} 1996 (t/day)	F_{SO4} 1996 (t/day)	F_{TOC} 1995 (t/day)	F_{TOC} 1996 (t/day)	$F_{Det.}$ 1995 (t/day)	$F_{Det.}$ 1996 (t/day)	F_{OrgCl} 1995 (t/day)	F_{OrgCl} 1996 (t/day)
Bazias	Km 1072.4	6550	8580	46.094	296.52	100.736	200.15	3740.73	3261.18	79.228	459.61	23721.9	17203.96	9081.07	27.164	17.05	1.132	0.593
Orsova	Km 952	7550	8250	1.304	156.82	126.550	135.43	4109.61	2822.69	0.652	263.74	52747.2	11663.48	2708.64	25.440	16.39	0.783	0.2138
	Km 911	7870	8650	12.239	186.84	130.553	104.63	2549.88	6965.40	101.315	411.05	29147.0	8859.98	1584.40	6.8000	22.42	1.020	0.1495
Ostrovu Mare	Km 866	5930	8650	1.025	171.89	94.785	89.68	3028.01	4117.95	4.611	179.37	5978.88	11866.07	6584.24	5.124	11.958	0.922	0.4484
	Km 709.5	7800	9800	11.456	101.61	81.544	59.27	3079.81	17806.52	0.674	279.42	36408.96	18290	13471.32	1824.26	19.47	0.741	0.6350
Jiu River		90	90	12.597	13.45	1.540	7.0762	220.06	421.69	0.801	1.5552	602.64	125.12	158.55	0.630	0.2333	0.017	0.0070
Olt River		160	160	0.166	4.009	2.723	2.488	127.87	106.168	0.028	4.009	594.43	222.57	34.97	1.341	3.1795	0.028	0.0028
Turnu Mãgurele	Km 596.3	8210	8250	0.709	92.25	90.796	63.84	3050.17	6958.66	0.709	539.10	31920.48	10774.93	2511.08	29.792	163.15	1.206	0.2840
	Km 445	8620	9370	12.661	80.09	96.819	48.06	4699.48	5854.78	69.263	240.28	29634.34	10471.43	21296.68	119.907	256.297	0.670	0.9611
Arges River		65	65	17.971	40.323	0.590	0.505	70.76	14.939	5.251	13.759	379.08	136.47	158.933	1.859	0.786	0.006	0.0067
	Km 426	8830	7060	76.291	164.696	141.900	42.699	4813.97	4135.69	142.664	1134.57	26839.30	16021.15	15499.70	32.805	37.090	0.763	0.6099
Ialomita River		40	40	13.651	17.902	6.324	10.437	21.81	40.746	24.240	7.085	6.48	112.527	63.107	0.660	0.048	0.005	0.0024
Brăila	Km 171	7000	6120	30.240	153.343	119.750	52.877	3900.96	486.466	186.278	285.535	21679.49	9767.52	6873.984	33.868	12.690	0.544	0.3123
Siret River		210	210	7.439	6.532	22.135	7.802	146.05	185.976	5.171	5.443	1251.94	203.94	448.157	0.526	-	0.007	0.0154
Prut River		86	86	1.115	0.817	1.471	1.115	47.93	33.808	1.597	2.675	627.869	135.01	185.388	0.156	0.0297	0.006	0.0059
Mile 44	Mile 44	8740	8430	71.737	65.552	149.516	101.969	4870.62	2942.54	158.578	254.923	33504.2	8321.59	18172.38	7.551	160.237	0.076	0.6565
Chilia Distributary	Km 20	3280	2763	26.355	26.260	79.349	90.715	1927.06	1580.347	26.355	74.004	10742.54	6271.46	5232.815	3.401	5.968	0.170	0.1193
Sf.Gh.eorghe Distributary	Km 1.3	2138	2000	19.395	28.512	57.633	67.392	1690.20	1370.301	24.198	58.752	7603.20	4880.38	3787.776	3.325	4.32	0.166	0.0864
Sulina Distributary	Hm 72	1680	915	18.144	11.463	18.144	18.973	1146.70	455.363	16.837	47.434	3557.52	3013.35	1659.385	2.032	3.162	0.102	0.0474
Total Danube Distributary		**7098**	**5678**	**63.894**	**66.235**	**155.126**	**177.08**	**4763.96**	**3406.014**	**67.39**	**180.19**	**21903.26**	**14065.19**	**10679.97**	**8.758**	**13.45**	**0.437**	**0.2532**

Table 2 Heavy metal contents in the bottom sediments of the River Danube (comparative results 1995/1996)

Station	Km / Mile	Q 1995 m^3/s	Q 1996 m^3/s	F_{Cu} 1995 (t/day)	F_{Cu} 1996 (t/day)	F_{Pb} 1995 (t/day)	F_{Pb} 1996 (t/day)	F_{Zn} 1995 (t/day)	F_{Zn} 1996 (t/day)	F_{Cd} 1996 (t/day)	F_{Ni} 1995 (t/day)	F_{Ni} 1996 (t/day)	F_{Fe} 1996 (t/day)	F_{Mn} 1995 (t/day)	F_{Mn} 1996 (t/day)	F_{Hg} 1995 (t/day)	F_{Hg} 1996 (t/day)
Bazias	**Km 1072.4**	6550	8580	1.641	2.376	9.224	11.612	24.221	251.078	0.931	1.200	3.802	440.462	40.293	19.129	1.0805	0.604
Orsova	**Km 952**	7550	8250	2.870	2.894	3.914	13.971	7.828	614.520	9.245	0.744	2.886	145.446	17.090	25.929	1.676	1.464
	Km 911	7870	8650	4.325	4.052	2.312	9.703	4.828	257.688	17.107	0.626	2.506	223.465	14.755	35.770	1.659	1.570
Ostrovu Mare	**Km 866**	5930	8650	1.998	1.622	1.024	6.442	1.486	405.667	2.758	0.497	3.475	107.956		20.418	1.390	1.532
	Km 709.5	7800	9800	1.280	7.396		21.876	4.246	540.458	5.296		5.072	431.222		59.946		1.840
Jiu River		90	90	0.038	0.0523	0.021	0.1342	0.100	7.196	0.0174	0.052	0.0219	5.430	0.949	0.309	0.072	0.0064
Olt River		160	160	0.026	0.038	0.026	0.175	0.026	3.598	0.205	0.012	0.0374	7.816	0.422	0.652	0.040	0.0209
Turnu Măgurele	**Km 596.3**	8210	8250	1.348	3.103	1.348	13.918	2.979	374.086	51.070		3.096	274.374	16.031	22.777	1.795	1.578
	Km 445	8620	9370	13.853	3.154	9.681	14.040	14.522	695.261	2.264	2.614	2.670	297.475	61.518	32.003		1.780
Arges River		65	65	0.304		0.228		1.859			0.135			2.067		0.047	
	Km 426	8830	7060	7.324	3.275	7.400	7.975	7.858	675.173	5.080	0.633	2.134	303.428	27.083	18.230		1.382
Ialomita River		40	40	0.034	0.0069	0.047	0.0999	0.044	0.2032	0.0491	0.100	0.0315	2.6300	0.588	0.3905	0.021	0.0069
Brăila	**Km 171**	7000	6120	3.871	3.421	4.717	12.182	2.601	622.400	10.498		4.735	392.766	22.014	16.096		1.166
Siret River		210	210	0.189	0.0640	0.248	0.0462	0.793	2.978	0.0105	0.310	0.0475	32.106	2.994	1.2887	0.127	0.0008
Prut River		86	86	0.049	0.025	0.048	0.0231	0.265	1.920	0.0143	0.014	0.0388	10.368	0.580	0.3413	0.023	0.0002
Mile 44	Mile 44	8740	8430	12.082	2.160	7.778	3.413	37.379	157.585	7.923	2.500	2.834	461.195	57.239	19.518		1.624
Chilia Distributary	Km 20	3280	2763	3.485	1.123	4.563	3.041	5.753	83.393	2.091	0.995	1.063	133.721		6.169		0.190
Sf.Gh.eorghe Distributary	Km 1.3	2138	2000	2.013	0.639	1.385	1.745	2.401	55.659	1.287	0.392	1.045	157.352	10.881	7.093	1.077	0.142
Sulina Distributary	Hm 72	1680	915	1.626	0.294	1.845	1.909	1.945	79.618	1.503	0.268	0.760	44.142	8.8397	3.015		0.064
Total Danube Distributary		**7098**	**5678**	**7.124**	**2. 056**	**7.793**	**6. 695**	**10.099**	**218. 670**	**4. 881**	**1.655**	**2. 868**	**335. 215**	**19.721**	**16. 277**		**0. 396**

Danube River. These very polluted areas are limited because the distributaries' discharges are small comparatively with the Danube River (that has a high regenerating capacity). There are high contents in heavy metals in the bottom sediments from Arges (Cu-134 ppm, Pb-157 ppm, Zn-789 ppm, Cr-231 ppm), Vedea (Ni-92.8 ppm, Fe-4.3 %, V-114 ppm) and Ialomita (Cd-9.37 ppm) rivers (Fig.5)

The analysis of the water quality shows that Ialomita and Vedea rivers are the most polluted with PO_4^{3-}, phenols, organic Cl (Fig.6) and Arges river with heavy metals (Cu, Pb, Zn, Cd, Hg) (Fig.7). The heavy metals natural contents in rivers (e.g. Cd -1 ppb/l, after Maybeck et al., 1989) are generally overstepped in the tributaries.The explanation is related to their retention basins that drain areas with dense population (e.g. city of Bucharest for the Arges River), with intense industrial and agricultural activities. Heavy metals are generally located near point sources that use them in large quantities According to the RIVM/GLOBE (1992), the agricultural runoffs and sewage effluents from animal farms induce high nutrients contents.

Studies were made regarding the **diatoms assemblages** on the surficial sediment samples from the Portile de Fier I lake (Pestrea in Panin et al., 1995). The studies completed by Kobayasi and Mayama (1982, 1989) for the Japanese polluted rivers proposed the diatoms as indicators for polluted, less polluted and not polluted environments. For the Portile de Fier I lake there is a high percent of species tolerant to low pollution level.

High resolution **gamma spectrometry** analyses were performed in 1995 on two cores from Portile de Fier I lake (Ruzsa in Panin et al., 1996). The purpose was to determine the vertical distribution of artificial radionuclides. The highest values for Cs-134 and Cs-137 (Osvath, 1990) were interpreted as being sedimented in 1986 (the year of the Chernobyl accident). The sediment accumulation rates ever since were computed in relation with this moment. These sedimentation rates from the Portile de Fier I lake vary between 1.6 cm/year (the core collected at Km 969.5) and 2.5 cm/year (the core from Km 947.2-3 Km upstream the Portile de Fier I dam).

The natural flowing regime of the Danube River was disturbed by the anthropic activities (damming, canals, industry, agriculture), the dam lakes representing traps for sediments and pollutants.

Nutrients and heavy metals contents in water and bottom sediments vary along the river. The highest values are located in zones with intense anthropic activities (e.g. Moldova Nouã - Cozla area) and/or with fine bottom sediments (e.g. the lower part of the Portile de Fier I dam lake).

The pollutants inputs from tributaries and industrial sites are limited in space, high values being significant downstream the port towns (e.g. Turnu Mãgurele-Km 596, Giurgiu-Km 481, Silistra-Km 375).

The regeneration capacity of the Danube River and the filtering role of the Danube Delta are the factors for the improvement in quality of water and partially sediment load. Tables 1 and 2 present a synthesis of the fluxes of the river into the Black Sea.

The **comparative study of the results of 1995 and 1996 analyses** show:

◊ heavy metals contents in bottom sediments
  - the Danube River - the state of the river is generally improved, exception being Cd contents;
  - the main Romanian tributaries - the measured values for 1996 are generally lower than those from 1995; the situation is worse only for Jiu and Vedea rivers. Arges River maintains the same high pollution level for both years.

◊ nutrients variations for the water samples
  - phenols and organo-chlorinate compounds decreased in 1996 compared with 1995. detergents concentrations have similar values both in 1995 and 1996 ;
  - for the main Romanian tributaries phenols and organo-chlorinate compounds decreased, while detergents concentrations are constant for 1995 and 1996.

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