INTERNATIONAL COMMISSION FOR THE PROTECTION OF THE DANUBE RIVER

Study on Bioindicators, Inorganic and Organic Micropollutants in Selected Bioindicator Organisms in the River Danube and its tributaries

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Prepared by

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In co-operation with the Secretariat of the ICPDR

Preface

VITUKI Plc, Budapest, Hungary, performed the Study on Bioindicators, Inorganic and Organic Micropollutants in Selected Bioindicator Organism in the River Danube and its tributaries in co-operation with the Secretariat of the ICPDR in Vienna. It was a follow-up activity to the UNEP/OCHA Balkan Task Force Mission, which investigated the environmental impacts of the Kosovo conflict in FRY in 1999.

The major aim of the Study on Bioindicators was to investigate the accumulation of organic and inorganic micropollutants in sediments and biota and to analyze the macrozoobenthos in the Danube reach impacted by the Kosovo conflict. The Study was financially supported by the governments of Germany and Austria and organized by the Secretariat of the ICPDR.

The sampling mission was carried out on 17-23 July 2000 by the VITUKI team with the kind support of Yugoslavian authorities. The samples were analyzed in VITUKI and VUVH, Bratislava, Slovakia. The actual report was prepared by Dr. Béla CSÁNYI (Project Manager). The findings, interpretations and conclusions of the Study contribute to mapping of the quality status of the Danube reach, which has been excluded from the regular monitoring activities of the ICPDR (Transnational Monitoring Network) until now.

Content

1 INTRODUCTION

An important mission of the International Commission for the Protection of the Danube River (ICPDR) is to ensure reliable assessment of the quality, the pollution and the biological/ecological status of the rivers (Danube and its tributaries) in the Danube river basin. Earlier monitoring efforts (EPBRD) provided data on the water quality at selected locations. The present monitoring activity (TNMN) does not include the Yugoslavian Danube stretch due to the previous war situation and its consequences. However, the need for inclusion of that river section in the overall assessment of the Danube river basin is inevitable.

The NATO intervention in Yugoslavia during March-May 1999 and its environmental consequences called for an assessment and actions by international community. The UNEP/Habitat Balkans Task Force (BTF) together with the ICPDR conducted a so called “Danube mission” in the FRG in August 1999 to target the analysis of pollutants, potentially related to the war. The sampling and the analysis were conducted in the water, sediment, and mussel species. Parallel the aquatic macroinvertebrate community was investigated also. It was obvious that a more detailed follow-up study was necessary to include more sites and pollutants.

Realizing the necessity of the continuation of the BTF program and the inclusion of the Danube section situated in the Federal Republic of Yugoslavia (FRG) a sampling program supported by the ICPDR was completed on the Danube River between 1534 river km (Paks, Hungary) and 849 river km (confluence of Timok River, Yugoslavian-Bulgarian border) and on its main tributaries. The program was realized in order to collect information on the pollution situation in that section together with the hydrobiological water quality of the rivers following the war period.

Therefore the work plan and sampling protocol approved by the ICPDR and the sampling campaign included those sites that are situated in the vicinity of the war-damaged sites along the Danube, too. The fieldwork consisted of the sampling of macrozoobenthic community having bioindicator character, and collecting sediment and mussel samples at the same sites for hazardous substance enrichment analysis.

A team of Yugoslavian scientists lead by the Deputy Minister Zoran Cukic (Belgrade) involved the experts of the Hydrometeorological Institute of FRY (Belgrade) and the University of Novi Sad was accompanied the project mission as a partner expert group during the sampling program. They provided essential information for the practical work and the design of the sampling network since the beginning. Later on they provided the necessary help in logistics, organizing the campaign along the whole FRY Danube section (renting the boats needed for the sample collections, working in the field, etc.), as well.

Before starting the mission to the FRY a detailed sampling and analysis plan had been prepared on the basis of all existing information from reports of the UNEP/Habitat Balkans Task Force, particularly the findings of the second mission to FRY, which included the biological information, too (UNEP/Habitat BTF 1999).

It is written in the Introduction of the Work Plan that the main objective of the project is to provide lacking information and support the improvement of the biomonitoring program of TNMN in the Danube river.

All of the chemical data are presented in **ANNEX 1**. **ANNEX 2** is a photographic illustration of the sampling mission. **ANNEX 3** shows the diagrams detected heavy metals in Danubian and tributarian sediment samples, as well as in different mussel samples.

2 MATERIAL AND METHODS

2.1. Sampling plan and sampling network

The preparation of the sampling plan was carried out together with the Yugoslavian experts during the preliminary workshop held in the VITUKI prior to the sampling campaign. Two hot spots were investigated in a detailed way during the sampling program. The vicinity of Novi Sad and Pancevo being the central complex of the Yugoslavian Petrochemical Industry both were heavily damaged by the NATO bombardment during the war. As a result of that, serious pollution happened in the Danube River (i.e. crude and refined oil spill) and the surrounding territory during the war. Therefore upstream and downstream localities were investigated together with both sides of the Danube at these cross sections.

Altogether 30 sites on the River Danube and 22 Danubian sampling cross sections were selected for the detailed investigations. According to the advice of the Yugoslavian experts, 7 tributaries and 11 sites were included in the sampling program also. This way several locations were included in the sampling network between the Hungarian stretch in the vicinity of the Nuclear Power Plant at Paks and the Yugoslavian-Bulgarian border formed by the Timok River, downstream Radujevac, including the Iron Gate Reservoir I and II, respectively. The length of the investigated Danube stretch is 685 km.

The identification of sampling locations on the Danube River and its tributaries, sites and positions are indicated in **Table 2.1.1** together with the investigated components (sediment=S, biota=B, mussel=M). During the mission 34 sediment and 38 biological samples were collected, mussels were found at 28 sampling sites. Altogether 7 mussel species were detected along the rivers and 53 mussel samples were analyzed. Sampling locations are illustrated on a map (**Figure 2.1.1**).

Table 2.1.1 List of sampling locations on the Danube River and its tributaries (17-23 July 2000)

No.	River	River km	Name of sampling site			
1	Danube	1534	Paks, left (Hungary)	-	B	-
2	Danube	1534	Paks, right (Hungary)	S	B	M
3	Danube	1480	Baja, left (Hungary)	-	B	-
4	Danube	1480	Baja, right (Hungary)	S	B	-
5	Danube	1440	Mohács, left (Hungary)	-	B	-
6	Danube	1440	Mohács, right (Hungary)	S	B	M
7	Danube	1363,5	Bogojevo, left (FRY)	S	B	M
8	Danube	1365	Erdut-Dalj, right (Croatia)	S	B	M
9	Danube	1259,1	Novi Sad u/s, left (FRY)	S	B	M
10	Danube	1259	Novi Sad u/s, right (FRY)	S	B	M
11	Danube	1251	Novi Sad, d/s, left (FRY)	S	B	-
12	Danube	1215	Stary Slankamen, left (FRY)	S	-	-
13	Danube	1215	Stary Slankamen, right (FRY)	S	B	M
14	Danube	1194	Stary Banovci, left (FRY)	S	B	M
15	Danube	1194	Stary Banovci, right (FRY)	S	B	M
16	Danube	1157	Bela Stena, Pancevo u/s, left (FRY)	S	B	M
17	Danube	1157	Bela Stena, Pancevo u/s, right (FRY)	S	B	M
18	Danube	1151	Pancevo d/s, left (FRY)	S	B	-
19	Danube	1151	Pancevo d/s, right (FRY)	S	B	M
20	Danube	1117	Smederevo, right (FRY)	S	B	M

No.	River	River km	Name of sampling site			
21	Danube	1097	Kostolac, right (FRY)	S	B	M
22	Danube	1095	Dubovac, left (FRY)	S	B	M
23	Danube	1072	Bazias, left (Rumania)	S	B	M
24	Danube	1040	Golubinje, right (FRY)	-	B	-
25	Danube	1033	Brnjica, right (FRY)	S	B	M
26	Danube	991	Donji Milanovac (FRY)	S	B	M
27	Danube	956	Tekija (FRY)	S	B	M
28	Danube	925	Mala Vbrica (below Iron Gate I. (FRY))	S	B	M
29	Danube	871	Mihajlovac (Iron Gate II (FRY))	S	B	M
30	Danube	849	Radujevac (FRY)	-	B	M
31	Drava	152,7	Barcs (Hungary)	-	B	-
32	Drava	77,7	Drávaszabolcs (Hungary)	-	B	-
33	Drava	19,3	Osijek (Croatia)	S	B	-
34	Tisa	147	Novi Knjezevac (FRY)	S	B	M
35	Tisa	2	below Titel, confluence (FRY)	S	B	M
36	Plovni Begej	29	Srpski Itebej (FRY)	S	B	-
37	Bega Vege	36	Hetin (FRY)	S	B	M
38	Sava	180	Sremska Raca (FRY)	S	B	M
39	Sava	16,5	Ostruznica (FRY)	S	B	M
40	V. Morava	34	Ljubicevo bridge (FRY)	S	B	M
41	Timok	0,2	Usce, Yugoslavian-Bulgarian border	S	-	-

(S = sediment, B = Biota, M = Mussel)

As far as the River Danube is concerned, three cross sections are found on the lower Hungarian Danube where 6 sites were included in the sampling program (Paks downstream of Nuclear Power Plant, Baja, Mohács). The Erdut-Dalj section belongs to Croatia (downstream of the Drava confluence), in front of the FRG at Bogojevo having bridge connection between the two countries. Both of the riversides (left and right) were included in the sampling program at Novi Sad (oil refinery), Stary Slankamen (confluence of the Tisa), Stary Banovci, Bela Stena (downstream of the Sava confluence and the capital of Beograd) and Pancevo (oil refinary and petrochemical industry). Only one (right) side of the Dnube was sampled from Smederevo, through the Iron Gate I (except Dubovac-Kostolac section) and II until Radujevac, the lowermost sampling site of FRY.

The 7 tributaries are as follows. The site on the Drava is situated in Croatia, representing one of the main tributaries of the Danube on this stretch. The Tisza River at Novi Knjezevac (147 rkm) is an upstream reference section arriving from Hungary. It has another investigated sampling site near to the Danubian confluence downstream Titel. The Old Bega (Bega Vege) and the navigable Bega (Plovni Canal) were selected as sampling sites on the transboundary watercourses and main pollution sources coming from Rumania. The Sava River is one of the largest tributaries of the Danube having two sampling locations. At Sremska Raca it is a border section between Bosnia and Hercegovina and the FRG. The other investigated site is situated near to Beograd (Ostruznica). Velika Morava at Ljubicevo represents the potential polluting source from the bombed Kragujevac industrial region. The Timok River forms the Yugoslavian-Bulgarian border where intensive copper mining activity takes place at the Yugoslavian upstream water shed.

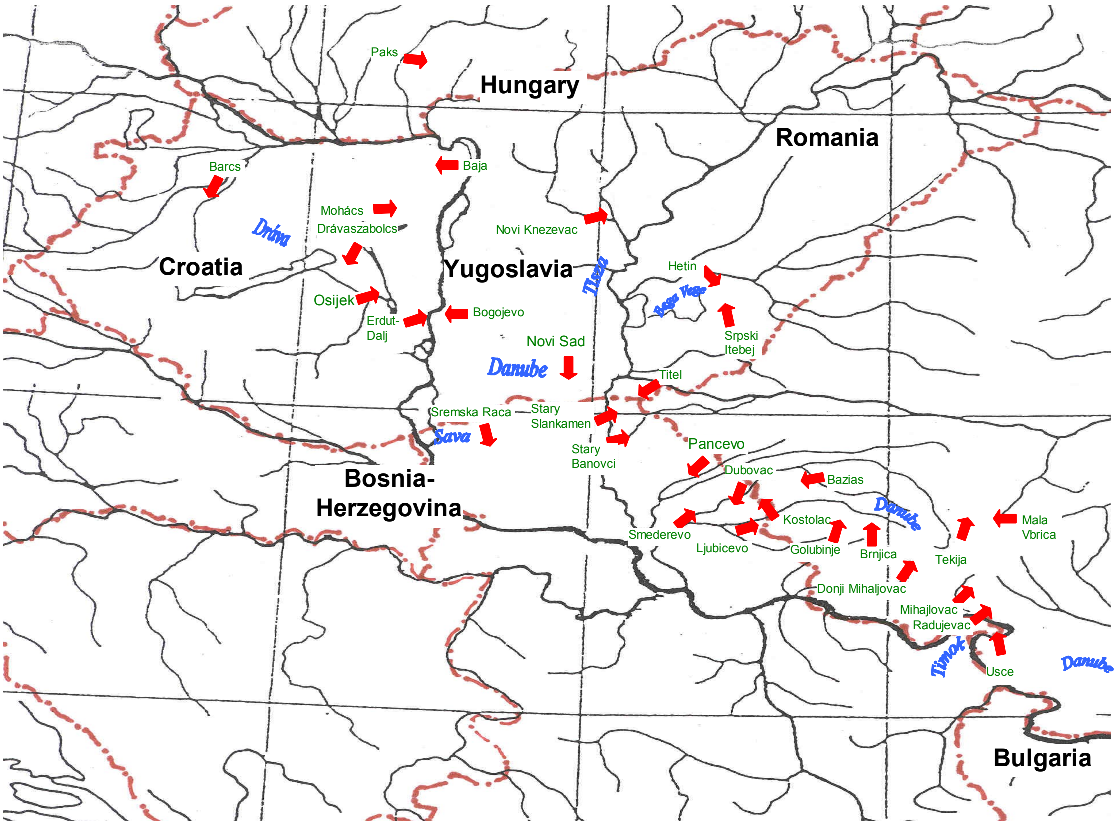


Figure 2.1.1 Map of sampling sites

2.2. Sample collection and in field sample treatment

In case of ***sediment sampling***, special care was taken in order to collect the finest fraction of the available bed material at each location. To achieve this only that sedimentation patches were searched that were characterized by lenitic (stagnant or slow flowing) conditions. To fulfill this requirement finer sediment fraction was collected than the sand fraction at all sampling locations.

Only the upper few centimeter thick layer of that kind of sediment was taken at all places. This was carried out using a hand net supplied by a rigid aluminum frame that had allowed to “shave” the surface of the bottom material.

Sediment samples were collected at 32 sites due to that fact that only hard coarse bed material was found at 8 sampling locations. According to the previous statement, only that type of sediment was collected which contained predominantly fine fraction. Therefore coarse material was not taken for sampling. Approximately 1 l of sediment was put in a plastic box and stored in cooling container. The samples collected during the day were put each night in the refrigerator. Wet sieving to obtain the clay-silt (less than 63 micron) fraction for pollutant analysis was carried out in laboratory.

The list of inorganic and organic micropollutants analyzed in the sediment and mussel samples in 1999 and 2000 is shown in **Table 2.1.2**.

Table 2.1.2 List of measured components

Component	**Sediment**	**Mussel**	**Sediment**	**Mussel**
	collected in 1999		**collected in 2000**	
Mercury			x	x
Cadmium	x	X	x	x
Lead	x	X	x	x
Chromium	x	X	x	x
Copper	x	X	x	x
Nickel	x	X	x	x
PAHs				
Naphthalene			x	x
Acenaphthylene			x	x
Acenaphthene			x	x
Fluorene			x	x
Phenanthrene			x	x
Antracene			x	x
Fluoranthene			x	x
Pyrene			x	x
Benzanthracene			x	x
Chrysene			x	x
Benzo(b)fluoranthene			x	x
Benzo(k)fluoranthene			x	x
Benzo(a)pyrene			x	x
Indeno(c,d)pyrene			x	x
Dibenzoanthracene			x	x
Benzo(g,h,i)perylene			x	x
Chlorinated hydrocarbon pesticides				
Lindane			x	x
Heptachlor			x	x

Component	Sediment	Mussel	Sediment	Mussel
	collected in 1999		collected in 2000	
Heptachlor-epoxide			x	x
Endosulphan			x	x
2,4-DDE			x	x
Endrin			x	x
DDT			x	x
DDD			x	x
Metoxichlor			x	x
Polychlorinated byphenyls (PCBs)				
PCB-28			x	x
PCB-52			x	x
PCB-101			x	x
PCB-118			x	x
PCB-138			x	x
PCB-153			x	x
PCB-180			x	x
Petroleum hydrocarbons			x	

Generally, ***aquatic macroinvertebrate community*** was sampled by the "kick and sweep" technique. Samples were collected in the littoral zone of the River Danube and the tributaries from the bottom in order to describe the macroinvertebrate community and the biological status of the investigated water bodies. Kicking was carried out in a rubber cloth using the British Standard FBA pond net near the shoreline in the water with 1.5-m depth. The applied effort for macroinvertebrate sample collection was similar in each site.

One methodological problem has to be mentioned concerning the macroinvertebrate sampling in the Danube River in the FRY section. In case of considerable and frequent changes of water level (due to human impact in the reservoir) there are difficult conditions in the "littoral zone". The sudden change of water level destroys the real stable littoral macroinvertebrate (including the mussel species) community. According to our observations, in some cases water level fluctuations exceeded 2 m. Therefore the immediate method of diving must have been used for the simultaneous macroinvertebrate, mussel and sediment sampling.

It has to be mentioned also, that in the Iron Gate Reservoir mussels were available only in bigger depths than 4 m at several localities. The reason of this phenomenon is not known, further sampling programs will probably reveal this better. Thus, in deep waters macroinvertebrates were collected from the bottom substrate by diving. This case hand net was used similarly to the kicking method but instead of direct kicking of the substrate the hand net was dredged in it and moved sweeping together the bottom material and organisms, as well. Mussels were picked up by hand and collected to the net, too. In case of diving the upper 5 cm layer of the fine, soft sediment was dredged by the hand net in the deep water, similarly to the littoral zone. The maximum depth reached by this diving (without any SCUBA supply) was no more than 5.5 m (the depth was measured by the rope of an Ekman-Birge sediment grab).

The diving method of sampling proved to be the most effective way of ***mussel collection*** at most of the sites, even in case of smaller depths, as well. In case of unsuccessful sampling by diving (only one location can be mentioned in this respect: Donji Milanovac, deeper than 6 m) an Ekman-Birge grab was the applied method during the sampling program. It should be mentioned that the small transparency of the Danube River did not affect negatively the sampling efficiency. Generally transparency changed between 0 and 20 cm but the greatest value was experienced in Tekija (lower end of Iron Gate I) and Radujevac (below Iron Gate II) approaching 1.5 m.

A dredge with a triangle mouth surrounded by forks was applied some cases also for the collection of mussel species. The dredge was pulled on the surface of the muddy bottom from motorboat with the help of a 30 m long rope. The mud was sieved through a rough iron net. Five of the collected sediment and mussel samples were provided to the VUVH Water Quality Laboratory (Bratislava) as a sub-contractor. Similarly they took the Oligochaeta group of the macrozoobenthos samples in order to perform the taxonomic determination.

Macroinvertebrate samples were labeled and than preserved with 70% ethanol solution. Selecting the taxa was carried out in laboratory. The taxonomic determination of *Oligochaeta* and *Chironomidae* species was taken by the Slovakian VUVH Laboratory at Bratislava, other groups were determined in the VITUKI Hydrobiological Laboratory, Budapest. Each individual of taxa was taken in consideration. The sampling effort was the same at each sampling site in order to allow the quantitative comparison of data to each other. The calculation of Saprobic index was done according to Zelinka and Marvan. The Saprobic list of the Fauna Aquatica Austriaca was used during the calculation.

The samples were transported in iceboxes during the sampling campaign. Mussel samples were transported alive during the first four days in cooling boxes. Later on all of the samples were placed in the deep-freezer to avoid the spontaneous mortality and consequent damage of the mussels. This deep-freezing was applied each night during the travel and sampling. Using that technique all of the samples arrived to the VITUKI Laboratory safe after the 8 days trip.

After arrival to the Hungarian (VITUKI) laboratory the macroinvertebrate samples were processed by selecting, determining, evaluating/calculating. Sediment and mussels samples were prepared as follows:

- the sediment samples were wet sieved and the particle size fraction < 63 μm was air dried.
- the mussel samples were counted, weighed and the meat part taken by species and sizes for freeze-drying. Before freeze-drying the homogenized wet-weight was measured to allow calculation of the percentage of the dry tissue after drying. The freeze-dried tissue was powdered.

2.3 Laboratory methods

In general, the available ISO methods were applied for the analysis of the different components.

The heavy metals, trace elements were analyzed by atomic absorption spectrophotometry: mercury by cold vapor technique, the other elements by graphite furnace or flame atomization method.

The organic micropollutants were analyzed by gas chromatography/mass spectrometry (GC/MS). In the case of the overall assessment of the petroleum hydrocarbon contamination, the total fluorescence method - which is recommended in the Danube basin transnational monitoring network – was used.

The taxonomic determination was carried out using relevant keys for the different aquatic macroinvertebrate groups. Quantitative taxon list was prepared for the Danube River and for the tributaries, respectively. Each of the collected individuals in the sample was taken in consideration when individual numbers were determined. Abundance value of taxa (i.e. individual number) was used for determining relative abundance values (%), and, abundances expressed on interval scale subsequently, as follows:

Empiric scale	Relative abundance *(%)*	Abundance on interval scale *(h)*
Very rare	<1	1
Rare	1,1-3,0	2
Not rare	3,1-10,0	3
Abundant	10,1-20,0	5
Very abundant	20,1-40,0	7
Massive amounts	40,1-100,0	9

Saprobic index was calculated for the different samples according to Zelinka and Marvan (1961) using the saprobic valence of the given taxon.

However, the simple qualitative data have numerous interesting information about the Danubian distribution of many benthic taxa. Presence data and Saprobic index values are both used for the characterization of the pollution situation of different sampling sites along the Danube River, the Iron Gate Reservoir and the tributaries.

Detailed quantitative taxon lists of the Danubian macroinvertebrate taxa and those that were detected in the tributaries of the Danube are given in the Report. Detailed analysis is shown concerning the micropollutant content of the sediment and the selected bioindicator organisms of the rivers. The different locations are classified using the bioaccumulation data measured in the different mussel species. The comparison of these data to the earlier results gained during the UNEP-Balkan Task Force mission performed in August 1999 is discussed also.

3 RESULTS

All of the chemical data measured in the framework of this project are collected in the end of the Final Report, in the **ANNEX 1**.

The lists of the concentrations of heavy metals and all of the measured organic pollutants referring both to the sediment of the Danube river and in the tributaries, as well as different mussel species is available there (**Table A-1.1.-A-1.9**).

3.1 Heavy metal content of the sediment and different mussel species

The behaviour of heavy metals along the longitudinal section of the Danube is characteristic. There is a continuous increase in the sediment samples along the river. Generally, it can be concluded that mercury, lead, chromium, nickel and copper were almost always in higher amount in the sediment than the mussel species. In contrast, cadmium was found in higher amount in mussels than in the sediment samples.

3.1.1. Mercury

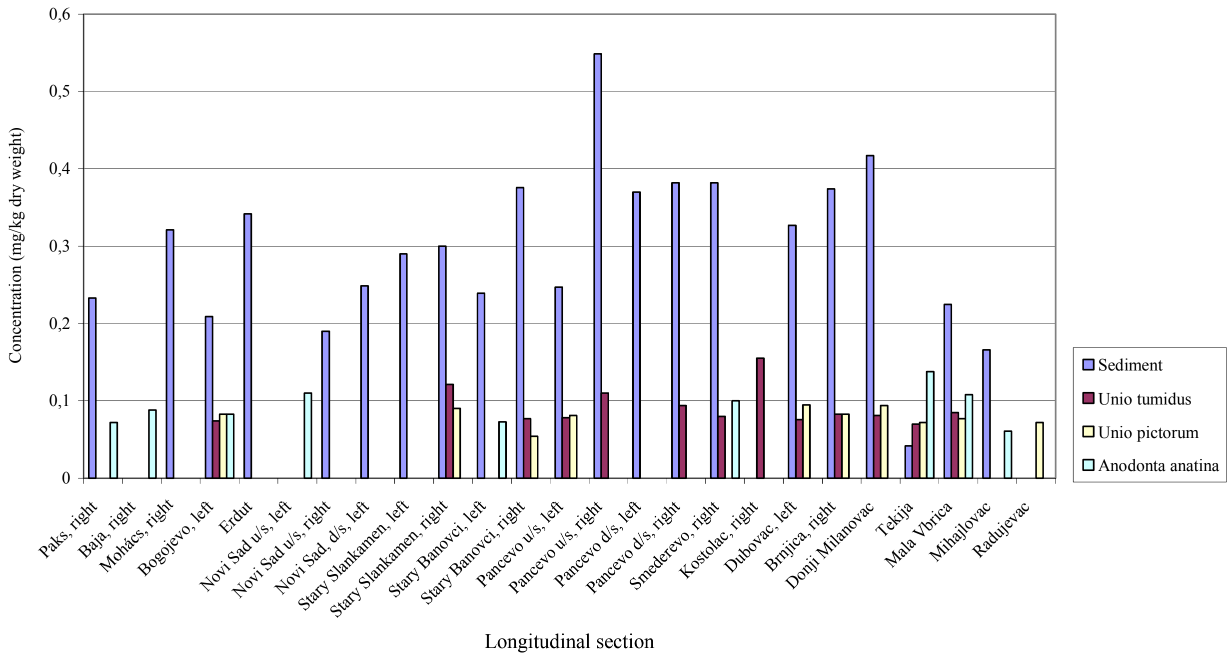


Figure 3.1.1. Mercury concentrations along the Yugoslavian Danube in 2000

Mercury is present only in very limited amounts both in the Danube and the tributaries. The concentration starts with approximately 0,2-0,3 mg/kg (dry weight) that reaches the maximum in the Danube at upstream Pancevo, right bank (that is just downstream Beograd) with a concentration of 0,55 mg/kg. The amount of this heavy metal decreases after the Iron Gate Reservoir sections (**Fig. 3.1.1**). The sediment of tributaries contain mercury in the same order of magnitude except the Velika Morava where the concentration almost reaches the maximum 1.2 mg/kg value (**Fig.3.1.2**).

Mercury is present always in fewer amounts in the mussel species than 0,2 mg/kg except in case of the Velika Morava where juvenile *Anodonta anatina* specimens contain almost the same amount as the sediment (**Fig.3.1.2**).

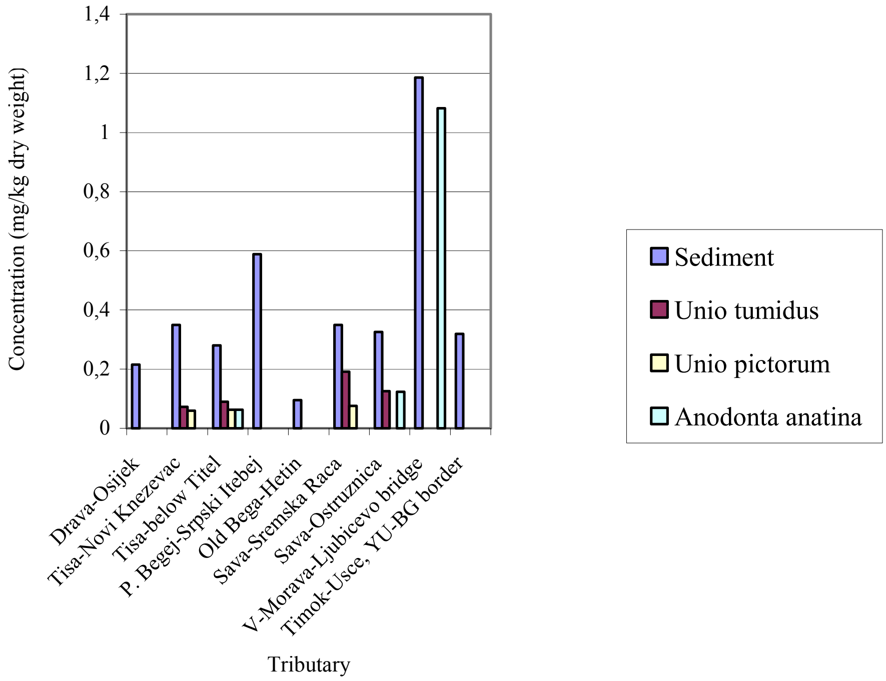


Figure 3.1.2. Mercury concentrations along the Danubian tributaries of FRG in 2000

3.1.2. Cadmium

Cadmium was characteristically in higher amount in the sediment of the lower Danube (from Pancevo region, max. in Kostolac, 3,6 mg/kg) than in the upper sections. Tisa sediment had the same order of magnitude of pollution among the tributaries than the Danube itself. The navigable Bega Canal had the most polluted state with maximum value of 23 mg/kg Cd content (**Fig. 3.1.3.**).

It is evident from the data that mussels contain much more cadmium than the sediment, especially in the lower stretch of the Danube (below Stary Banovci) and in the two Tisa sections together with the lower Sava section (**Fig.3.1.4**). This phenomenon can be seen only in case of two heavy metals (*Cd and Ni, see that later on!*). *Unio pictorum* and *Unio tumidus* mussel species accumulated the largest amount of cadmium. The maximum Danubian concentration was measured at Tekija in *U. pictorum* (more than 8 mg/kg) but in the Tisa bigger values were registered in the same species (more than 12 and 16 mg/kg in Novi Knjezevac and Titel, respectively). The overall maximum was detected in the *Unio tumidus* in the Sava at Ostruznica (almost 20 mg/kg).

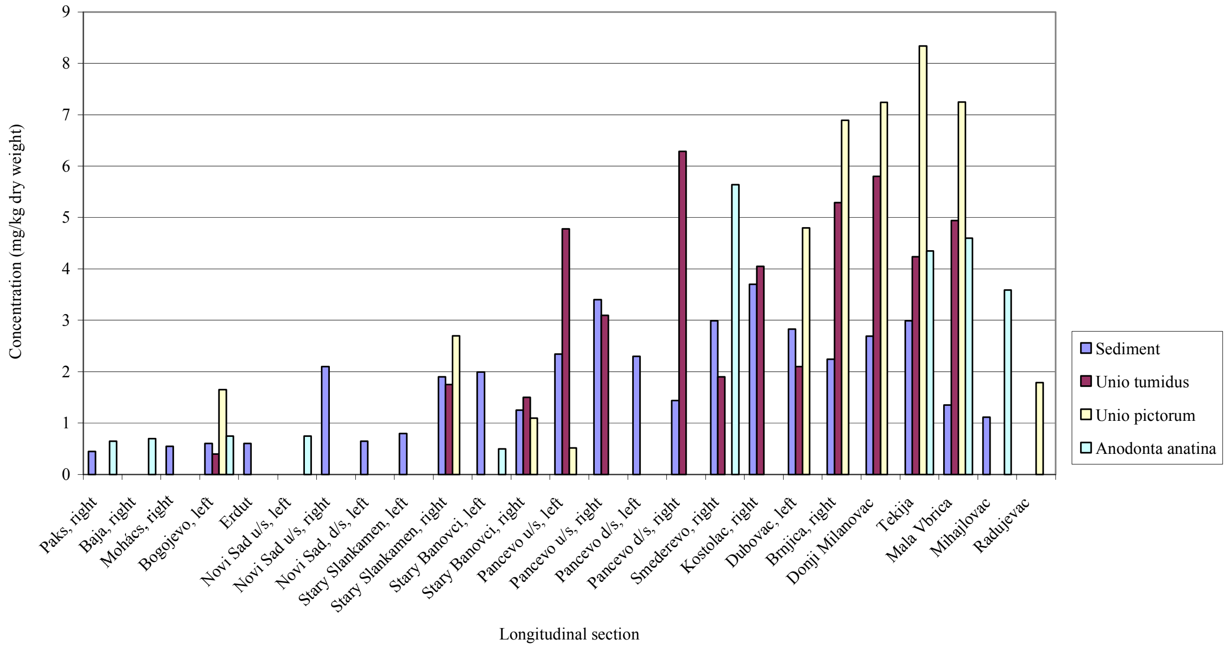


Figure 3.1.3. Cadmium concentrations along the Yugoslavian Danube in 2000

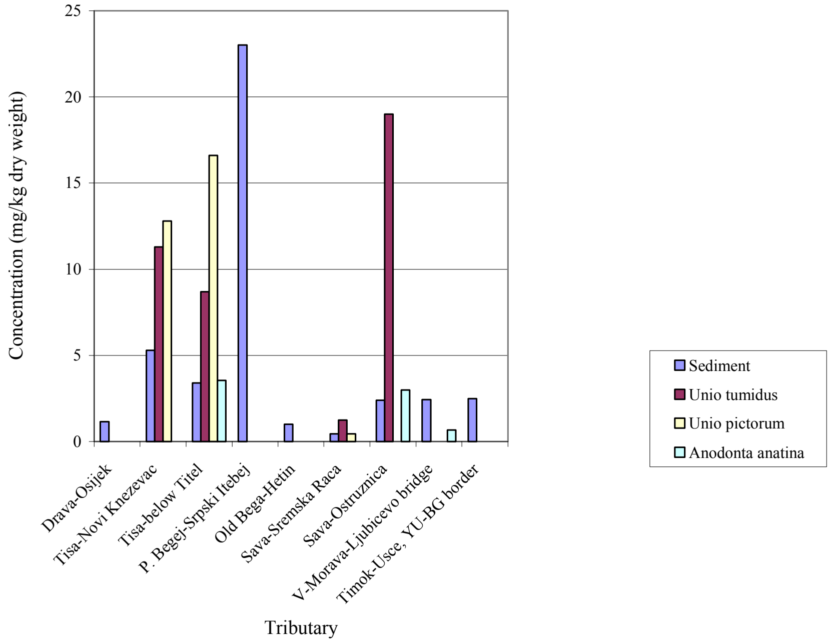


Figure 3.1.4. Cadmium concentrations along the Danubian tributaries of FRG in 2000

3.1.3. Lead

The amount of **lead** is increasing in the Danubian sediment along the longitudinal section having the maximum value (almost 120 mg/kg) at upstream Pancevo (right) that corresponds to the downstream site of Belgrade (**Fig. 3.1.5.**). The concentration values vary around 100 mg/kg in the Iron Gate section. Mussels collected in the Danube always contain much less amounts than sediment (approx. 10% of that), the species *Unio pictorum* contains more than others, especially in the Iron Gate section (max. 18.6 mg/kg at Brnjica).

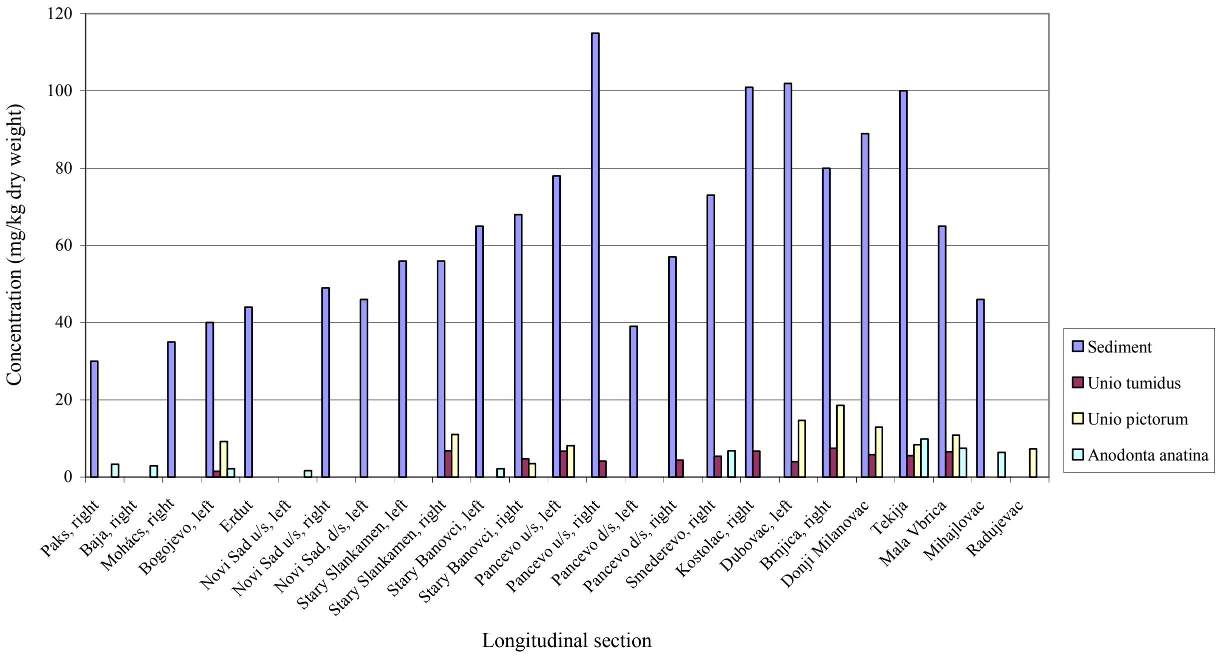


Figure 3.1.5. Lead concentrations along the Yugoslavian Danube in 2000

Drava and Tisa have similar level of lead contamination in the sediment part as the more polluted lower Danube but Sava resembles to the cleaner upstream Danube sections. However, the Navigable Canal of Bega at Srpski Itebej has the largest measured value (175 mg/kg Pb) indicating serious pollution arriving from Romanian (**Fig. 3.1.6**).

Mussels collected at the two sampling sites of the Tisa contain the same level of lead as the Danubian mussels living in the Iron Gate section. The species *Unio pictorum* accumulated higher amount than *U. tumidus*. Mussels in other tributaries have negligible lead contamination.

3.1.4. Chromium

Increasing **chromium** concentrations are characteristic along the longitudinal Danube section in the sediment (**Fig. 3.1.7**). The amounts measured the upstream parts are generally doubled in the lower stretches (downstream Belgrade and in the Iron Gate) reaching 120 mg/kg values. The concentration of Cr in mussel species is much less than in the sediment fraction, never reaching the concentration value 10 mg/kg in the Danube. There is no evident difference in the accumulative character of different mussel species in the Danube.

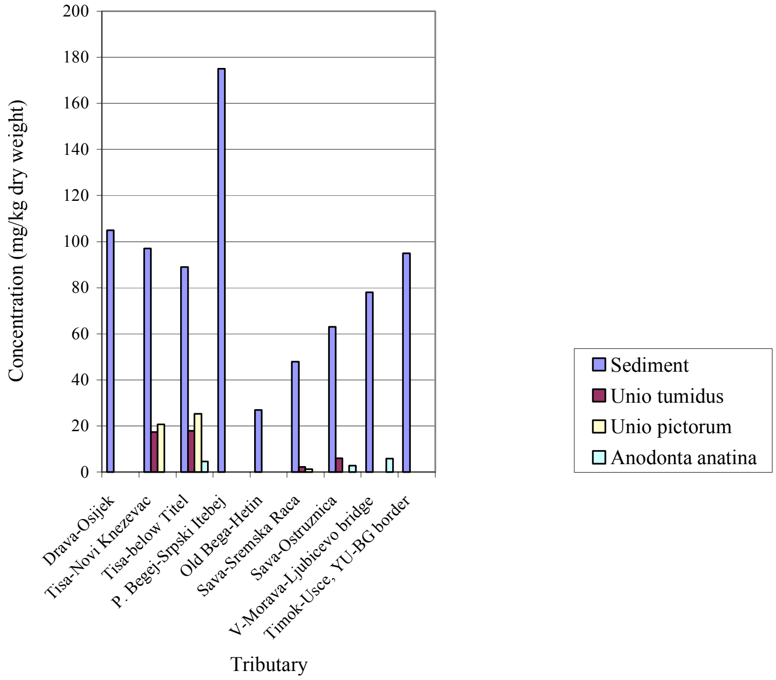


Figure 3.1.6. Lead concentrations along the Danubian tributaries of FRG in 2000

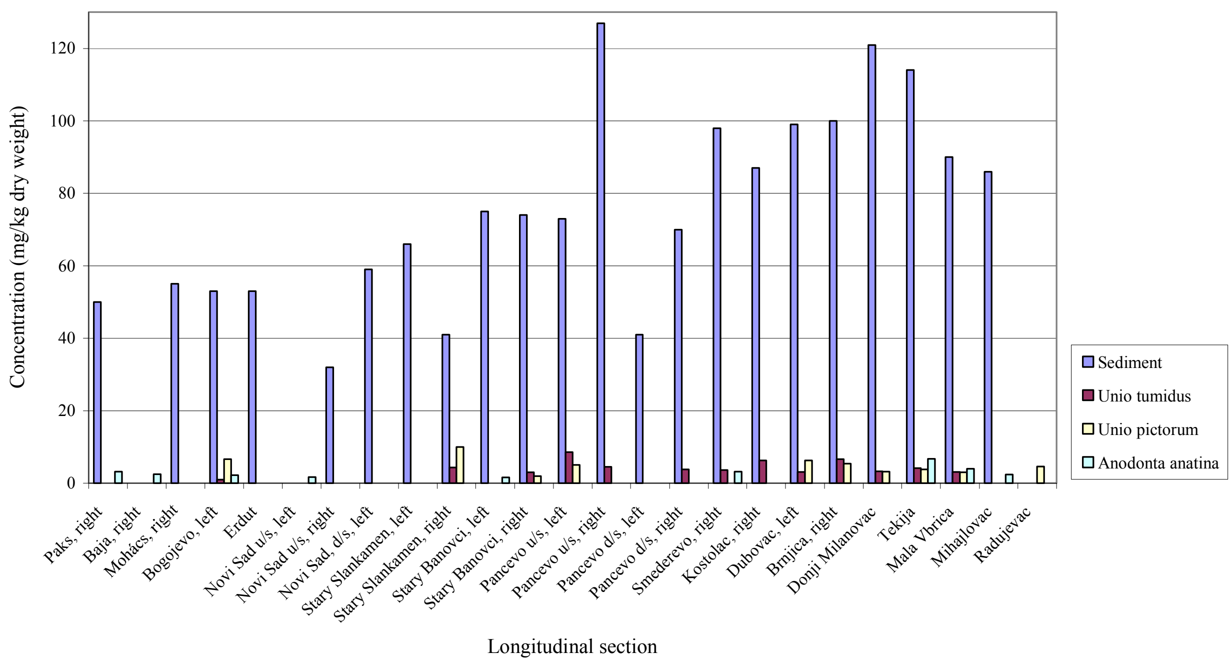


Figure 3.1.7. Chromium concentrations along the Yugoslavian Danube in 2000

Higher concentration values were detected in the sediment of some tributaries (Sava and Velika Morava) reaching the amount of 150 mg/kg (**Fig. 3.1.8**). However, the Navigable Canal of Bega was far more polluted by chromium (427 mg/kg). The species *Unio tumidus* collected in the two sites of the Tisa had the maximum measured Cr concentrations among all mussel species (24.8 and 13 mg/kg at Novi Knjezevac and Titel, respectively).

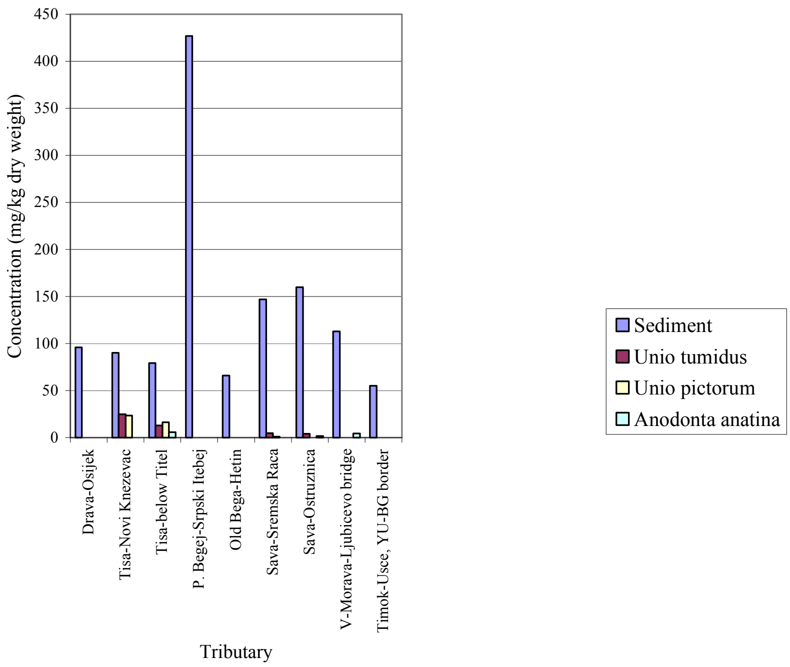


Figure 3.1.8. Chromium concentrations along the Danubian tributaries of FRG in 2000

3.1.5. Nickel

The longitudinal distribution of **nickel** in the Danube sediment indicates interesting picture. One sudden peak is observable downstream Belgrade (upstream Pancevo, right bank) with 115 mg/kg value (**Fig. 3.1.9**). The Iron Gate section is characterized by double values than the upper stretch, with another peak in Kostolac with the same concentration value as u/s Pancevo.

Two tributaries contain more Ni in their sediment fraction than the Danube: Sava at both investigated sites (136 and 137 mg/kg, respectively) and Velika Morava (117 mg/kg). It has to be mentioned that the chromium concentrations were relatively high in both Sava sections also (**Fig. 3.1.10**).

Concerning the Ni content of the mussels, some anomalies are seen in case of the Pancevo upstream left site where the amount of Ni exceeds very much the measured levels of the sediment fraction. It is suspicious because at the very polluted Sava sites the metallic content of the mussel tissues remain low (approx. 10 %). Therefore, these results need further investigations in future programs. Similar problem occurs in case of the Mohács section where more Ni was measured in Anodonta anatina than in the sediment.It is important to notice also that all of the three mussel species contained Ni in the same magnitude in the Bogojevo site as the Danube sediment. In case of tributaries sediment samples had always-bigger concentrations of Ni than mussel tissues.

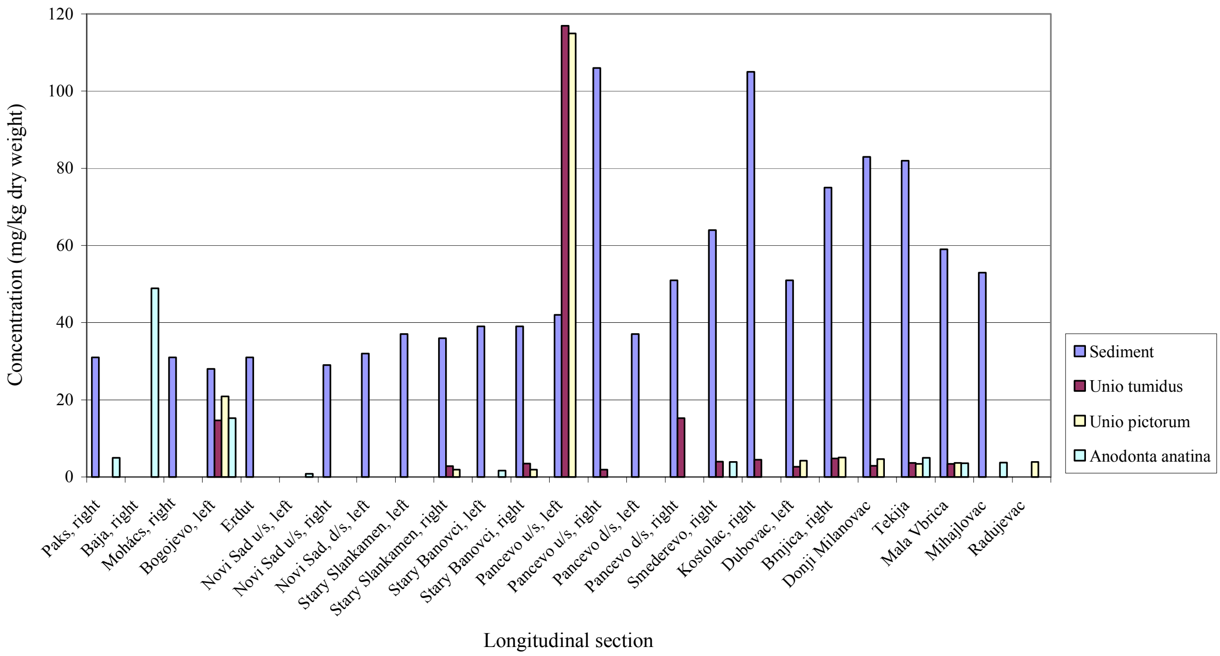


Figure 3.1.9. Nickel concentrations along the Yugoslavian Danube in 2000

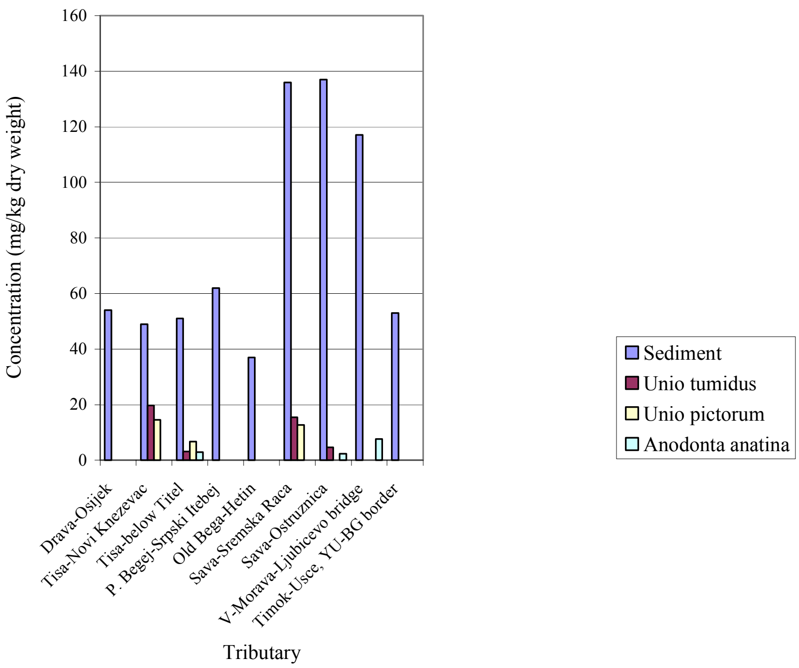


Figure 3.1.10. Nickel concentrations along the Danubian tributaries of FRG in 2000

3.1.6. Copper

The behavior of **copper** is very similar to other heavy metals along the Danube and the tributaries (**Fig. 3.1.11**). Increasing values were detected in sediment having two maximums (Pancevo and Tekija, here 121 mg/kg Cu was measured). The concentration of Cu in mussel tissues always remains around 10 %. Old Bega was almost the most polluted one with concentration value of 224 mg/kg (**Fig. 3.1.12**). The sediment of River Timok is extremely contaminated by copper due to mining activity along the upper watershed (4800 mg/kg peak!).

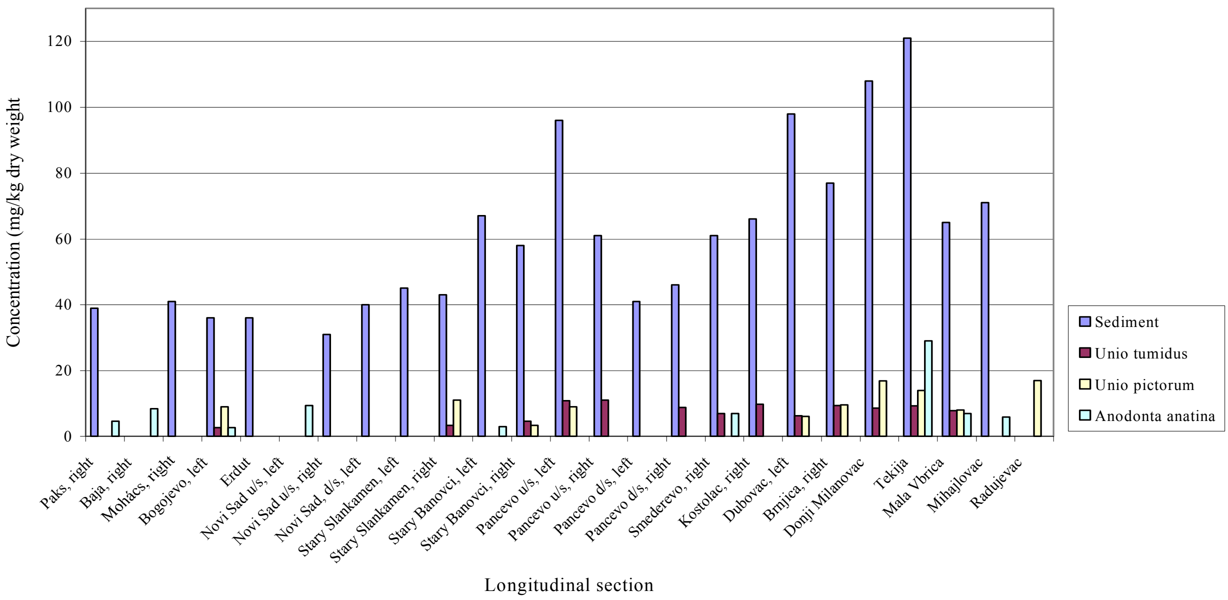


Figure 3.1.11. Copper concentrations along the Yugoslavian Danube in 2000

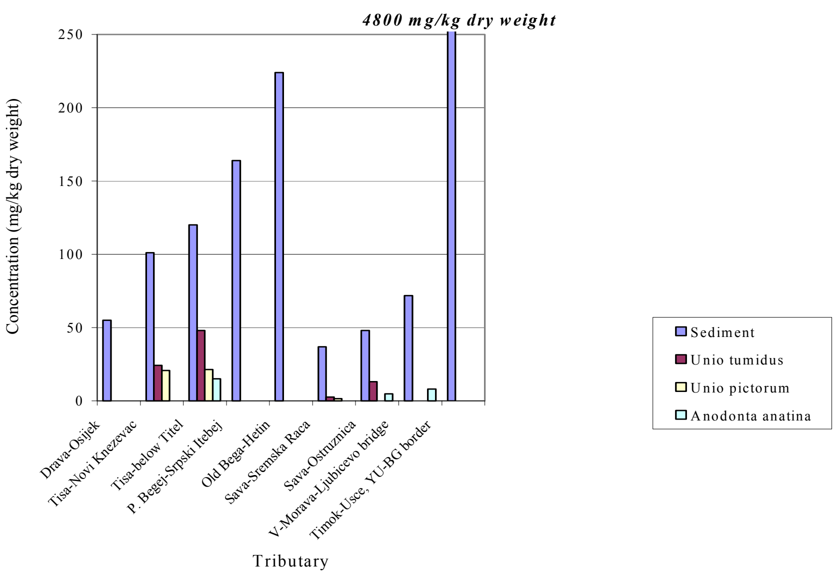


Figure 3.1.12. Copper concentrations along the Danubian tributaries of FRG in 2000

It can be seen that mussels collected in the Tisa sampling sites contained the higher amount of copper in their tissues (101 and 120 mg/kg in Novi Knjezevac and Titel, respectively).

3.2 Organic micropollutant content of the sediment and different mussel species

There are three main organic micropollutant groups measured in the sediment and mussel samples collected during the Bioindicator Study in 2000. All results of the analysis are collected in the *ANNEX 1 (Table A-1.1-A-1.9)*. In his chapter only illustration is given concerning several important compounds from each of the three main groups as **Cl-pesticdes**, **PAH's** and **PCB's**. Generally Cl-pesticides and PCB's were in higher amount in the tissues of living aquatic organisms (mussels) than in the river sediment samples. PAH's occur in bigger amounts in sediment samples usually.

3.2.1. Cl-pesticides

Lindane

It is characteristic that **Lindane** was detected only at one of the Danubian and tributary sampling sites (**Fig.3.2.1**). The name of the place is Stary Banovci, right bank where the amount of the compound is a bit higher (1.2 µg/kg) in the collected mussel species (*Unio tumidus*) than in the sediment itself. There was not detectable amount of Lindane neither at the other Danubian sampling sites nor at the locations of the investigated tributaries. All of the measurements concerning the mussel species and sediment samples resulted in the same figure.

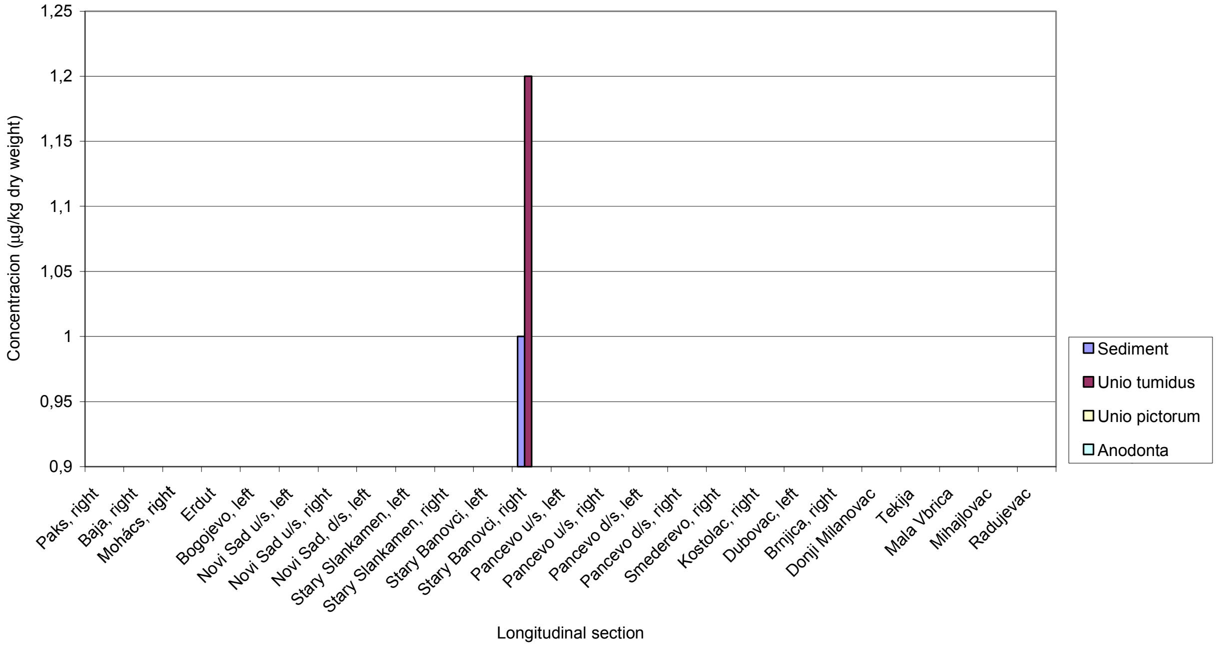


Figure 3.2.1. Lindane concentrations along the Yugoslavian Danube in 2000

2,4 DDE

In case of 2,4 DDE it can be concluded that the sediment phase in the Danube and in the tributaries contained *no detectable amount* of this compound at all. However, it is worthwhile to notice that the mussel samples contained signficant amount of this compound at certain sampling sites. Both of the species *Unio pictorum* and *U. tumidus* has to be mentioned as very polluted organisms. There was a maximum value (46 µg/kg) in the *U. tumidus* at Bogojevo (**Fig 3.2.2.**). High value was measured at Tekija (end of the Irin Gate I) in the *U.pictorum* (35 µg/kg).

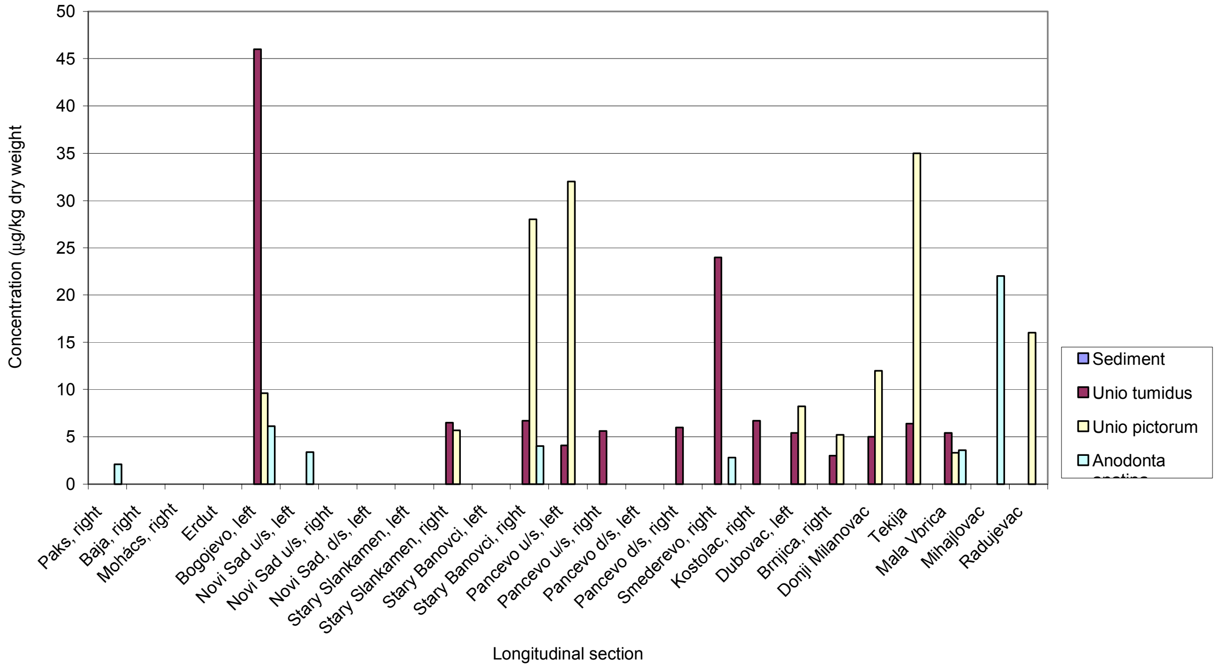


Figure 3.2.2. 2,4 DDE concentrations along the Yugoslavian Danube in 2000

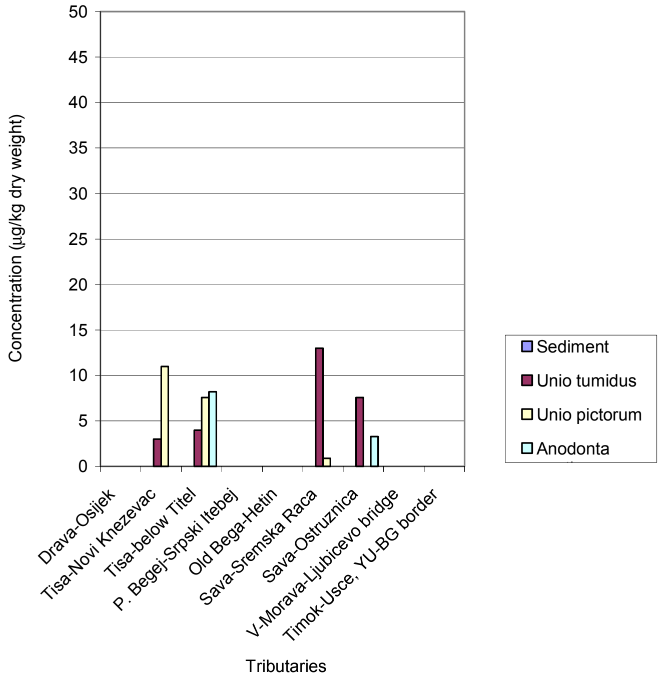


Figure 3.2.3. 2,4 DDE concentrations along the Danubian tributaries of FRG in 2000

This compound was found in the mussels collected in the tributaries in smaller but significant amount (max.: 13 µg/kg in Unio tumidus at Sava, Srmska Raca). There was no detectable concentration of 2,4 DDE in the sediment samples collected in the Danubian tributaries (**Fig. 3.2.3.**).

DDD

The distribution of DDD is highly similar to the 2,4 DDE. It was detected in negligible amount only at one sediment sample (**Fig.3.2.4.**). Other concentration values were measured in mussels. All of the three species had relatively high concentrations in their tissues. The maximum vales are as follows:

Unio pictorum:	8.6 µg/kg at Stary Slankamen, right
Unio tumidus:	14 µg/kg at Smederevo, right
Anodonta anatina	11 µg/kg at Mala Vrbica, right

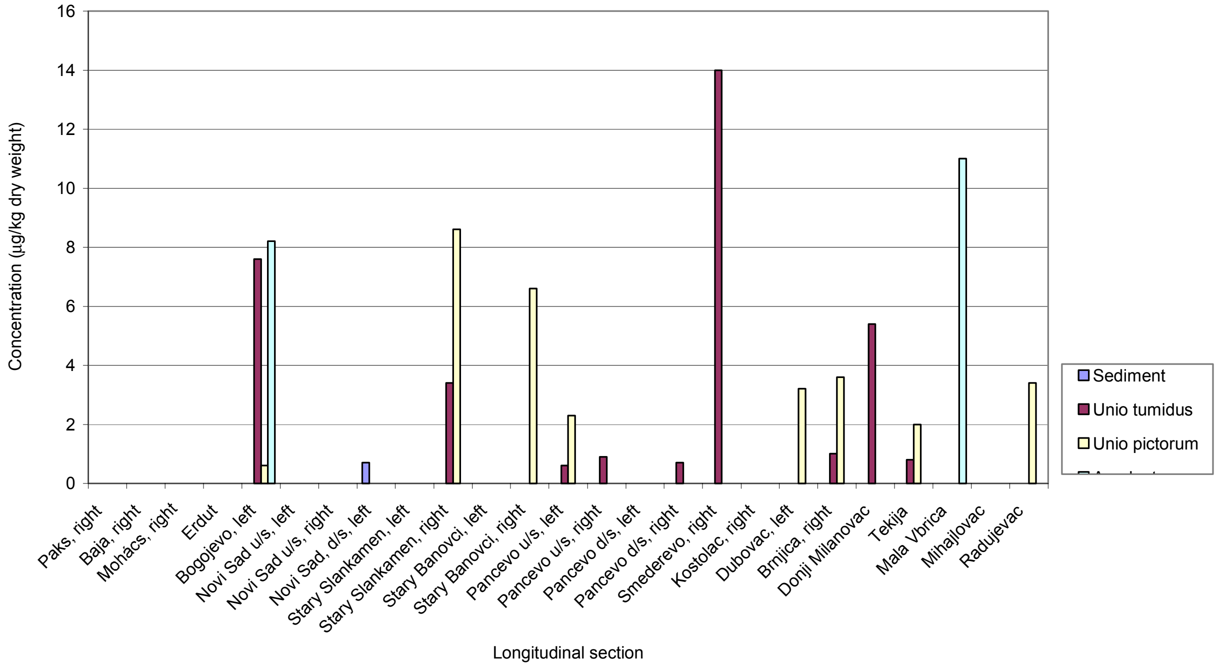


Figure 3.2.4. DDD concentrations along the Yugoslavian Danube in 2000

DDD occurred in detectable amount of in the sediment of the Sava at Ostruznica (0.5 µg/kg). More than three times higher concentration was measured in the mussel species *Unio tumidus* at the same site (1.6 µg/kg). The same value characterise the *U.pictorum* in the Tisza at Titel (**Fig. 3.2.5**).

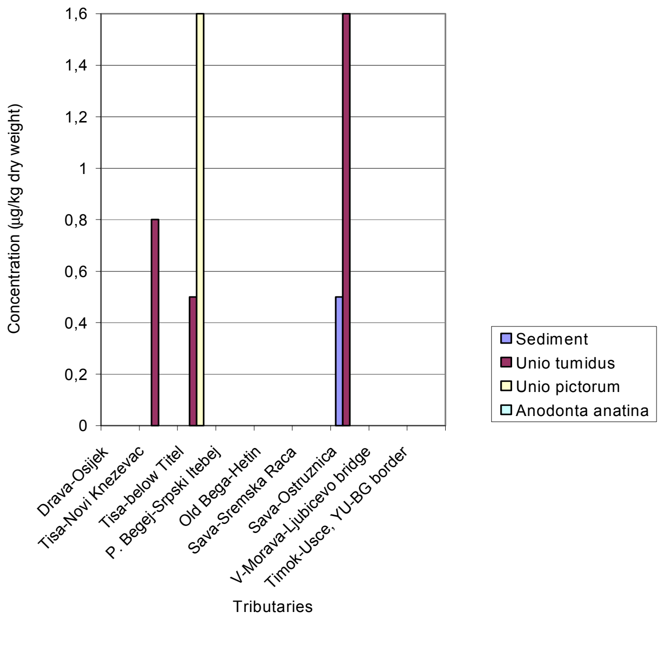


Figure 3.2.5. DDD concentrations along the Danubian tributaries of FRG in 2000

DDT

It is very interesting that DDT is still present in the aquatic environment. Mussel tissues contain significantly higher amounts than the sediment samples (**Fig. 3.2.6**).

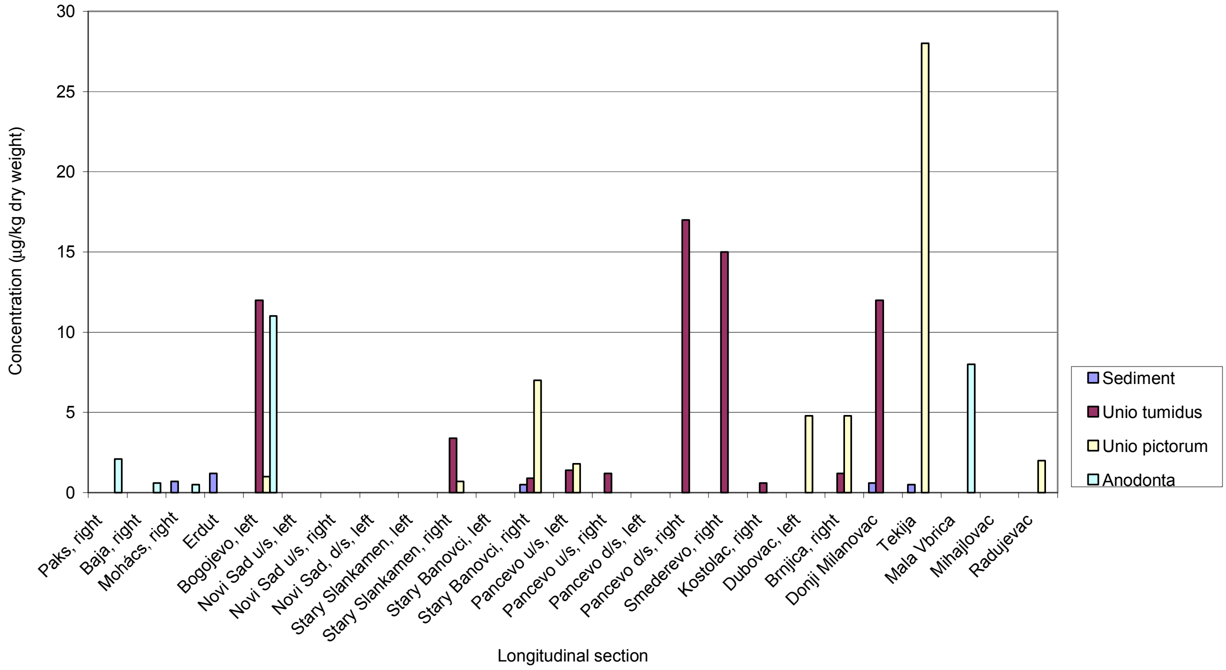


Figure 3.2.6. DDT concentrations along the Yugoslavian Danube in 2000

Only a small amount is measures in the Hungarian Danube stretch both in sediment and mussel samples. Two mussel species (*Unio tumidus* and *Anodonta anatina*) at Bogojevo contain more than µg/kg concentrations. Stary Banovci (*Unio pictorum*), Pancevo, Smederevo and Donji Milanovac (*Unio tumidus*), Tekija (*U. pictorum*) and Mala Vbrica (*Anodonta anatina*) has to be mentioned as sites where bigger values than 5 µg/kg DDT concentrations were detected. It has to be noticed that the overall maximum (28 µg/kg) was measured in *U. pictorum* at the end of the Iron Gate I at Tekija (**Fig. 3.2.6.**).

There were just detectable DDT concentrations in the sediment samples of tributaries (**Fig. 3.2.7**). However, *Unio pictorum* from the Tisa at Novi Knjezevac contained 17 µg/kg DDT as a maximum value among tributaries.

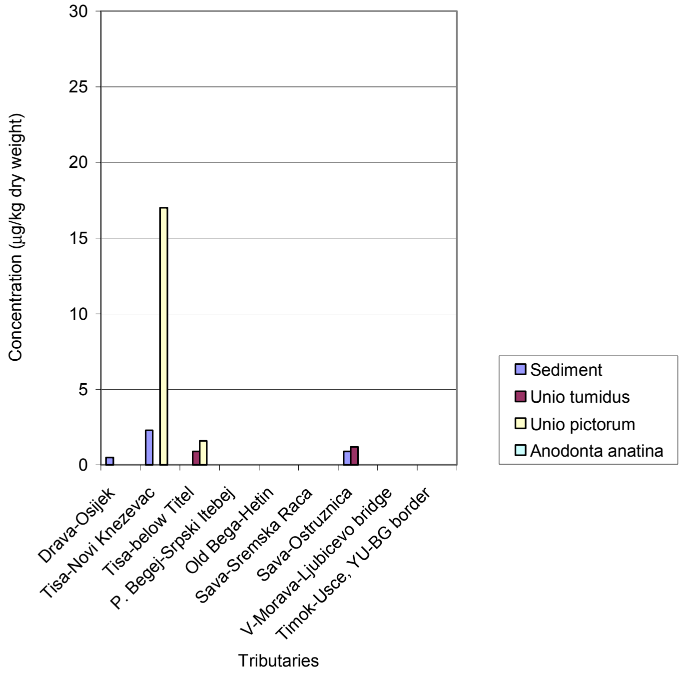


Figure 3.2.7. DDT concentrations along the Danubian tributaries of FRG in 2000

3.2.2. PAH's

Benzo(a)pyrene, fluoranthene and pyrene were selected from the group of PAH's for illustration purposes. These compounds generally refer to oil contamination that is originated from river shipping.

The sediment fraction contains almost every case much bigger concentrations than the mussel samples.

Benzo(a)pyrene

The sediment of the upper Danube is characterised by higher values than the downstream section (max. value at Paks and Bogojevo: 237 and 238 µg/kg, respectively, **Fig. 3.2.8**). Some localities have to be mentioned where mussels contain relatively high amounts of this pollutant (bigger than the sediment fraction!), like Stary Banovci (*Unio pictorum*: 130 µg/kg), Smederevo and Brnjica (*Unio tumidus*: 80 and 81 µg/kg, respectively).

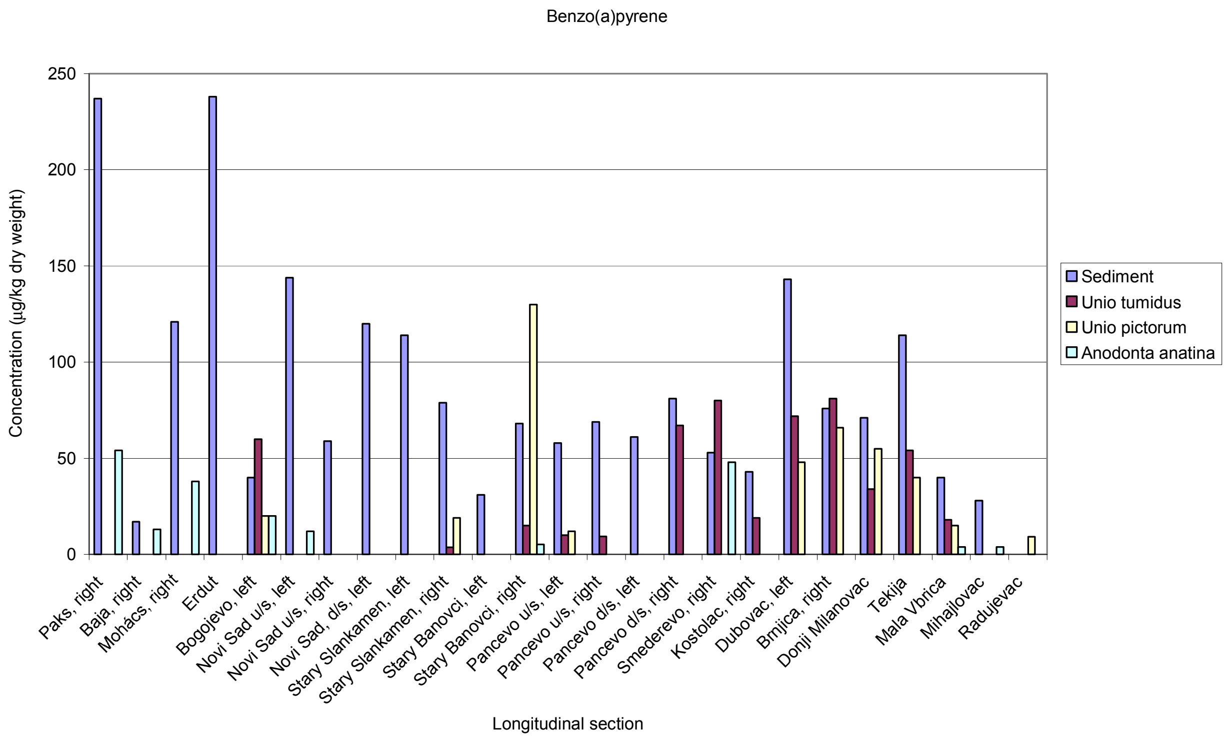


Figure 3.2.8. Benzo(a)pyrene concentrations along the Yugoslavian Danube in 2000

The pollution level of the sediment of tributaries is similar to the lower Danube stretch (max. value: 129 µg/kg in the Sava at Srmska Raca, **Fig. 3.2.9**). *Unio tumidus* has 71 µg/kg concentration measured in the Sava sample at Srmska Raca, as well.

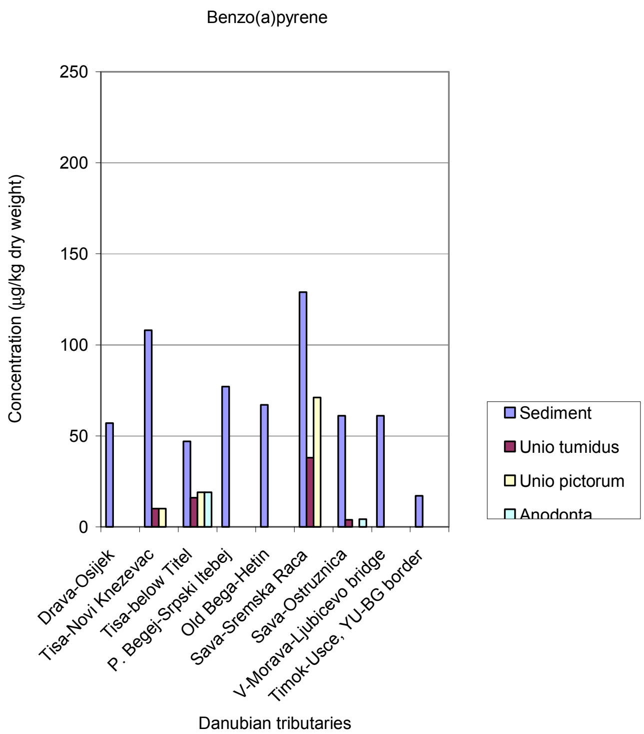


Figure 3.2.9. Benzo(a)pyrene concentrations along the Danubian tributaries of FRG in 2000

Fluoranthene

The longitudinal distribution of this pollutant is very characteristic in the Danubian sediment. It has an overall maximum (almost 800 µg/kg) in the uppermost section at Paks. The concentration reaches the range of 100 µg/kg at Stary Slankamen already and it lasts until the end of the Iron Gate I (Tekija). It decreases further on in the Iron Gate II and downstream of it (**Fig. 3.2.10**).

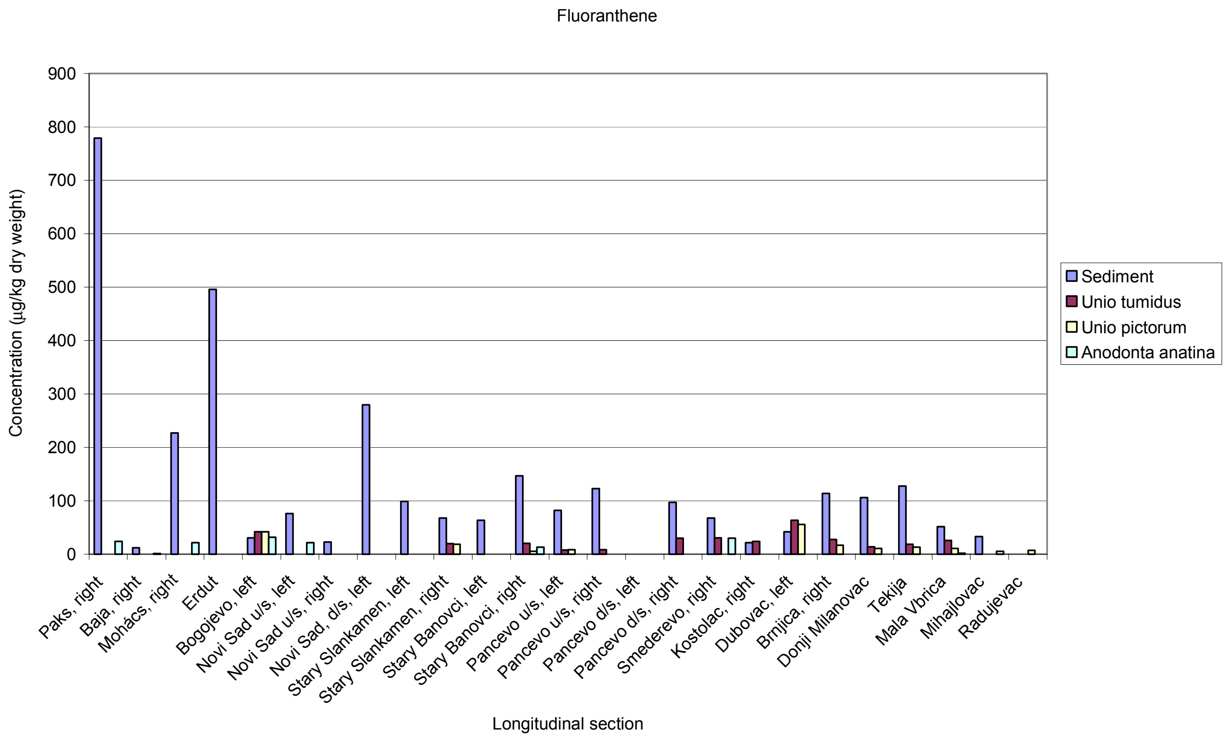


Figure 3.2.10. Fluoranthene concentrations along the Yugoslavian Danube in 2000

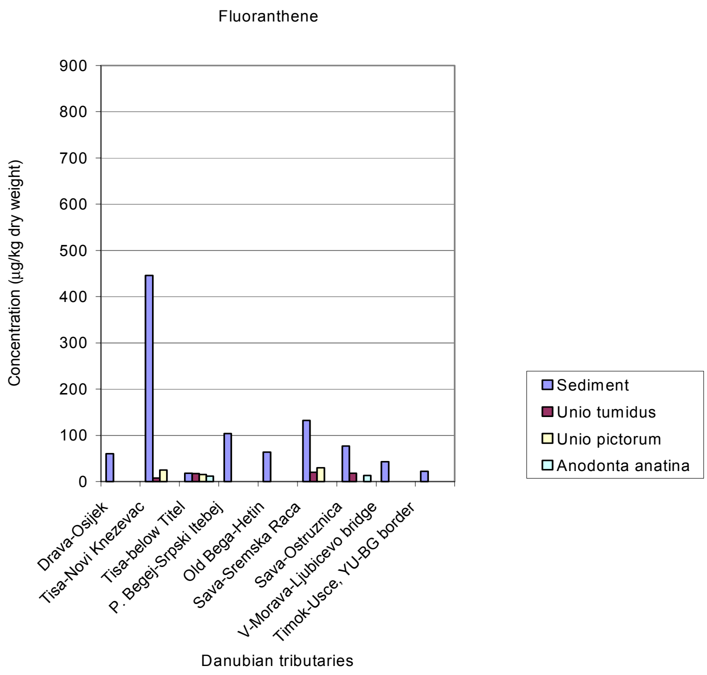


Figure 3.2.11. Fluoranthene concentrations along the Danubian tributaries of FRG in 2000

The amount of fluoranthene in the mussel samples reaches its maximum at Dubovac (64 µg/kg) but generally it is well below this value in the mussel tissue samples collected along the other sections.

Tributaries are characterised by the same order of magnitude as the Danube in its lower stretch (**Fig. 3.2.11**). Only the Tisa at Novi Knjezevac contains almost 450 µg/kg fluoranthene in its sediment fraction. The concentrations of this pollutant in mussel tissues remain low in the samples collected at different sites.

Pyrene

The behaviour of pyrene is very similar to the fluoranthene both in the sediment fraction and the mussel samples (**Fig. 3.2.12.**). Higher values are seen only upstream (Paks and Erdut). The range that characterises the lower stretch is between 200 and 100 µg/kg.

The maximum value detected in the species *Unio tumidus* is 119 µg/kg that exceeds the concentration measured in the same sediment sample!

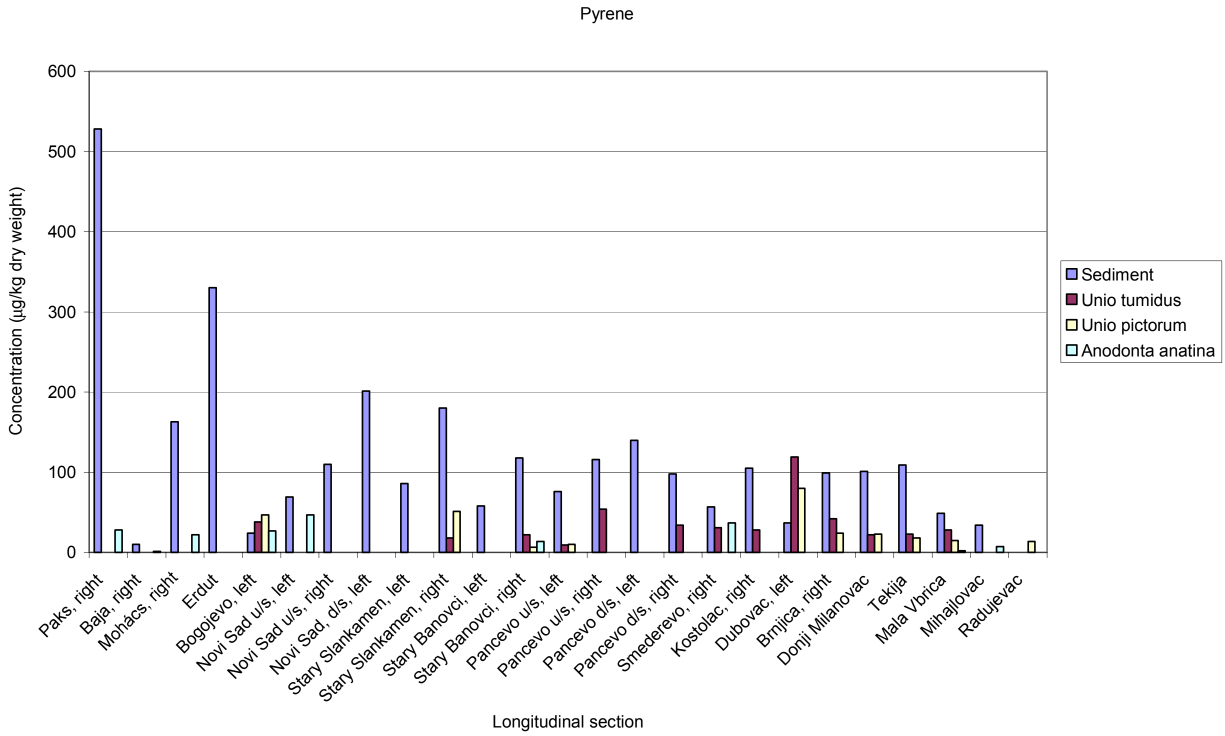


Figure 3.2.12. Pyrene concentrations along the Yugoslavian Danube in 2000

Tributaries do not exceed 100 µg/kg except the Tisa at Novi Knjezevac (392 µg/kg, **Fig. 3.2.13**). All of the three mussel species collected in the Tisa at Titel contained significant amount of pyrene in their tissues. The highest concentration (51 µg/kg) was detected *Unio tumidus.*

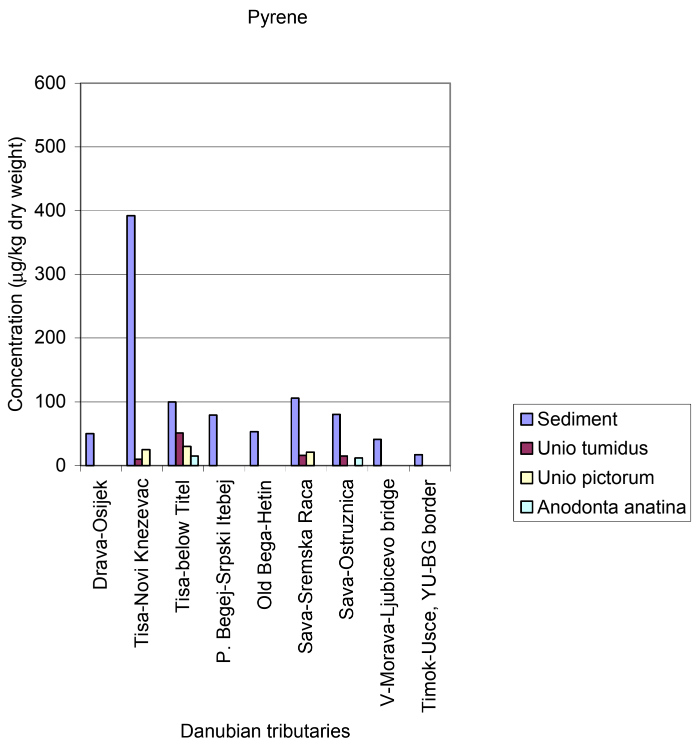


Figure 3.2.13. Pyrene concentrations along the Danubian tributaries of FRG in 2000

3.2.3. PCB-s

Only three PCB compounds are illustrated in this chapter (PCB-52, PCB-101 and PCB-118) because others occurred in smaller amounts than the detection limit.

The distribution of different PCB compounds illustrates very variable picture as far as the detected amounts in sediment and mussel samples are concerned.

PCB-52

Relatively low amounts are shown on **Fig. 3.2.14.** and **15.** It is interesting that Anodonta anatina samples collected in the three Hungarian localities (Paks, Baja and Mohács) all contained bigger concentrations than the sediment fraction (maximum value at Paks, 2,8 µg/kg PCB-52)

Increasing sediment concentrations are started at Novi Sad, and occurring in Mala Vbrica (almost 2.5 µg/kg). Overall maximum value is detected in *Unio pictorum* collected in the Iron Gate I at Donji Milanovac (near to 3.5 µg/kg, **Fig 3.2.14**).

There are three tributaries where PCB-52 was detected. The values of Drava (Osijek), Sava (Srmska Raca) and Velika Morava are illustrated on **Fig. 3.2.15**. The Sava point is especially interesting because the detected concentration value is bigger in the mussel species (*Unio pictorum*) than in the sediment sample itself.

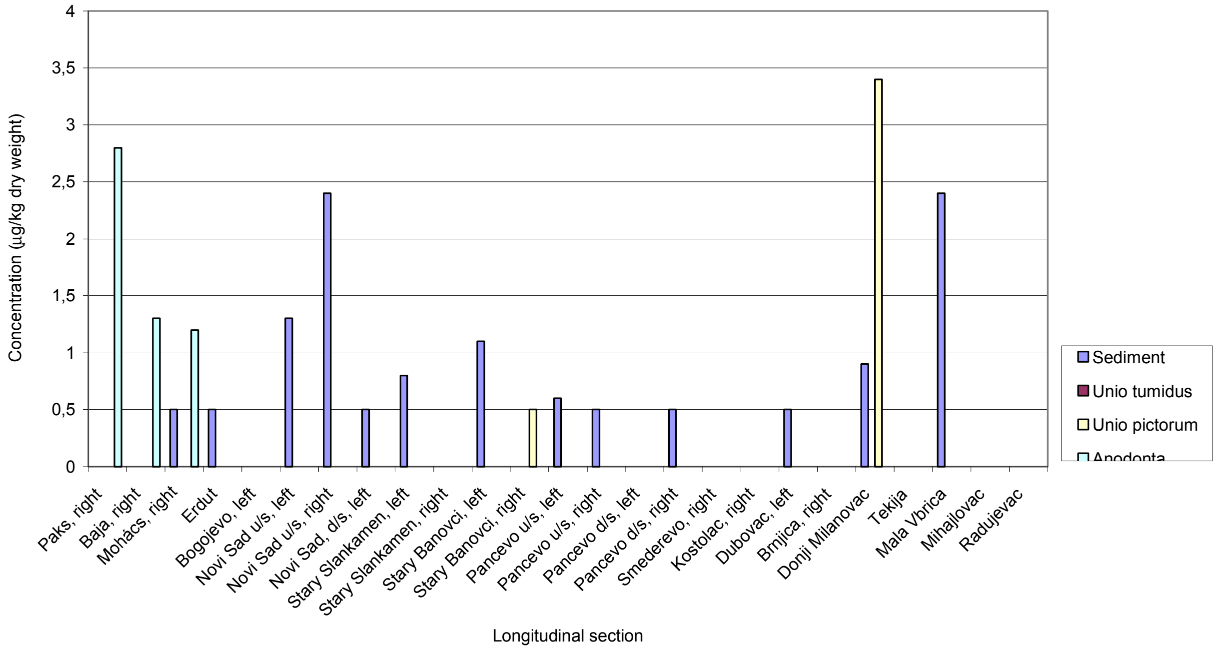


Figure 3.2.14. PCB-52 concentrations along the Yugoslavian Danube in 2000

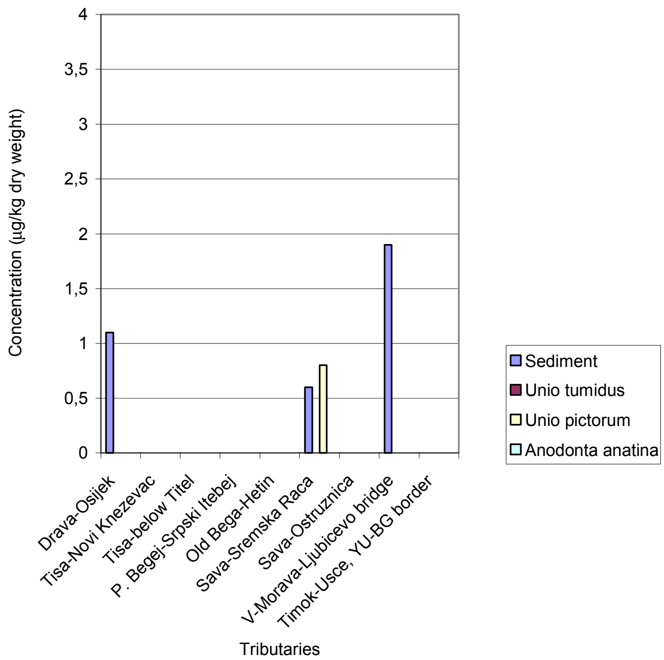


Figure 3.2.15. PCB-52 concentrations along the Danubian tributaries of FRG in 2000

It is worthwhile to emphasise that these values are usually just above the detection limit of that compound.

PCB-101

This PCB-compound occurs in the sediment in relatively low amount because the values measured are similar to the previous one: they are nearly around the detection limit. However, the different mussel species collected in the Danube and the tributaries have some more interesting character.

Generally, mussel samples always contain more PCB-101 compound than the corresponding sediment samples (**Fig. 3.2.16**). The first peak is registered at Bogojevo in *Unio tumidus* (22 µg/kg). *U. pictorum* shows similar high values in Stary Manovci and Tekija (8.8 and 17 µg/kg, respectivey).

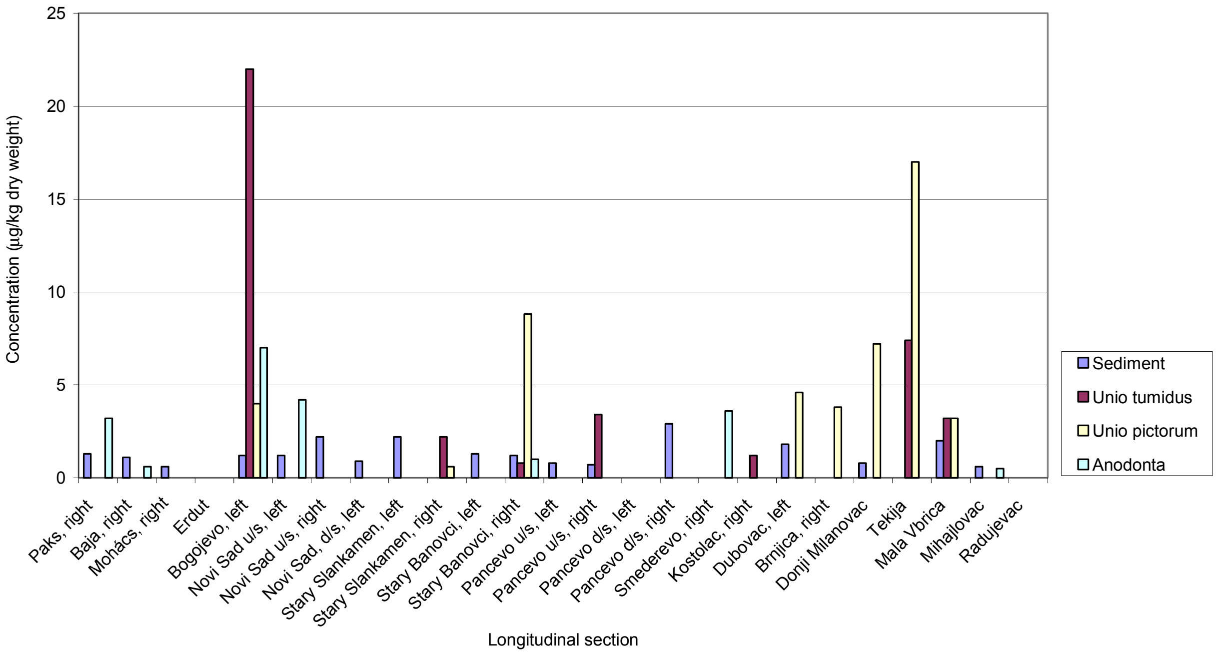


Figure 3.2.16. PCB-101 concentrations along the Yugoslavian Danube in 2000

There are values above the detection limit measured in the sediment samples collected in the tributaries but only the site of the River Sava at Ostruznica has to be mentioned as a site characterised by specially high PCB-101 level in the mussel tissues. **Figure 3.2.17** illustrates that 13 µg/kg vale was measured in *Unio tumidus* mussel species. The amount of this compound almost reached 5 µg/kg concentration in case of the *Anodonta anatina*, as well.

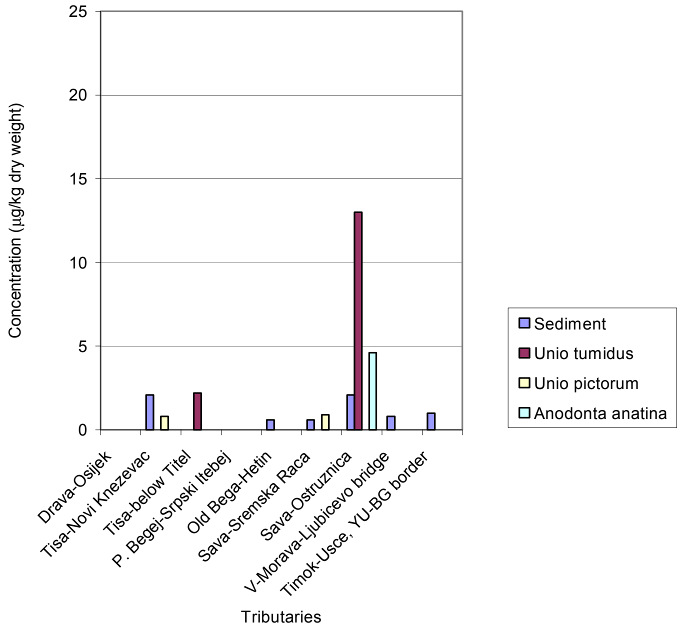


Figure 3.2.17. PCB-101 concentrations along the Danubian tributaries of FRG in 2000

PCB-118

In case of this PCB-compound a very variable behaviour can be seen. Concentrations are in the same order of magnitude in case of both the sediment and the mussel samples (**Fig. 3.2.18** and **19**).

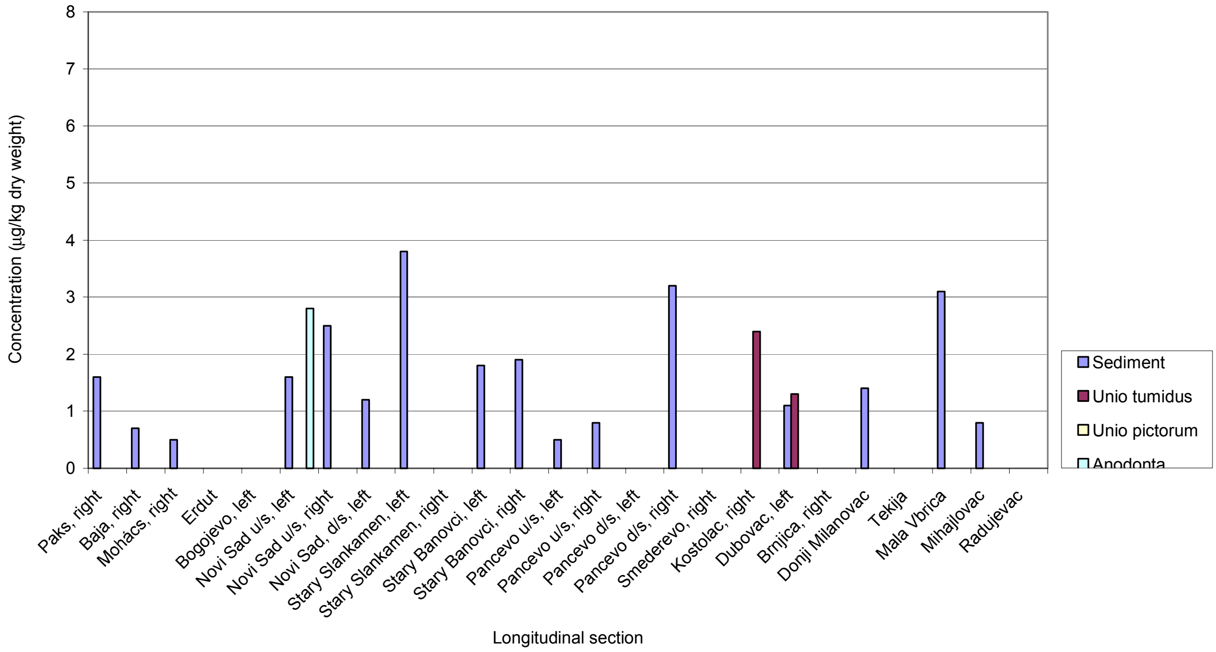


Figure 3.2.18. PCB-118 concentrations along the Yugoslavian Danube in 2000

Generally, the concentrations measured in the sediment fraction are dominating. The scale of the diagrams of the Danube and the tributaries are the same. The highest sediment concentration were detected in Stary Slamkamen, left, Pancevo downstream, right and Mala Vrbica (3.8, 3.2 and 3.1 µg/kg, respectively). Generally, tributary sediments contain fewer amounts than these concentrations. The values of *Anodonta anatina* (2.8 µg/kg at Novi Sad upstream, left) and *Unio tumidus* (2.4 µg/kg at Kostolac and Sava, 7.4 µg/kg at Ostruznica) can be mentioned as examples representing the peak values measured in mussels among all sites.

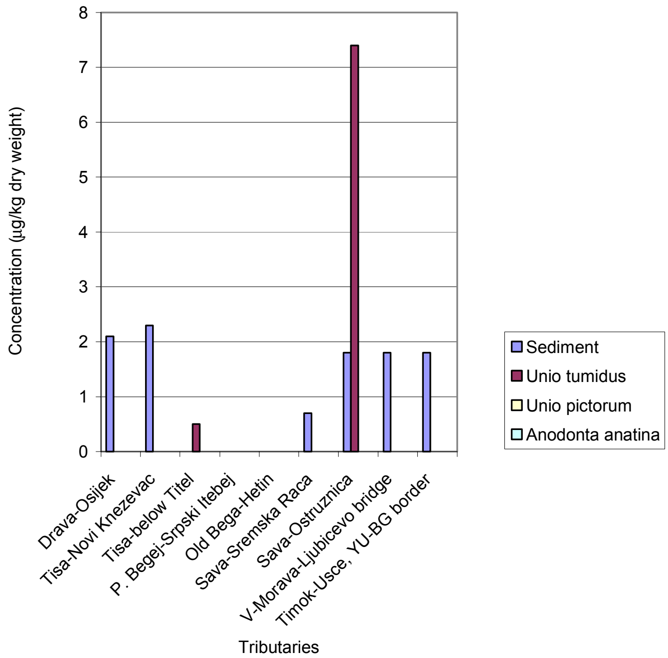


Figure 3.2.19. PCB-118 concentrations along the Danubian tributaries of FRG in 2000

3.3 Macroinvertebrate community analysis

3.3.1 Fanunistic results

The macrozoobenthic community of the River Danube and its main tributaries was investigated during this project. Serial numbers of the investigated sites show the sampling localities that are indicated in **Table 2.1.1.** Quantitative taxonomic results are summarised in **Table 3.3.1** (Danube River) and **3.3.2** (Tributaries). Number of detected taxa and the Saprobic index values of the different sections of the Danube are shown in **Table 3.3.3.**

In order to analyse the faunal results of the sampling program it is necessary to investigate the most important variables that have the primary influence on the composition of potamal macroinvertebrate community. Theoretically it can be supposed that the water quantity and quality both have primordial effect on the community structure. Several quantitative hydrological variables of the Danube River such as average flow rate, annual dynamics of the flow, differences between minimum and maximum water levels, range of flow velocity, etc. are all promoting the development of characteristic Danubian aquatic habitat types.

It can be recognised that three main substrate types occur along the main river arm. Sand indicates that this stretch is a typical middle section of the river containing mostly taxa that occur both in lotic and lenitic conditions. Slower sections, current shadows contain the finest sediment fraction (mud) that can cover extended areas and small mosaics, as well. These patches provide the habitat for the lenitic taxa. Coarse material occurs at faster flowing sites only. The typical rheophilous community characterised by really lotic Danubian species can be found at these habitats.

However, this recognition of differences in particle size characterising the main habitats of the Danube (that are determined directly by the hydrological conditions) was essentially important in case of the sediment sampling, too.

There was increased flow rate during the beginning of the sampling program resulted in an immediate increase of the water level at the sampling sites of the Danube upstream of the Iron Gate. This high water flow period made the sampling especially difficult. The section of the Iron Gate is characterised by huge periodic water level fluctuations according to the operation of the power plant. The influenced zone of littoral region is around 4 m of elevation. There was high water level in the reservoir area during the sampling program. Therefore sampling of the reservoir stretch was especially difficult, too, due to the water level fluctuation, and, the coincidental high water level, respectively.

The river has very sudden sloppy banks at certain sections (Erdut, Stary Slankamen- left) due to the strong current line passing close to the shoreline. There were relatively poor communities detected at these types of sampling sites.

Based on the field experiences it is suggested that the number of detected macroinvertebrate taxa at different sites be strongly influenced by the actual **flow rate**, the consequent **water level** and the available **habitat type** of the river. Results indicate that this large European river basically has very rich macroinvertebrate fauna on the Yugoslavian section also. The species richness depends on the available stable bottom. Moving sand, strong sediment transport, permanently changing bottom structures are not suitable for most of the macroinvertebrate species having sessile character.

Altogether 38 macroinvertebrate samples were successfully collected in the sampling program. Living organisms were not available at one site in the Danube (Stary Slankamen, left) because the extremely close main flow to the left riverbank resulted in a very deep river channel where the riverbed was built up from hard clay material. Practically this habitat proved to be lacking in macroinvertebrates even after a long lasting checking (only one hatching imago of the river dragonfly of *Gomphus (Stylurus) flavipes* was detected on the bank side over there). Another unsuccessful trial of biological sampling happened to be in the Timok River, due to its very polluted status caused by the toxic copper metal. No living creature was detected at this site at all, even using the diving/Hand Net combined sampling method.

The number of sites is 27 where living mussel species were collected. Some sites contained more than one species, so altogether 53 mussel samples were analyzed. The following species were collected during the sampling campaign: (**1**) *Anodonta anatina*, (**2**) *Unio tumidus* (**3**) *Unio pictorum* (**4**) *Unio crassus* (**5**) *Sinanodonta woodiana*, (**6**) *Pseudanodonta complanata* (**7**) *Anodonta cygnea.*

Several *Oligochaeta* genuses are common on the middle Danube such as *Limnodrilus*, *Potamothryx* and *Tubifex*. However, the low number of species suggests that maybe the preservation was not sufficient for this group of animals, because their soft body tissue is easily destroying among the sediment particles during the transportation. This result suggests at least that the selection of the samples *on site* is better for the later exact determination of *Oligochaeta* taxa.
Two of the detected nine leech species were found only on the Hungarian section (*Dina lineata, D. punctata*). The occasional occurrence of the others illustrates that leeches are not very abundant on this river stretch at all.

The group of *MOLLUSCA* (aquatic snails and mussels) represents the richest community. This Danube section and most of the tributaries contain the characteristic large potamal mussel and snail species living in the sediment layer. Some of them are typical for the rheophilous habitats like the two *Theodoxus* and *Fagotia* species that were detected in the Danube and the Sava Rivers. *Amphimelania holandrii* is similarly a character species of the Danube River occurring strictly on the lower section (Golubinje, Radujevac). The *T. danubialis* was found first at St. Banovci and at several places downstream up to Radujevac, whereas *T. fluviatilis* is more common starting from the Hungarian section already.

The mussel species live more or less in slower flowing habitats that are rich in finer sediment particles. Only one of them is a real stagnant water species (*Anodonta cygnea*) that has a large population in the beginning section of the Iron Gate II. Others were frequently detected along the whole investigated Danube stretch. The frequency of the large mussels is the following (in decreasing order): *Unio tumidus* (at 24 sites), *U. pictorum* and *Anodonta anatina* (18-18 sites), *Sinanodonta woodiana* (10), *Pseudanodonta complanata* and *Unio crassus* (4-4), *Anodonta cygnea* (1 site only).

The effect of the water quality on the community structure is evident also. Poor fauna having only common species with wide tolerance to organic pollution was described at both Novi Sad and Pancevo sections downstream of the industrial area. Upstream Pancevo the immediate effect of the communal wastewater of Belgrade was detected, too. Large mussels were present only u/s Novi Sad and Pancevo but they are absent at the downstream sections of the mentioned sampling sites on the left bank. The most abundant taxon is *the Lithoglyphus naticoides* and the *Sphaerium rivicola*. Both of them are in much larger amount on the left side, upstream the industrial section in the samples (**Table 3.3.1**) than on the downstream part of the channel.

Based on the faunal data the flowing stretch of the Yugoslavian Danube has similarly rich macroinvertebrate community as the upstream section in Hungary. The main difference is the main available substrate type: small sediment particles are predominantly present at many sites. Beside of that the Danubian fauna is very similar. Only few special taxa illustrate small variation: The *Viviparus acerosus* snail species is slowly replaced by the *Viviparus viviparus* along the long section of the river. The first registered *V.viviparus* population was detected at

Stari Slankamen, than it is more and more frequent along the Iron Gate and below that reservoir.

However, the taxonomic determination of the species belonging to this genus means difficulties in many cases. Our determination is based on overall morphological attributes due to the lack of available keys.

The section of the Iron Gate I. reservoir shows a big mixture in rheophilous and stagnant water species. The same phenomenon was experienced during the BTF 1999 sampling mission already both cases at Ram and Banatska Palanka. Stagnant shallow littoral habitats were detected at several places in the reservoir where aquatic macrophytes were seen. This is a bit contradictory to the fact that the frequent water level fluctuations kill many aquatic macroinvertebrates in a huge layer (several meters). The only explanation could be given by the duration of dry periods. Different creatures have different mortality rate due to this strong physical impact. It was frequently examined that living mussel populations were available around at 4-5 m depth only, or below that. The colonisation of the area having fluctuating water by certain groups of animals is most probably very variable.

The most diverse and unexpected picture of the community structure was detected at Radujevac where no sediment layer was found at all. The only available substrate on the bottom was consisted of dead mussel and snaiol shells (mostly *Unio pictorum, U. tumidus, Viviparus viviparus*). This enormous amount of shells was found in 4 m depth where the water transparency exceeded 1 m. According to our experiences this massive layer is produced completely by human impact. The operation of the power plant and the two reservoirs transported and deposited the empty shells in such a large amount due to the strong hydraulic force of the water flow fluctuation.

The miraculous variation of species living in this unnaturally produced substrate is shown by the list of taxa present in that section (**Table 3.3.1, column 30**). Most of the Danubian rheophilous snail species are present in large individual number (*Theodoxus danubialis, T.fluviatilis, Fagotia acicularis, F. esperi, Amphimelania holandrii*). *Corbicula "fluminalis*" was detected also. Even fish species was caught in that sample: two of freshwater needlefishes were found in that site. Unfortunately the Saprobic index does not indicate this beautiful diversity at all. Further investigations would be essential in the future.

Table 3.3.1 Macrozoobenthic taxa of the Danube River between 1534 and 849 river km

Number of sampling sites	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
TAXA																													
Polychaeta																													
Hypania invalida (GRUBE, 1860)					1						1	8							7										38
Oligochaeta																													
Eiseniella tetraedra (SAVIGNY, 1826)														1										1	1		1		
Naididae sp.											1		1																
Branchiura sowerbyi BEDDARD, 1892																										3			
Limnodrilus claparedeianus RATZEL, 1868											1														1				
Limnodrilus hoffmeisteri CLAPAREDE, 1862												1							1		1			1	1				
Limnodrilus profundicola (VERIL, 1871)														1		1			1	1	1			1			1		
Limnodrilus udekemianus CLAPAREDE, 1862												1		1	1				1					1					
Limnodrilus sp.																1													
Potamothryx moldaviensis (VEJDOVSKY & MRAZEK, 1902)											3																		
Potamothryx sp.												1	1					1		1	1								
Tubificidae sp.											2	1							1					1	1				
Enchytraeidae sp.													1	1															
Lumbriculidae sp.													1		1			1							1				
Oligochaeta sp.	15	100		50	1												7					12							
Hirudinea																													
Glossiphonia complanata (LINNAEUS, 1758)				2								1							2			3	1					46	
Glossiphonia paludosa (CARENA, 1824)																						2							
Alboglossiphonia heteroclita (LINNAEUS, 1761)																												6	
Helobdella stagnalis (LINNAEUS, 1761)				1																								25	
Hemiclepsis marginata (M_LLER, 1774)																											1		
Haemopis sanguisuga (LINNAEUS, 1758)												1										1							
Erpobdella octoculata (LINNAEUS, 1758)	4			2			2			3	2			2					4	2		4	2	1	1			59	
Dina lineata (O. F. MÜLLER, 1774)				1																									
Dina punctata JOHANNSON, 1927	4			13																									
Mollusca																													
Theodoxus danubialis (C. PFEIFFER, 1828)														1	2				1	16	*	5	6	2	2	3			23
Theodoxus fluviatilis (LINNAEUS, 1758)	7			2						4	5	1		4	1					4	*		3		*	2			19
Theodoxus transversalis (C. PFEIFFER, 1828)																													*
Viviparus acerosus (BOURGUIGNAT, 1862)		1		1			5	*			*	2			3									5			5	8	
Viviparus viviparus (LINNAEUS, 1758)												30			1				35	8	*		5	1	5	5	6		6
Valvata naticina (MENKE, 1845)					1						1	2				5													
Valvata piscinalis (O. F. MÜLLER, 1774)															1							5		6				*	
Lithoglyphus naticoides (C. PFEIFFER, 1828)	25	150			1	1	8	3	53		9	10	54	36	50	25	8	45		3	*	13	12	20	5	35	6		45
Fagotia acicularis (FERUSSAC, 1823)							1	1	1	5	1	1	2		1			1	6						2		6		25
Fagotia esperi (FERRUSAC, 1823)	3																		4						3		7	*	31
Amphimelania holandrii (C. PFEIFFER, 1828)																							18				*		19
Bithynia tentaculata (LINNAEUS, 1758)		5		14			3			3	6									2		5	15		16	5		5	15
Lymnaeae auricularia (LINNAEUS, 1758)																						3		4					

Number of sampling sites	1	2	3	4	5	6	7	8	9	10	11	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
TAXA																													
Lymnaea peregra var. ovata (DRAPARNAUD)		4		1	1																	5		2		1	14	2	
Lymnaea stagnalis (LINNAEUS, 1758)											*																1		
Physa acuta DRAPARNAUD, 1805				1		1																			2				
Unio pictorum (LINNAEUS, 1758)		5	1	1	1	1	4		2			3		1						1	5	3		2	2	2	4		
Unio tumidus RETZIUS, 1788	1	8	1	1	1	1	4					3	2	8		8		8	7	5	3	5		7	3	5	5	2	
Anodonta anatina (LINNAEUS, 1758)	1	7	1	1	1	1	6		8			2		2					3			4				1	6	8	
Anodonta cygnea (LINNAEUS, 1758)																												16	
Sinanodonta woodiana (LEA, 1834)	1	9	1		1	1	2					3		2							1								
Pseudanodonta complanata (ROSSMASLER, 1835)																											1	1	
Dreissena polymorpha (PALLAS, 1771)	9	24	1	25	1	1	20	5	3	35	8	8	3	5	2			3	2	12		8	10	4	25	3	3	27	
Corbicula fuminea (O. F. MÜLLER, 1774)		1		14		1																							
Corbicula "fluminalis" (O. F. MÜLLER, 1774)		1		8		1													4								13		22
Sphaerium corneum (LINNAEUS, 1758)				1		1		1		8																			
Sphaerium rivicola (LAMARCK, 1799)	7	35		70			6					20		45	55				9	5	3				30	12	1		
Pisidium amnicum (O. F. MÜLLER, 1774)	1	5			1																								
Pisidium henslowanum (SHEPPARD, 1823)																										10			
Pisidium moitessierianum PALADILHE, 1866						1																							
Pisidium sp.		10																											
Crustacea																													
Limnomysis benedeni CZERNIAVSKY, 1882											2											4							
Corophium curvispinum (SARS, 1895)				15	1	1					3												56			3			
Dikerogammarus haemobaphes (EICHWALD, 1841)							3		3	2	1			1	1	1		1	1	1				6	2				7
Dikerogammarus villosus (SOVINSKY, 1894)	13			30	1	1	5	4	5	12	8									2		6	21		1			3	26
Obesogammarus obesus (SARS, 1894)	5			4	1	1			1		1											2	4		1				9
Jaera istri VIEUILLE, 1979				1		1		2			2					1													12
Astacus leptodactylus ESCHSCHOLZ, 1823																										1			
Ephemeroptera																													
Cloeon sp.																												1	
Caenis sp.																												1	
Odonata																													
Anax imperator LEACH, 1815																												1	
Gomphus flavipes (CHARPENTIER, 1825)				1				1	1													2							
Gomphus vulgatissimus (LINNAEUS, 1758)															1														
Heteroptera																													
Aphelocheirus aestivalis (FABRICCIUS, 1803)		1																											
Aquarius paludum (FABRICIUS, 1794)								6										1											
Trichoptera																													
Hydropsyche bulgaromanorum MALICKY, 1977				12	1	1																							3
Hydropsyche contubernalis MCLACHLAN, 1865						1																							
Hydropsyche exocellata DUFOUR, 1841		1																											
Neureclipsis bimaculata (LINNAEUS, 1758)																									2				
Setodes punctatus (FABRICCIUS, 1793)																													2
Coleoptera																						1							
Hydrochara caraboides *(LINNAEUS, 1758)*																						1							

Number of sampling sites	1	2	3	4	5	6	7	8	9	10	11	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
TAXA																													
Diptera																													
Dicrotendipes nervosus (STAEGER, 1839)																					1								
Parachironomus varus (GOETGHEBUER, 1931)											1										1								
Polypedilum convictum (WALKER, 1856)																		1											
Chironomidae sp.											1														1		1		
Limoniidae sp.					1	13		1										1				5							

Generally similar macroinvertebrate fauna like the Danube River itself characterizes the Danubian tributaries. The navigable Bega (see *Table 2.1*) and the Old Bega (Bega Vege) both have massive communal organic pollution resulted in high degree of saproby. Therefore only the common eutrophic taxa were detected in these small watercourses. Only dead mussels (shells) were found in these rivers. The condition of the shells indicated that the taxa were died at leas ten years ago.

The other tributaries, especially the Sava and the Tisa have rich macroinvertebrate fauna where mainly the Mollusca group is containing faunistically interesting elements (**Table 3.3.2**).

Table 3.3.2 Quantitative taxon list of macroinvertebrate taxa of the Danubian tributaries

River	Drava			Tisa		Bega	B.V.	Sava		V.M.	Tim.	
Number	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**Total**
TAXA												
Polychaeta												
Hypania invalida (GRUBE, 1860)									7			**7**
Oligochaeta												
Eiseniella tetraedra (SAVIGNY, 1826)				1								**1**
Branchiura sowerbyi BEDDARD, 1892				1								**1**
Limnodrilus claparedeianus RATZEL, 1868					2				3	2		**7**
Limnodrilus hoffmeisteri CLAPAREDE, 1862									3	3		**6**
Limnodrilus sp.					1		1					**2**
Lumbriculidae sp.										1		**1**
Oligochaeta sp.	3	1										**4**
Hirudinea												
Glossiphonia complanata (LINNAEUS, 1758)									10			**10**
Helobdella stagnalis (LINNAEUS, 1761)	1											**1**
Erpobdella octoculata (LINNAEUS, 1758)	2					1			4			**7**
Mollusca												
Theodoxus danubialis (C. PFEIFFER, 1828)								19	2			**21**
Theodoxus fluviatilis (LINNAEUS, 1758)				7	5							**12**
Viviparus acerosus (BOURGUIGNAT, 1862)			*		2		*	1	8			**11**
Valvata piscinalis (O. F. MÜLLER, 1774)					2							**2**
Lithoglyphus naticoides (C. PFEIFFER, 1828)	43		3	26	13			12	50	9		**156**
Fagotia acicularis (FERUSSAC, 1823)								10	2			**12**
Fagotia esperi (FERRUSAC, 1823)								10				**10**
Bithynia tentaculata (LINNAEUS, 1758)	1								1			**2**
Lymnaeae auricularia (LINNAEUS, 1758)										1		**1**
Lymnaea peregra var. ovata (DRAPARNAUD)										2		**2**
Physa acuta DRAPARNAUD, 1805										12		**12**
Planorbarius corneus (LINNAEUS, 1758)						2						**2**
Unio crassus RETZIUS, 1788	8				1			1		1		**11**
Unio pictorum (LINNAEUS, 1758)					3		*	3				**6**
Unio tumidus RETZIUS, 1788					8		*	3	3			**14**
Anodonta anatina (LINNAEUS, 1758)					1		*		5	4		**10**
Sinanodonta woodiana (LEA, 1834)					3							**3**
Pseudanodonta complanata (ROSSMASLER, 1835)			1			1						**2**
Dreissena polymorpha (PALLAS, 1771)	4			4	9				5			**22**
Sphaerium corneum (LINNAEUS, 1758)	4											**4**
Sphaerium rivicola (LAMARCK, 1799)					2							**2**
Pisidium amnicum (O. F. MÜLLER, 1774)		1			1							**2**
Crustacea												
Limnomysis benedeni CZERNIAVSKY, 1882		2	1									**3**
Corophium curvispinum (SARS, 1895)	28	500		1				8	1			**538**
Dikerogammarus haemobaphes (EICHWALD, 1841)	20			1	8			3				**32**
Dikerogammarus villosus (SOVINSKY, 1894)	5	9		3	5			4	3			**29**
Gammarus roeseli GERVAIS, 1835	99	4										**103**
Obesogammarus obesus (SARS, 1894)			1	1				1				**3**
Asellus aquaticus (LINNAEUS, 1758)	3						7					**10**
Jaera istri VIEUILLE, 1979								3				**3**
Ephemeroptera												
Baetis fuscatus (LINNAEUS, 1761)							1					**1**

River	Drava			Tisa		Bega	B.V.	Sava		V.M.	Tim.	
Number	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**Total**
TAXA												
Ametropus fragilis ALBARDA, 1878				5								**5**
Odonata												
Calopteryx splendens (HARRIS, 1782)						2				3		**5**
Ischnura elegans (VAN DER LINDEN, 1820)						3				3		**6**
Anax imperator LEACH, 1815						1						**1**
Gomphus flavipes (CHARPENTIER, 1825)				5								**5**
Heteroptera												
Aquarius paludum (FABRICIUS, 1794)										3		**3**
Corixidae sp.						3	2					**5**
Ilyocoris cimicoides (LINNAEUS, 1758)							2					**2**
Micronecta sp.							4					**4**
Trichoptera												
Hydropsyche bulgaromanorum MALICKY, 1977				2								**2**
Hydropsyche contubernalis MCLACHLAN, 1865				1						3		**4**
Neureclipsis bimaculata (LINNAEUS, 1758)					1							**1**
Coleoptera												
Cybister laterimarginalis (DE GEER, 1774)				1								**1**
Laccophilus hyalinus (DE GEER, 1774)										2		**2**
Haliplus sp.						1				3		**4**
Diptera												
Procladius sp.										1		**1**
Cricotopus bicinctus (MEIGEN, 1817)							1					**1**
Cricotopus trifasciatus (MEIGEN, 1813)							1					**1**
Dicrotendipes nervosus (STAEGER, 1839)					1							**1**
Parachironomus varus (GOETGHEBUER, 1931)						1						**1**
Polypedilum convictum (WALKER, 1856)									1			**1**
Chironomidae sp.					1					3		**4**
Limoniidae sp.						1						**1**
Total	221	517	5	59	70	15	19	79	108	56	0	**1149**
Pantle-Buck index (S)	2,27	2,11	2,05	2,16	2,21	2,19	2,32	2,04	2,33	2,30	0	
Number of taxa	13	6	3	14	20	9	8	14	16	17	0	

Very similar Mollusc fauna was registered in the Danubian tributaries, too. The presence of *Theodoxus fluviatilis* in the Tisza was detected in both investigated sites. Characteristic occurrence of the species on clay was experienced. Until that the snail was observed only on hard substrate. The *T. danubialis* together with the two *Fagotia* species was found only in the Sava River. The richest mussel fauna lives in the Tisza near to the confluence.

Tisza has an *Ephemeroptera* species that is very characteristic to the Hungarian stretch since 1996: *Ametropus fragilis* is a typical surviving species after the cyanide-pollution along the whole Tisza stretch. The beetle *Cybister laterimarginalis* and the dragonfly larvae of Gomphus flavipes were found in the Tisza only.

Velika Morava had a macroinvertebrate community of mostly eutrophic taxa. There were no living creatures in the River Timok near to the confluence. The main sediment component is sand whereas black fine sediment is accumulated in several current "shadows". Both of the substrate types are empty in terms of a1quatic life, most probably due to the detected huge Cu-pollution level (4800 mg/kg).

3.3.2 The results of saprobiological analysis

The change of the Saprobic index is shown on the **Figure 3.3.1.** The investigated Danube section is mainly belonging to b-mesosaprobe and a-b-mesosaprobe zones.

The evaluation of the saprobic situation is not very clear i.e. the value of saprobic index upstream Pancevo is bigger than at downstream. The reason of that might be the effect of the wastewaters of Belgrade but it would need more detailed site-specific analysis. These

Table 3.3.3 Number of taxa and Saprobic index values along the Danube River

Sample number	Location	River km	Position	Number of taxa	Saprobic index	Saprobic Zone
1	Paks	1534	L	14	2.25	b-meso
2			R	17	2.19	b-meso
3	Baja	1480	L	5	2.13	b-meso
4			R	25	2.25	b-meso
5	Mohács	1440	L	16	2.16	b-meso
6			R	18	2.11	b-meso
7	Bogojevo	1363,5	L	13	2.17	b-meso
8	Erdut	1363	R	9	2.06	b-meso
9	Novi Sad	1259,1	L	9	2.13	b-meso
10	Novi Sad	1259	R	8	2.15	b-meso
11	Novi Sad	1251	L	20	2.18	b-meso
13	St.Slankamen	1215	R	19	2.33	a-b-meso
14	St.Banovci	1194	L	8	2.19	b-meso
15	St.Banovci	1194	R	15	2.3	b-meso
16	Pancevo	1157	L	13	2.2	b-meso
17	Pancevo	1157	R	7	2.3	b-meso
18	Pancevo	1151	L	2	2.2	b-meso
19	Pancevo	1151	R	10	2.18	b-meso
20	Smederevo	1117	R	17	2.3	b-meso
21	Kostolac	1097	R	14	2.14	b-meso
22	Dubovac	1095	L	9	2.5	a-b-meso
23	Bazias	1072	L	22	2.17	b-meso
24	Golubinje	1040	R	12	2.1	b-meso
25	Brnjica	1033	R	17	2.32	a-b-meso
26	Donji Milanovac	991	R	22	2.2	b-meso
27	Tekija	956	R	15	2.16	b-meso
28	Mala Vrbica	925	R	18	2.13	b-meso
29	Mihajlovac	871	R	16	2.32	a-b-meso
30	Radujevac	849	R	16	2.05	b-meso

data are most probably available and known by the Yugoslavian authorities but further scientific co-operation is needed for the future to delight it.

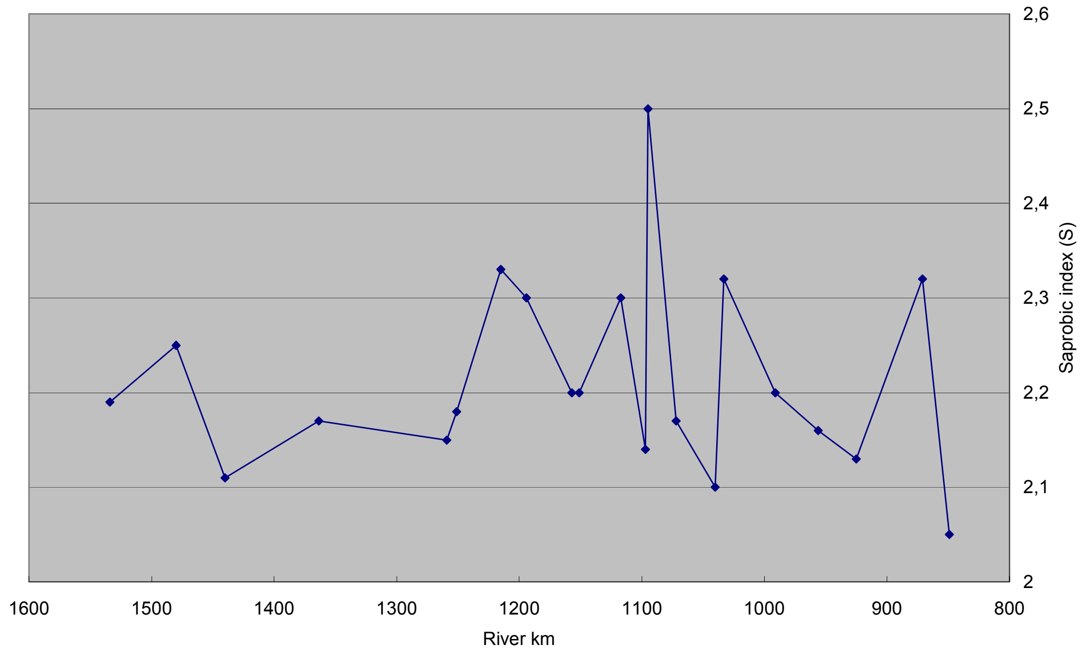


Figure 3.3.1 Longitudinal change of the Saprobix index on the Danube River section

3.4 Taxonomic results of the former (UNDP/BTF) sampling campaign

There were four localities investigated in 1999 in the framework of the BTF sampling mission: the vicinity of Novi Sad and Pancevo, the upper-middle section of the Iron Gate and the area of Kragujevac. It can be concluded that very similar taxonomic composition was experienced one year ago at these sampling locations. The vicinity of the industrial areas showed high degree of pollution that could be seen on the list of occurring taxa. All members of the macroinvertebrate fauna are characteristic to the eutrophic Middle and Lower Danube section, including the Iron Gate Reservoir.

The sample collected **upstream of Novi Sad** contains 13 taxa from which 7 is mussel and aquatic snail species. More taxa were found in 1999 comparing to the next year sampling, probably due to the better selection of the site. The bottom material consisted of soft mud sediment that forms a very uniform habitat type. The most abundant species was a snail species (*Lithoglyphus naticoides*) wich prefers the soft mud substrate, similarly to the large mussel species (*Anodonta anatina, Sinanodonta woodiana, Unio pictorum, U. tumidus*) and the dragonfly larva of *Stylurus flavipes*. The results of the littoral sampling **downstream of Novi Sad** oil refinery indicate that several taxa from the upstream section were present at this section, too. Their total number was even larger here (17) than upstream of Novi Sad because of the available macrophyte substrate found near to the shoreline. The molluscs, annelid worms, crustaceans and some insect larvae indicated that the shut down of the oil production resulted in better biological situation for this short period of time. Part of the taxa were common in the slow flowing rivers, another part prefers the stagnant water conditions indicating high degree of trophity. No signs of the heavy pollution during the bombing were detected in the aquatic macroinvertebrate fauna.

The fauna found **upstream of Pancevo** was almost the same as in the Novi Sad section. The number of taxa was 21 from which 13 belong to the mussels and snails (molluscs). The bottom dwelling *Lithoglyphus naticoides* was the most abundant (several thousands of individuals/m^2, similarly to upstream of Novi Sad) together with the large mussel species. The presence of insects was negligible, only the crustaceans form a characteristic Danubian community at this site (*Dikerogammarus villosus, Corophium curvispinum, Limnomysis benedeni*).

The number of species decreased sharply **downstream of Pancevo** similarly to the results of the sampling mission of 2000. Only 8 living taxa were identified here, together with the empty shells of 5 snail species. Only 5 living mollusc taxa were present here instead of the 13 that were registered upstream. This lower number comparing to the upstream situation indicated pollution. The lowest taxon number was observed directly at the **outlet of the Pancevo canal**. Only 6 taxa were found here and all of them were present in very low individual numbers. This phenomenon supposed serious pollution at this site, too.

The sampling sites in the **Iron Gate** reservoir had rich macroinvertebrate community at both (left and right) sides. There was an interesting mixture in rheophilous (preferring current) and stagnophilous (preferring stagnant water) species in the reservoir. The presence of the stagnophil taxa had obvious reasons but the occurrence of the rheophilous *Theodoxus danubialis* and *T. fluviatilis* is interesting character of the investigated Danube stretch. The left side at Stara Palanka contained more species (25 taxa) than the right one (13 at Ram) due to the more diverse habitat.

Based on rough taxonomical evaluation it can be concluded from the macroinvertebrate analysis that the Velika Morava upstream of the Lepenica confluence was much less polluted than the Lepenica itself. Only one mussel taxon (*Anodonta anatina*) was found here but the insect fauna was very diverse consisting of several mayfly and caddisfly species, too. The taxonomic identification of these animals is difficult because most of them belong to the diverse endemic group of the Balkanic fauna. It could be mentioned that only the *Hydropsychidae* group consisted of several taxa.

The upstream taxon number (15) decreased to 11 downstream of the Lepenica confluence but in can be seen that many pollution sensitive groups were still present here. The Lepenica river contained only 5 taxa, most of them pollution tolerant that indicated permanent organic pollution from upstream stretches. The Lepenica section upstream Kragujevac was not really free of antropogenic influences but some of the insect taxa found here were clear water indicating animals (*Onycogomphus forcipatus, Ephemerellidae* sp., *Heptageniidae* sp., etc.). This result showed that the influence of the Kragujevac city is very definite in terms of industrial pollution.

3.5 Analysis of BTF samples collected during 1999

3.5.1 Assessment of the heavy metal pollution of the sediment and mussel samples collected during the UNEP/Habitat BTF and ICPDR joint Danube mission in 1999

In 1999 only mercury was analyzed from the heavy metals, because it was considered as relevant pollutant originating from the Yugoslavian war-related damages. The report “Assessment of Target Pollutants in the FRY Reach of the Danube River Basin” (UNEP/Habitat BTF and ICPDR, 1999) documented the mercury pollution pattern in the sediment and mussel samples along the studied river stretch in details.

In the present project additional heavy metals (cadmium, lead, chromium, copper and nickel) were analyzed from the available sediment and mussel samples of the survey in 1999.
The results are shown in **Table 3.5.1.** and **2**, respectively.

Table 3.5.1 Heavy metal concentrations in sediment samples collected in 1999 during the UNEP/Habitat BTF and ICPDR joint Danube mission

Identification No.	*Sampling location*	*Cd mg/kg*	*Pb mg/kg*	*Cr mg/kg*	*Ni mg/kg*	*Cu mg/kg*
UNEPD-3	Danube upst. Novi Sad 1260 rkm	*0,15*	*15*	*10*	*17*	*14*
UNEPD-7	Danube, dst. Novi Sad 1252 rkm	*0,30*	*28*	*38*	*22*	*23*
UNEPD-12	DT canal at the mouth	*0,65*	*42*	*53*	*29*	*40*
UNEPD-16	Danube upst. Pancevo 1154.7 rkm	*1,25*	*46*	*60*	*34*	*46*
UNEPD-20	Danube dst. Pancevo 1149 rkm	*1,15*	*51*	*73*	*41*	*48*
UNEPD-24	Danube dst. the canal Pancevo ~ 100 m	*1,10*	*33*	*40*	*25*	*40*
UNEPD-28 core at Panchevo	Canal (petrochemical) Pancevo ~ 100 m	*2,15*	*60*	*75*	*39*	*81*
UNEPD-29 core at Panchevo	Canal (petrochemical) Pancevo ~ 100 m	*2,20*	*56*	*63*	*41*	*82*
UNEPD-30 core at Panchevo	Canal (petrochemical) Pancevo ~ 100 m	*1,60*	*37*	*40*	*21*	*49*
UNEPD-31 core at Panchevo	Canal (petrochemical) Pancevo ~ 100 m	*1,05*	*20*	*26*	*16*	*31*
UNEPD-32 core at Panchevo	Canal (petrochemical) Pancevo ~ 100 m	*1,55*	*54*	*47*	*30*	*56*
UNEPD-33 core at Panchevo	Canal (petrochemical) Pancevo ~ 100 m	*2,44*	*67*	*75*	*42*	*77*
UNEPD-34 core at Panchevo	Canal (petrochemical) Pancevo ~ 100 m	*3,39*	*85*	*98*	*47*	*84*
UNEPD-35 core at Panchevo	Canal (petrochemical) Pancevo ~ 100 m	*2,80*	*82*	*95*	*48*	*91*
UNEPD-38	Danube at Ram 1077.6 rkm	*2,05*	*69*	*85*	*48*	*68*
UNEPD-62	Lepenica river mouth	*0,80*	*52*	*261*	*135*	*60*
UNEPD-64	Morava upst. Lepenica	*1,90*	*49*	*126*	*124*	*48*
UNEPD-67	Morava dst. Lepenica	*0,20*	*29*	*181*	*100*	*32*
UNEPD-69	Lepenica mouth	*0,10*	*28*	*291*	*195*	*23*
UNEPD-73	Lepenica upst. Kragujevac	*0,30*	*36*	*245*	*101*	*48*
UNEPD-43	Danube at Ram 1077.6 rkm	*3,04*	*80*	*125*	*106*	*56*

Table 3.5.2 Heavy metal concentrations in mussel samples collected in 1999 during the UNEP/Habitat BTF and ICPDR joint Danube mission

Identification No.	Mussel species	Sampling location	*Cd mg/kg*	*Pb mg/kg*	*Cr mg/kg*	*Ni mg/kg*	*Cu mg/kg*
UNEPD-40/1	Anodonta anatina	Danube at Ram 1077.6 rkm	***0,90***	***2,75***	***1,70***	***1,55***	***3,55***
UNEPD-40/2	Sinanodonta woodiana	Danube at Ram 1077.6 rkm	***0,50***	***1,40***	***1,10***	***1,50***	***3,29***
UNEPD-40/3	Unio tumidus	Danube at Ram 1077.6 rkm	***2,99***	***6,14***	***3,14***	***2,49***	***5,89***
UNEPD-44/1	Anodonta anatina	Danube at Ram 1077.6 rkm	***4,24***	***11,76***	***3,09***	***3,44***	***5,43***
UNEPD-44/2	Sinanodonta woodiana	Danube at Ram 1077.6 rkm	***1,50***	***4,85***	***1,35***	***2,70***	***5,19***
UNEPD-44/3	Unio tumidus	Danube at Ram 1077.6 rkm	***3,44***	***8,97***	***3,64***	***4,19***	***6,23***
UNEPD-21/1	Anodonta anatina	Danube dst. Pancevo 1149 rkm	***3,59***	***3,64***	***1,65***	***1,25***	***7,28***
UNEPD-21/2	Unio tumidus	Danube dst. Pancevo 1149 rkm	***4,95***	***4,90***	***6,24***	***3,00***	***10,2***
UNEPD-5/1	Anodonta anatina	Danube upst. Novi Sad 1260 rkm	***0,85***	***1,65***	***1,55***	***1,50***	***4,55***
UNEPD-5/2	Anodonta anatina (juv)	Danube upst. Novi Sad 1260 rkm	***0,70***	***4,03***	***2,74***	***3,29***	***5,33***
UNEPD-5/3	Sinanodonta woodiana	Danube upst. Novi Sad 1260 rkm	***0,50***	***1,54***	***1,20***	***1,34***	***4,88***
UNEPD-17/1	Anodonta anatina	Danube upst. Pancevo 1154.7 rkm	***4,34***	***4,54***	***2,54***	***1,25***	***6,93***
UNEPD-17/2	Sinanodonta woodiana	Danube upst. Pancevo 1154.7 rkm	***3,80***	***4,85***	***2,75***	***1,90***	***16,5***
UNEPD-17/3	Unio tumidus	Danube upst. Pancevo 1154.7 rkm	***7,31***	***7,41***	***8,40***	***3,43***	***10,44***
UNEPD-10/2	Sinanodonta woodiana	Danube, dst. Novi Sad 1252 rkm	***0,50***	***1,45***	***1,10***	***1,69***	***4,59***

Figure 3.5.1. indicates the concentrations of heavy metals in the sediment along the Danube. The measured heavy metals had the lowest concentrations in sediment samples taken in the upstream section of the Danube. In the downstream part of the studied Danube section the concentrations were several times higher than in the upstream stretch. The guideline values were exceeded in the middle and downstream part of the studied Danube section.

The heavy metal concentrations in the mussel samples varied in a wide range in the same sampling location, depending on the collected species. Comparison of the heavy metal content of the same mussel species (*Sinanodonta woodiana*) shows that the concentration distribution along the Danube (**Figure 3.5.2.**) is not so characteristic as in the case of sediment. The differences in the concentrations of heavy metals in mussels – collected in the upstream and downstream part of the studied Danube section – are not so significant as in the sediment.

The heavy metal concentrations of the sediments of the Danube-Tisza (DT) canal, and the tributaries Lepenica river, Morava river revealed that in the Morava and Lepenica river very high chromium and nickel concentrations were found.

The sediment core samples taken in the Pancevo canal indicated heavy metal pollution along the whole vertical down to 80 cm (**Figure 3.5.3/a-e**). Another series of core samples were collected in the Iron Gate Reservoir at Ram (**Figure 3.5.4/a-l**). The vertical distribution of heavy metal compounds illustrate that the recent layer (the upper 10 cm) contains the less amount of the different metals at both, left and right sides. Generally, it can be concluded that the amount of cadmium, mercury and lead is approximately doubled in 30 cm comparing to the concentrations detected in the surface layer. There are no such big differences in copper, chromium and nickel, but the surface concentrations are always smaller than the amounts detected in deeper layers.

Figure 3.5.1 Heavy metal concentrations in sediment samples collected in the Danube in 1999 (mg/kg dry sediment)

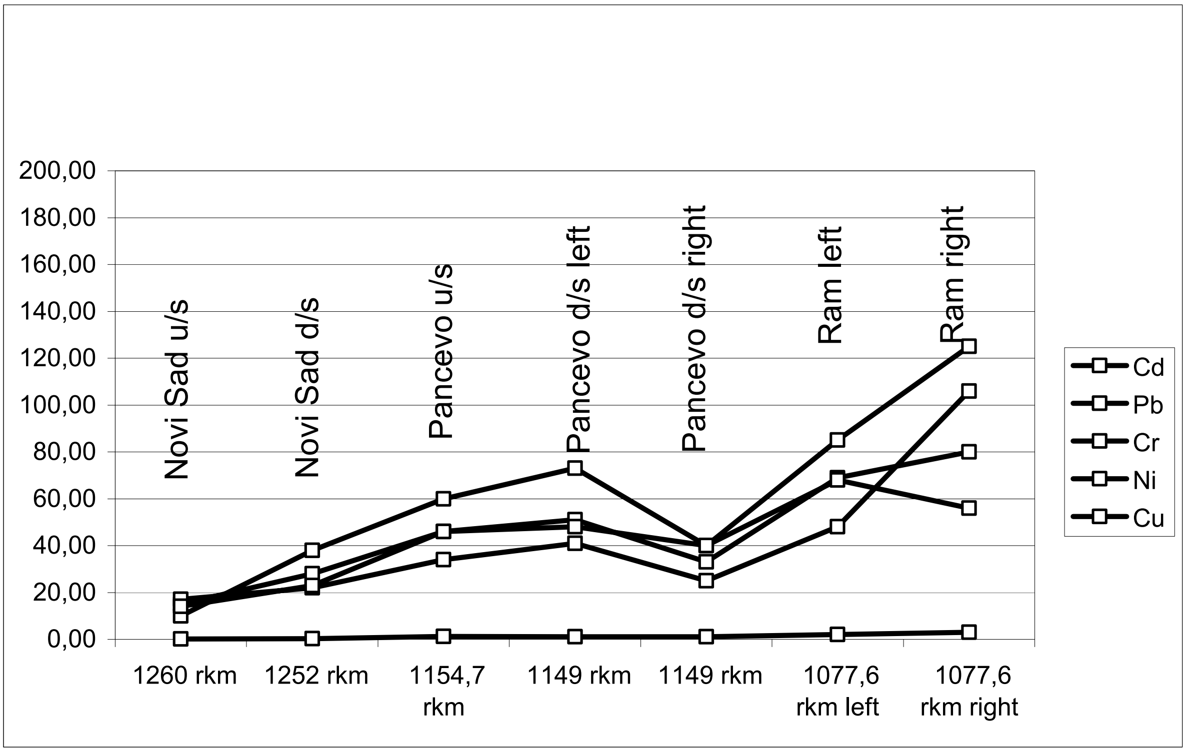


Figure 3.5.2 Heavy metal concentrations in the mussel species Sinanodonta woodiana collected in the Danube 1999 (mg/kg dry mussel sample)

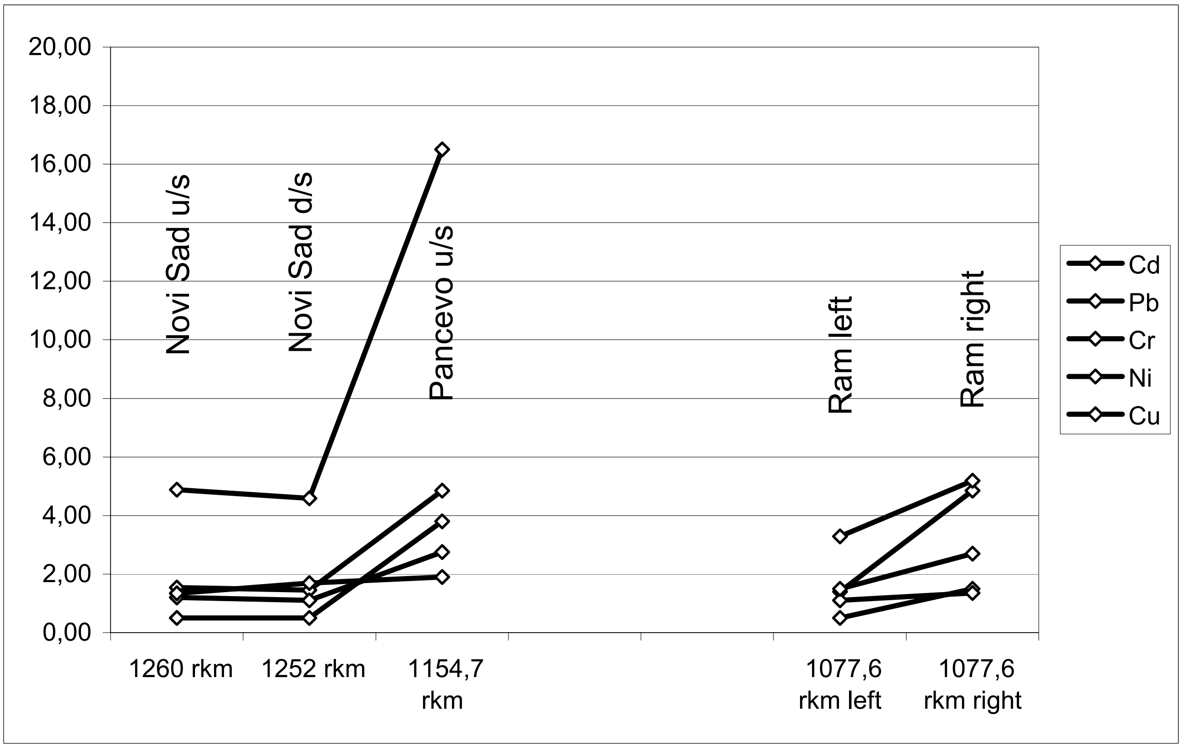


Figure 3.5.3. Vertical distribution of heavy metals in core sample from the Pancevo canal

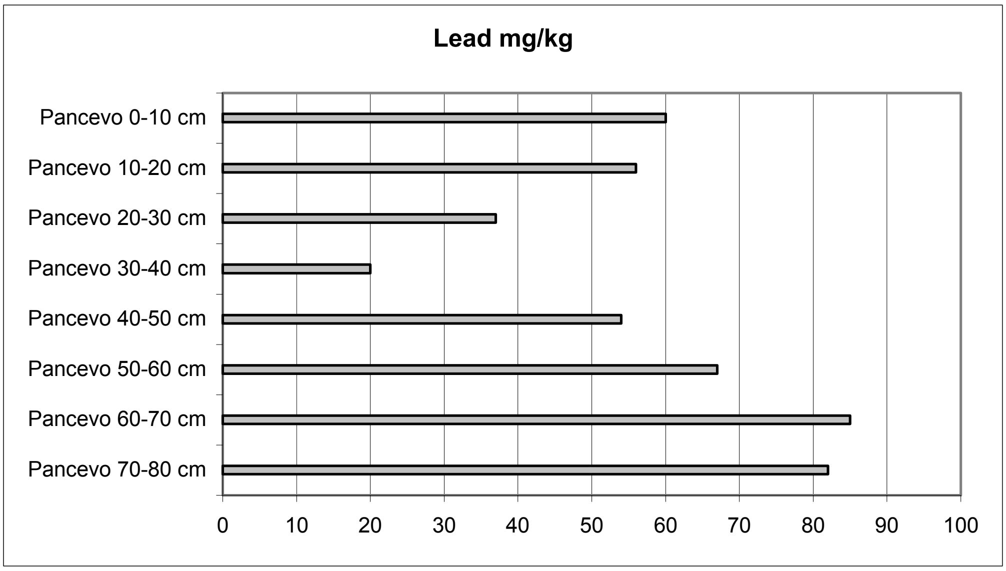


Figure 3.5.3./a.

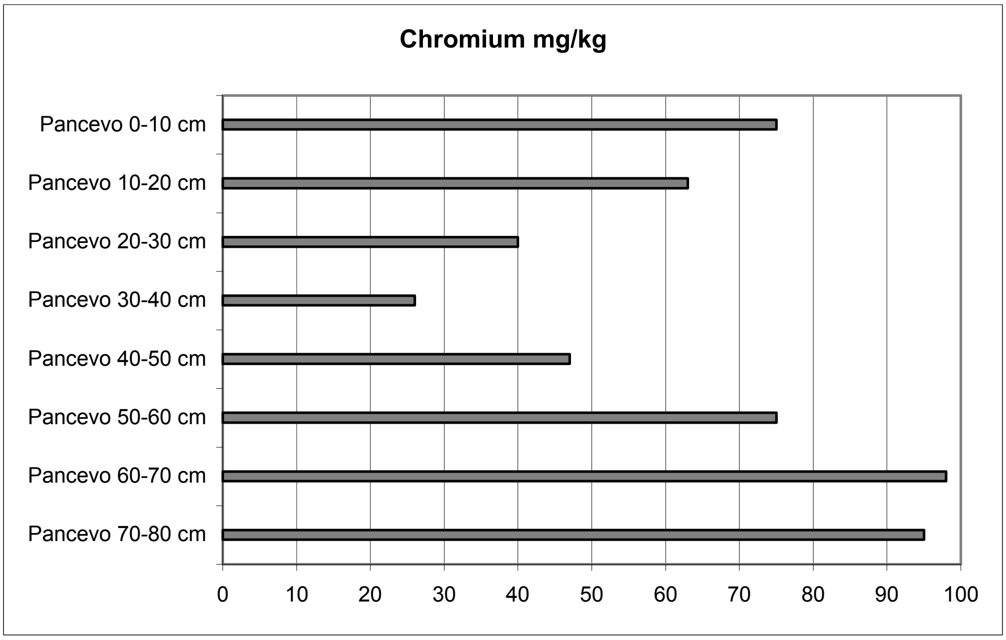


Figure 3.5.3./b.

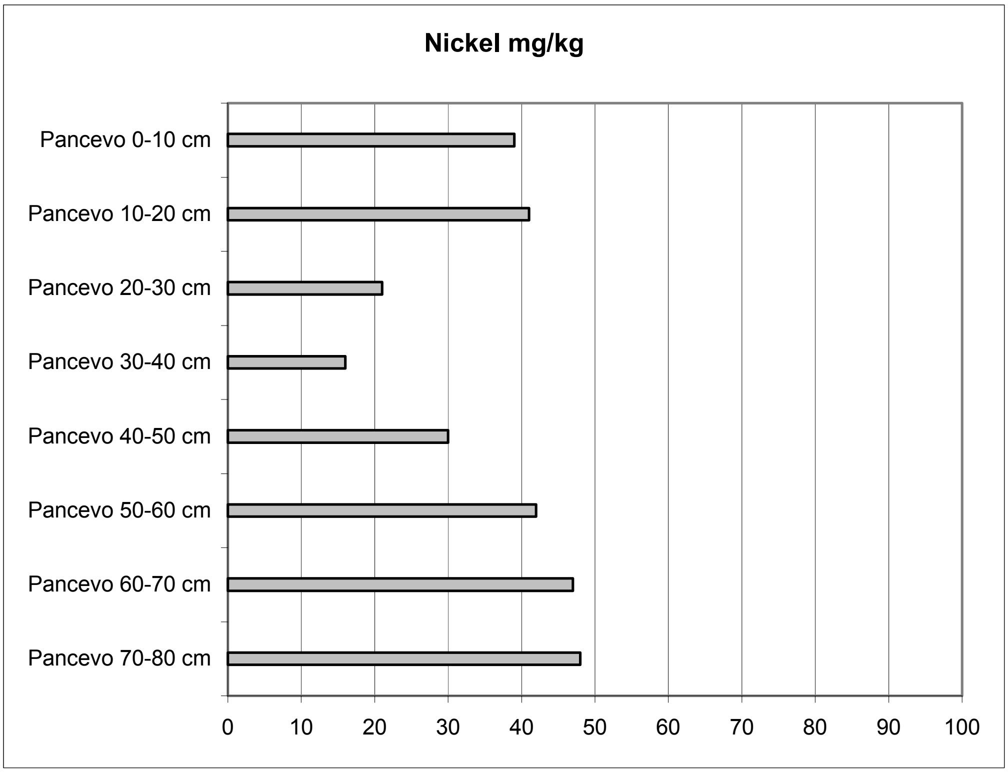


Figure 3.5.3./c.

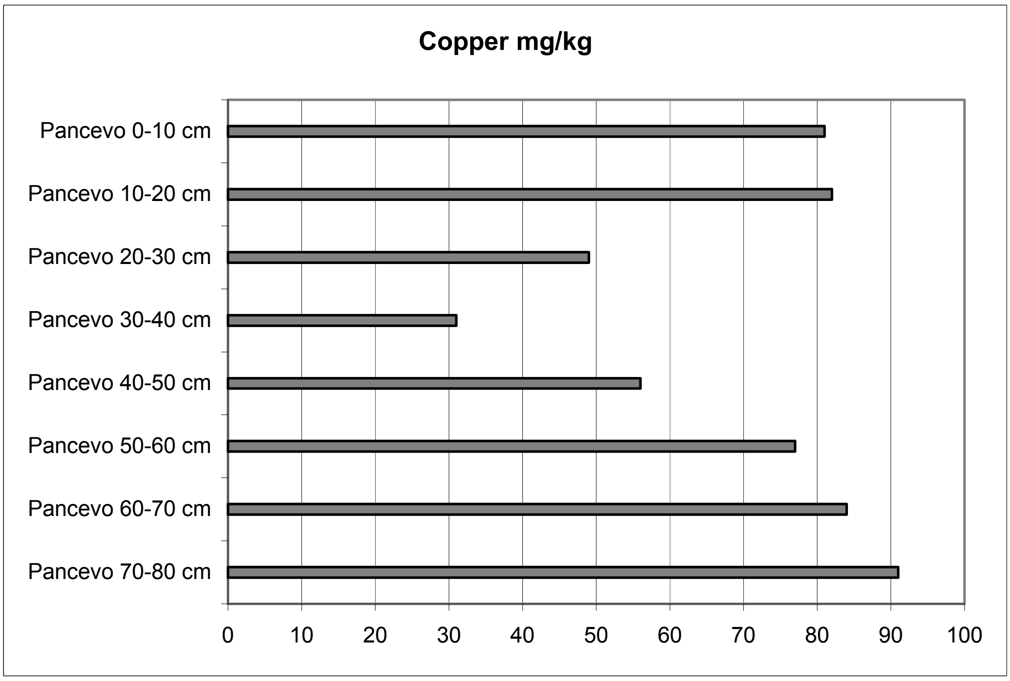
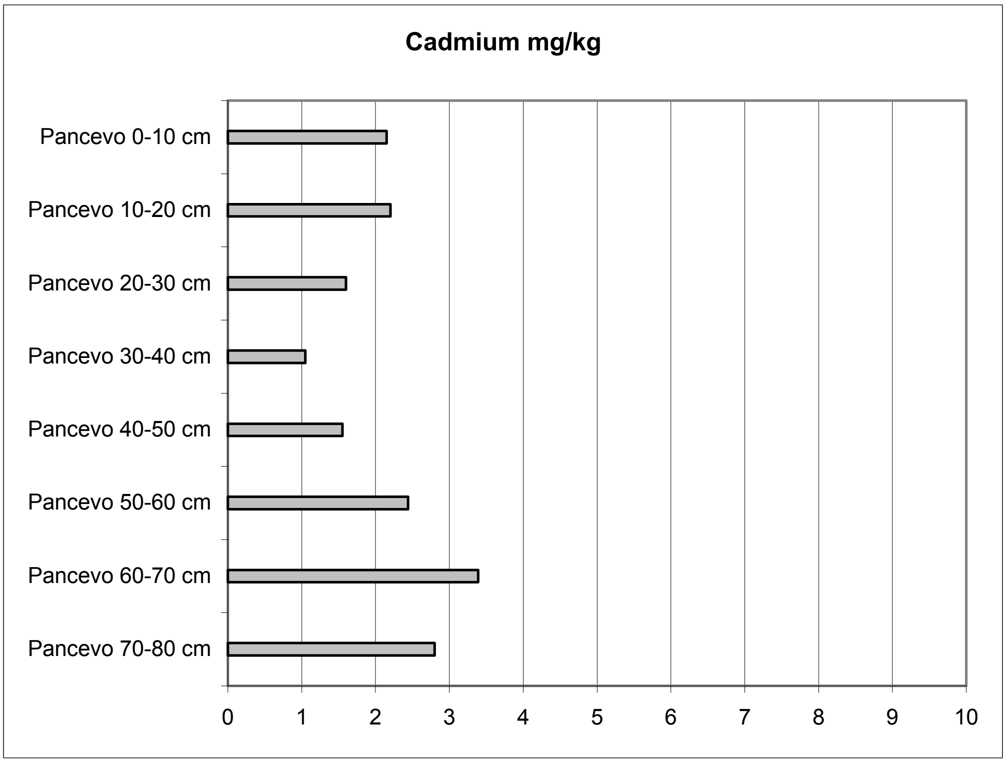


*Figure 3.5.3./*d.



Cadmium mg/kg
Pancevo 0-10 cm
Pancevo 10-20 cm
Pancevo 20-30 cm
Pancevo 30-40 cm
Pancevo 40-50 cm
Pancevo 50-60 cm
Pancevo 60-70 cm
Pancevo 70-80 cm
0
1
2
3
4
5
6
7
8
9
10

Figure 3.5.3./e.

Figure 3.5.4.. Vertical distribution of different heavy metals in core sample from the Iron Gate-Ram cross section (1077.6 rkm)

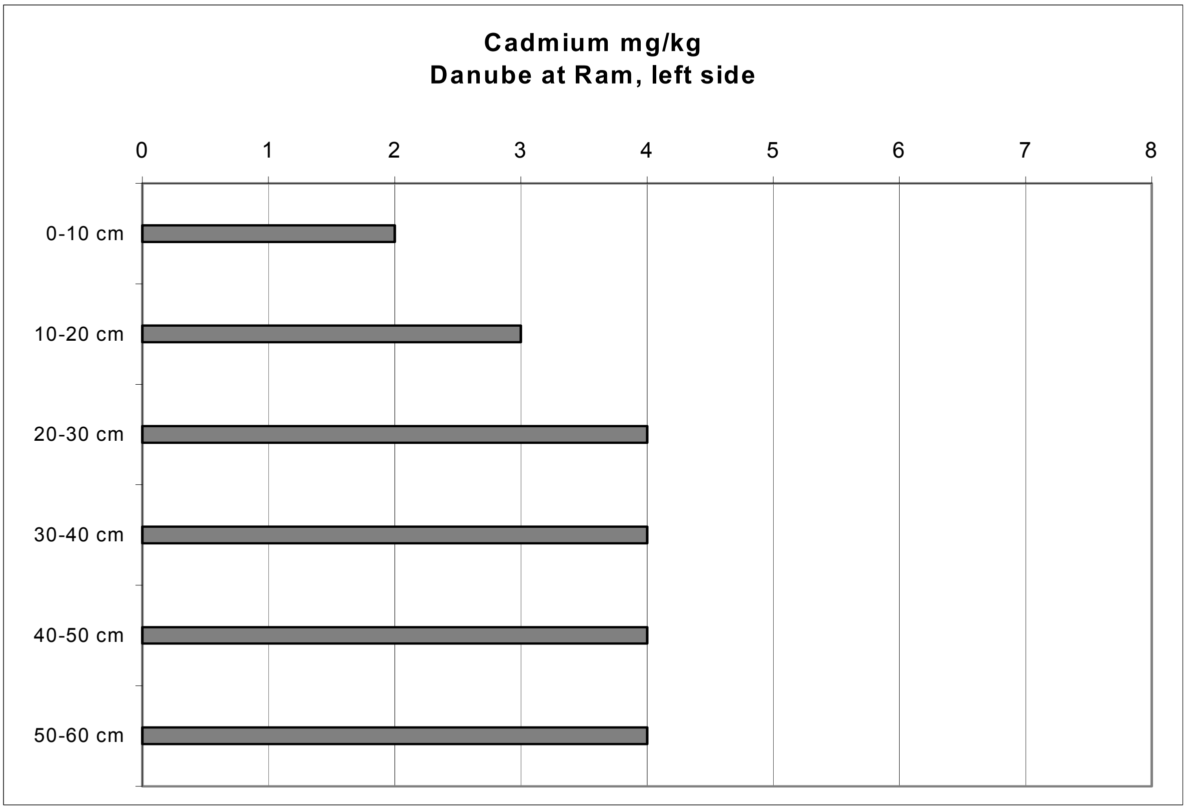


Figure 3.5.4./a.

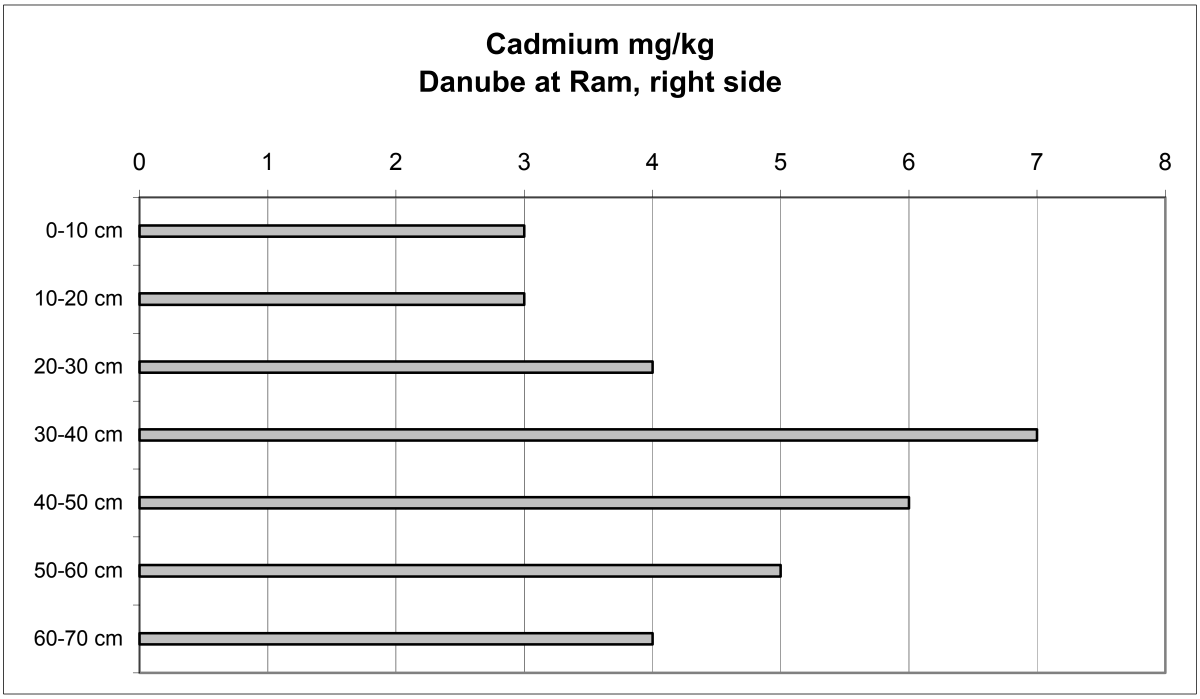


Figure 3.5.4./b.

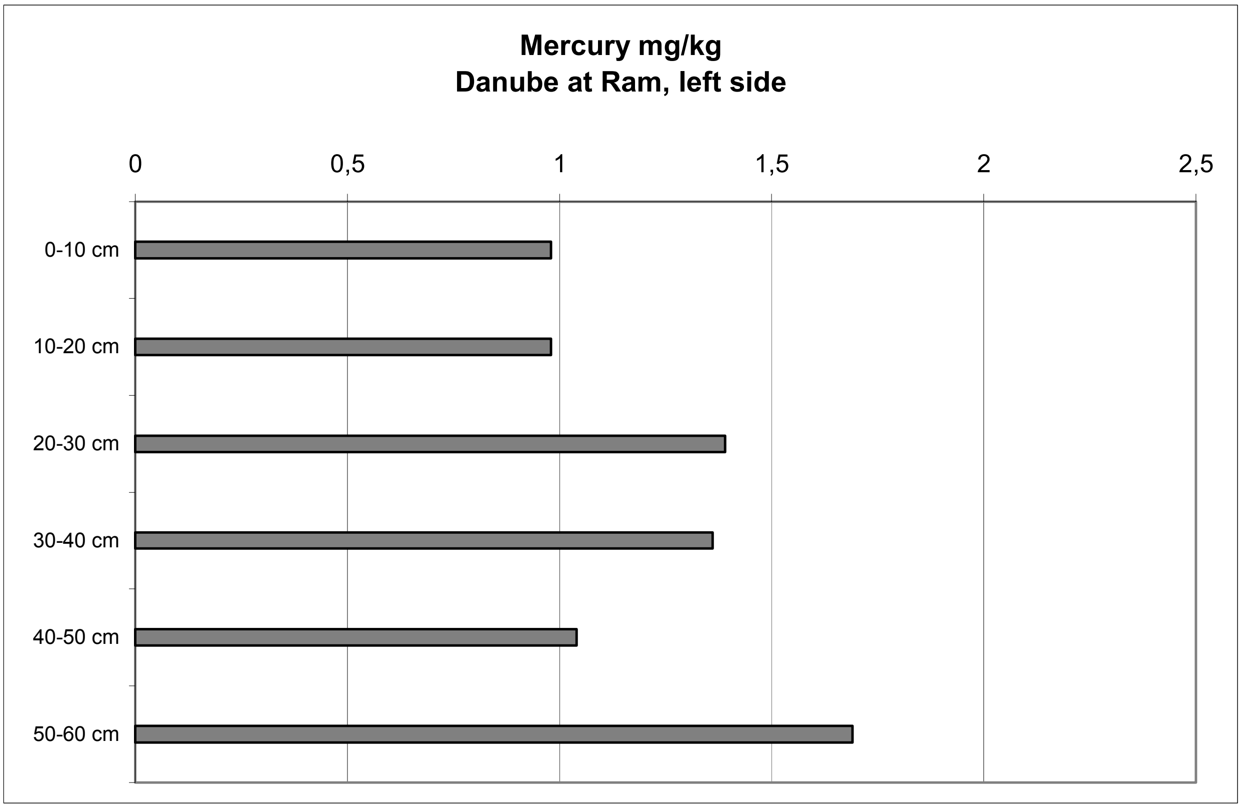


Figure 3.5.4./c.

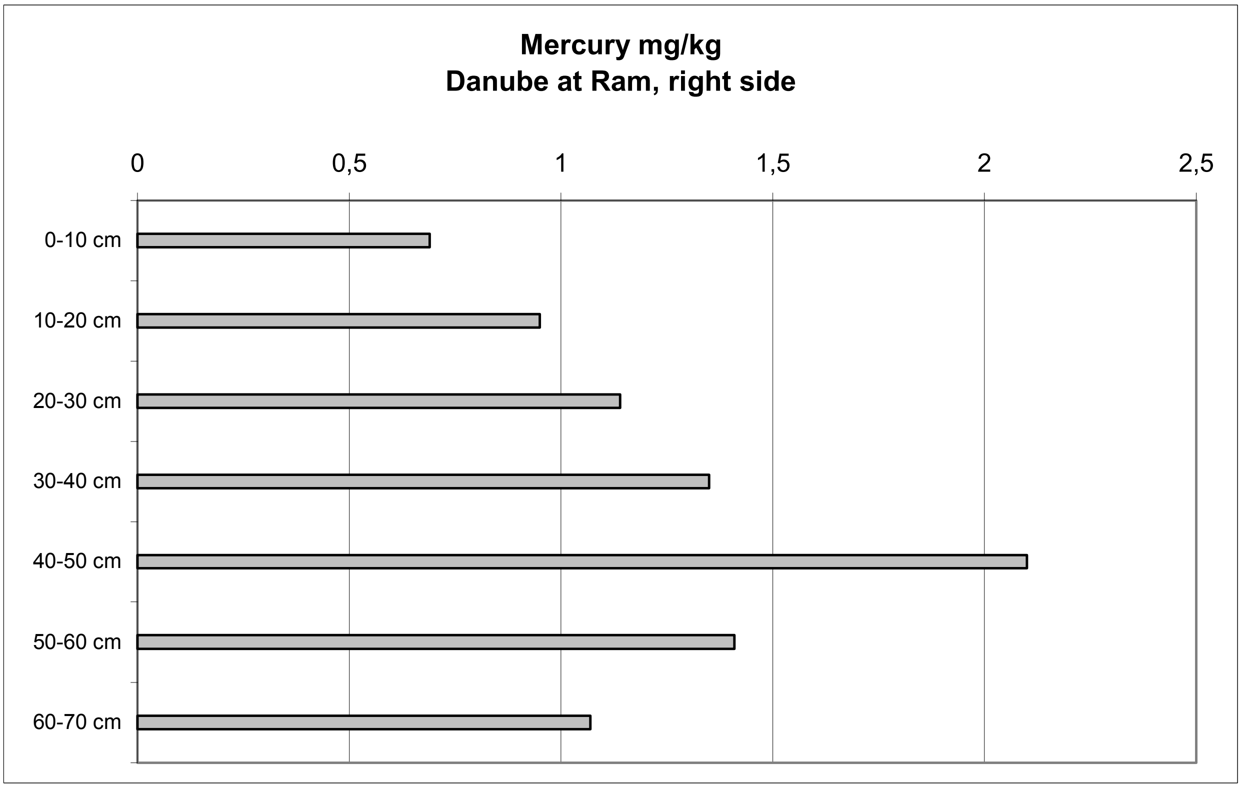


*Figure 3.5.4./*d.

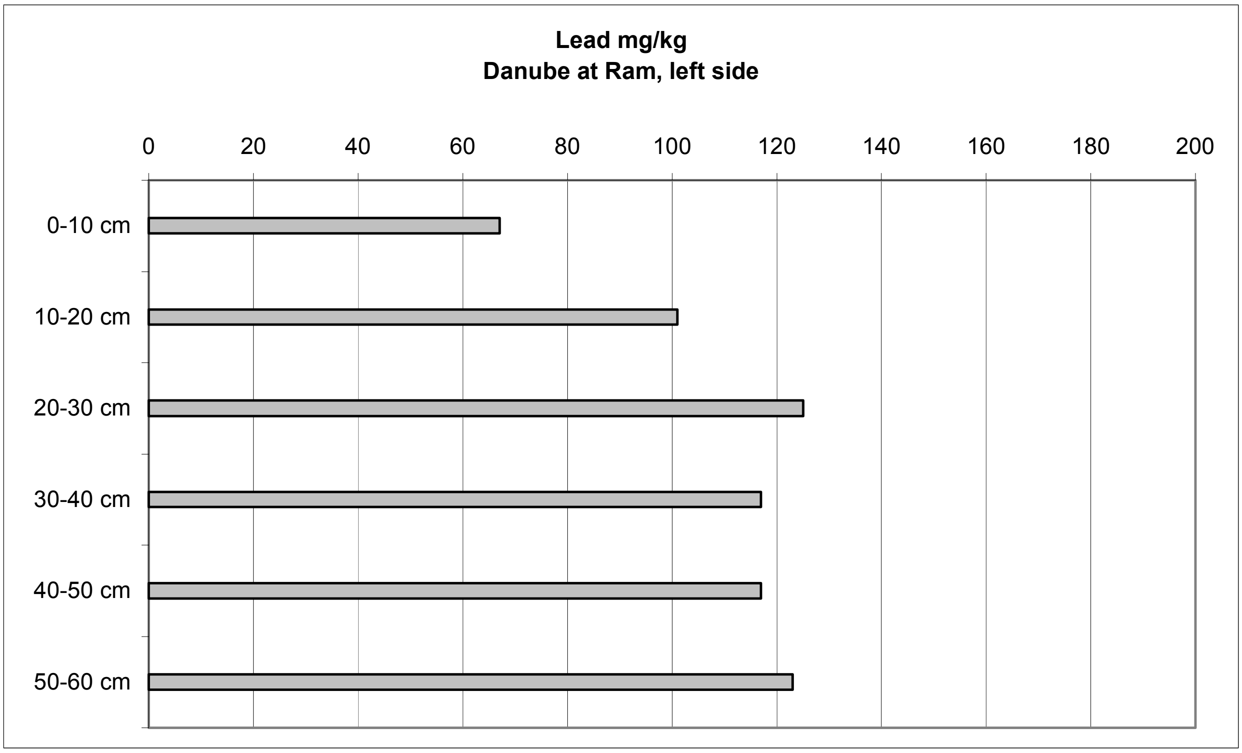


Figure 3.5.4./e.

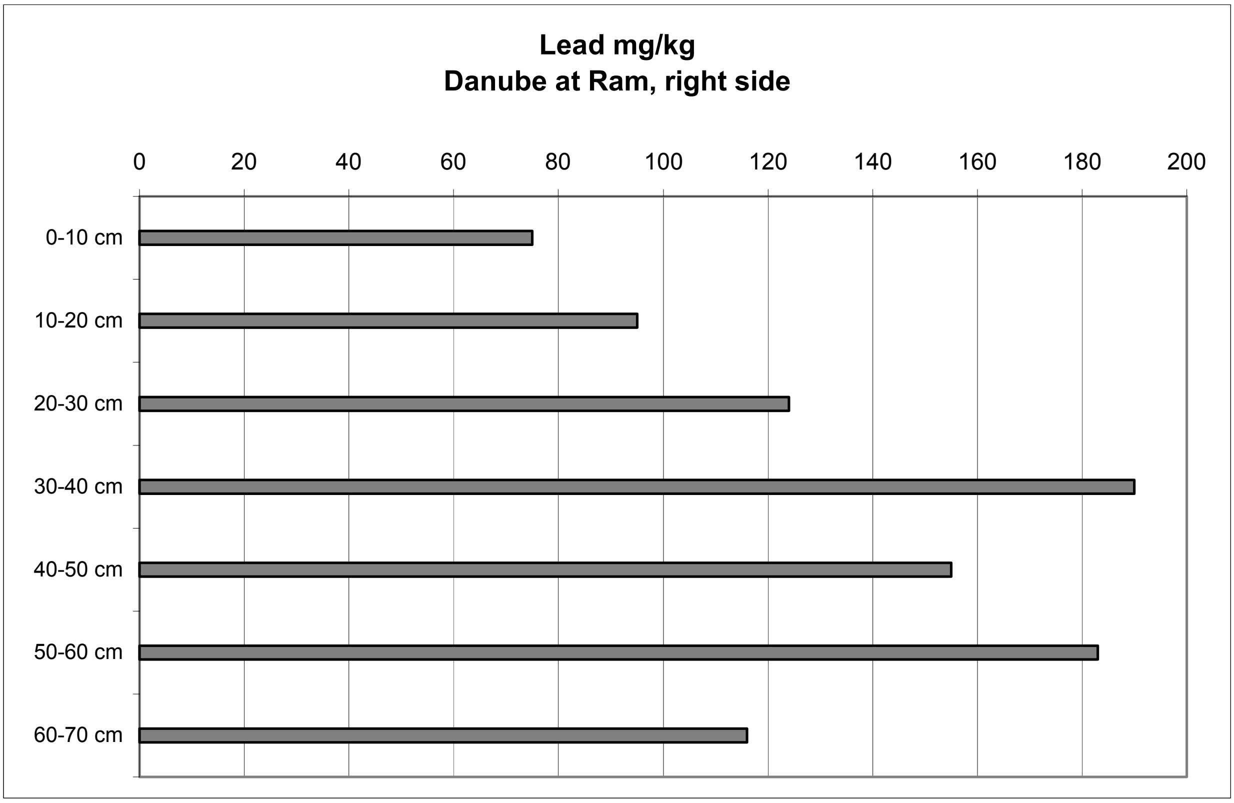


Figure 3.5.4./f.

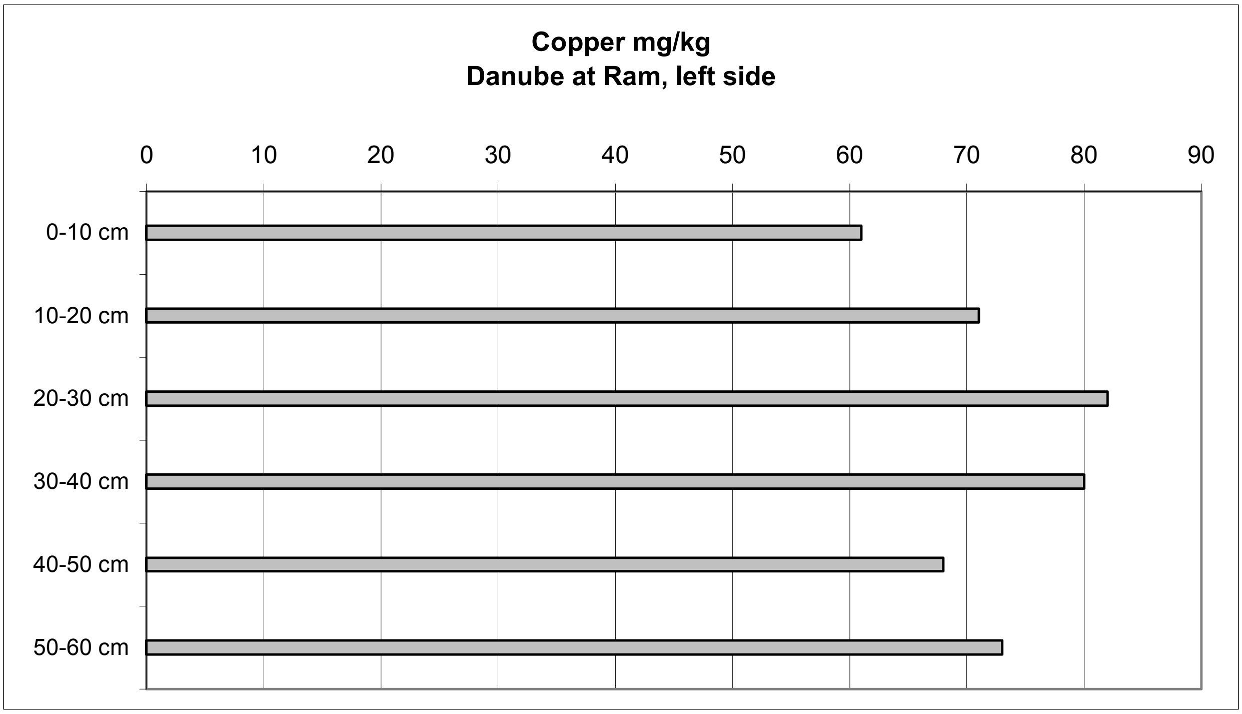


Figure 3.5.4./g.

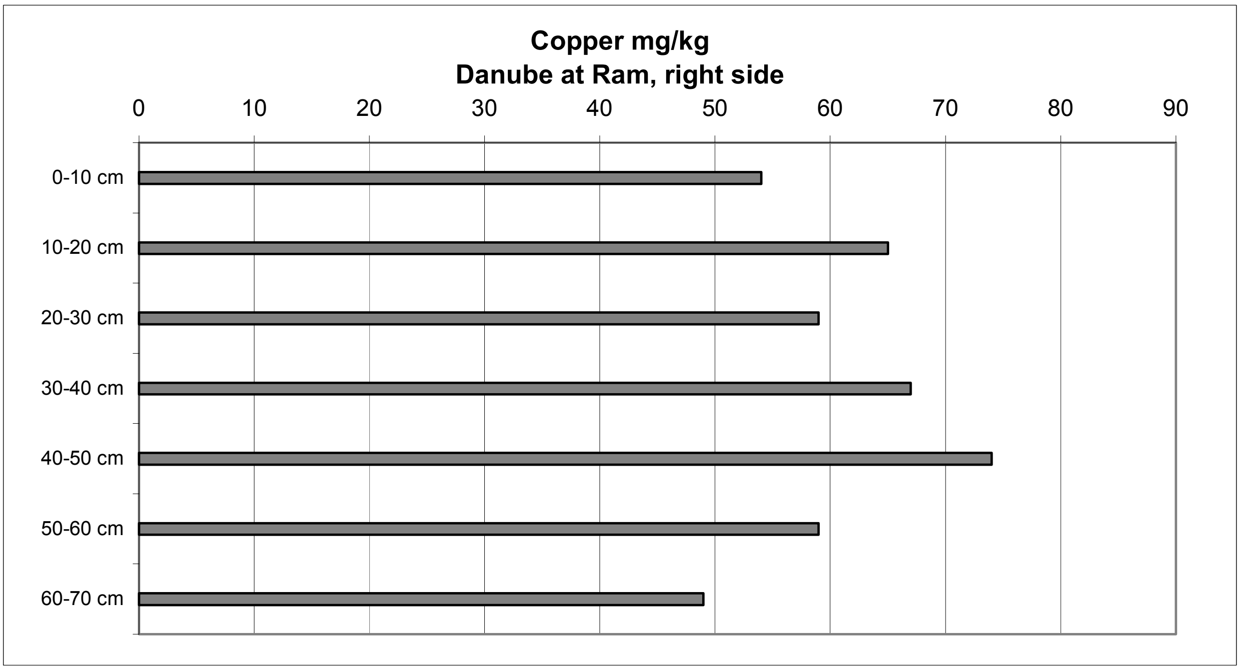


Figure 3.5.4./h.

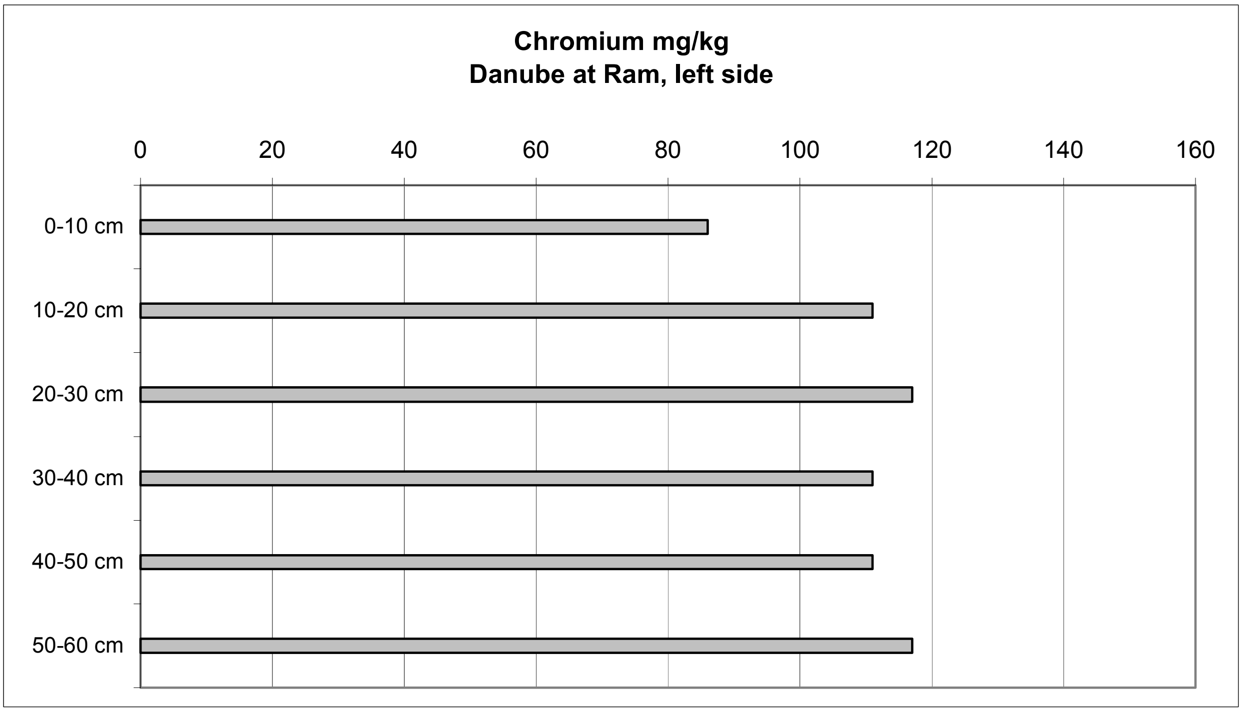


Figure 3.5.4./i.

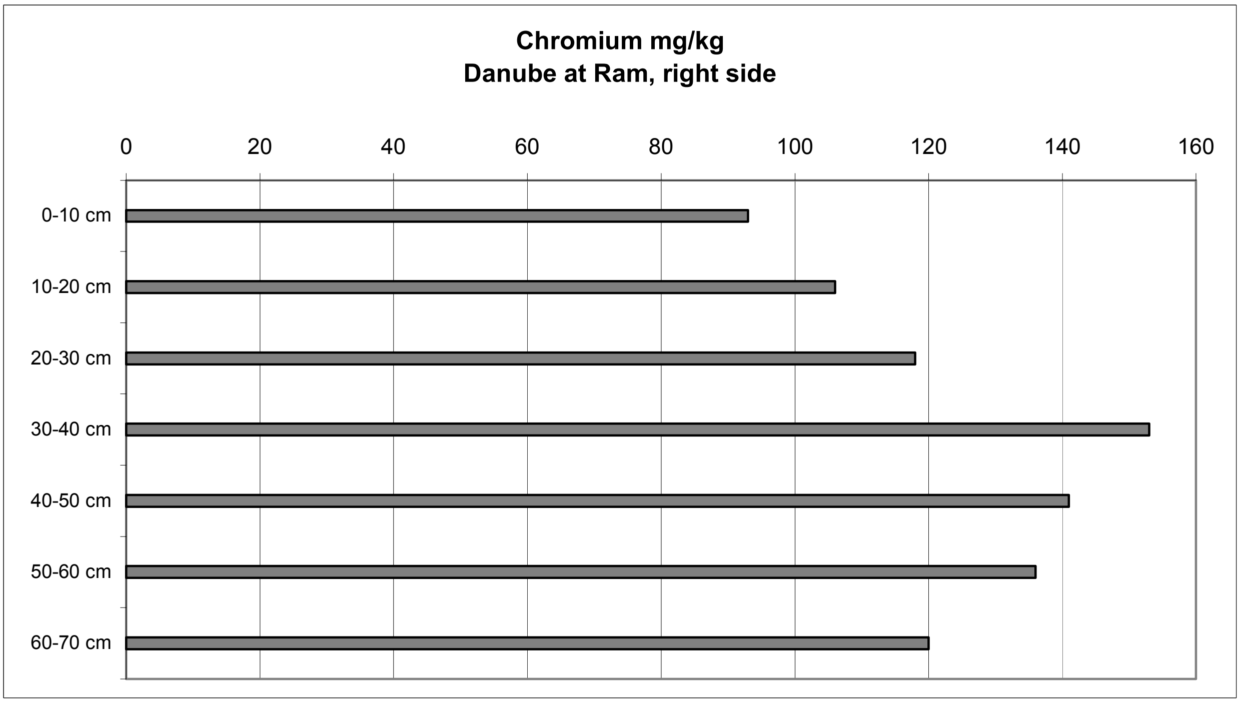


Figure 3.5.4./j.

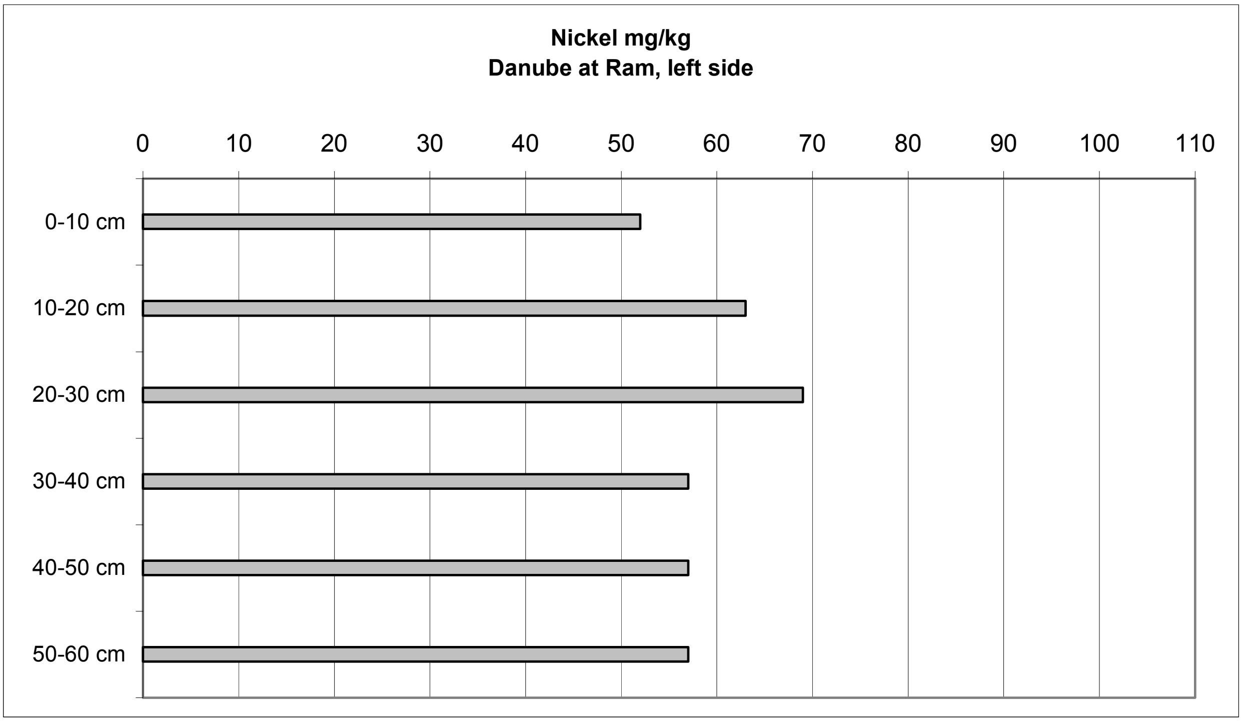


Figure 3.5.4./k.

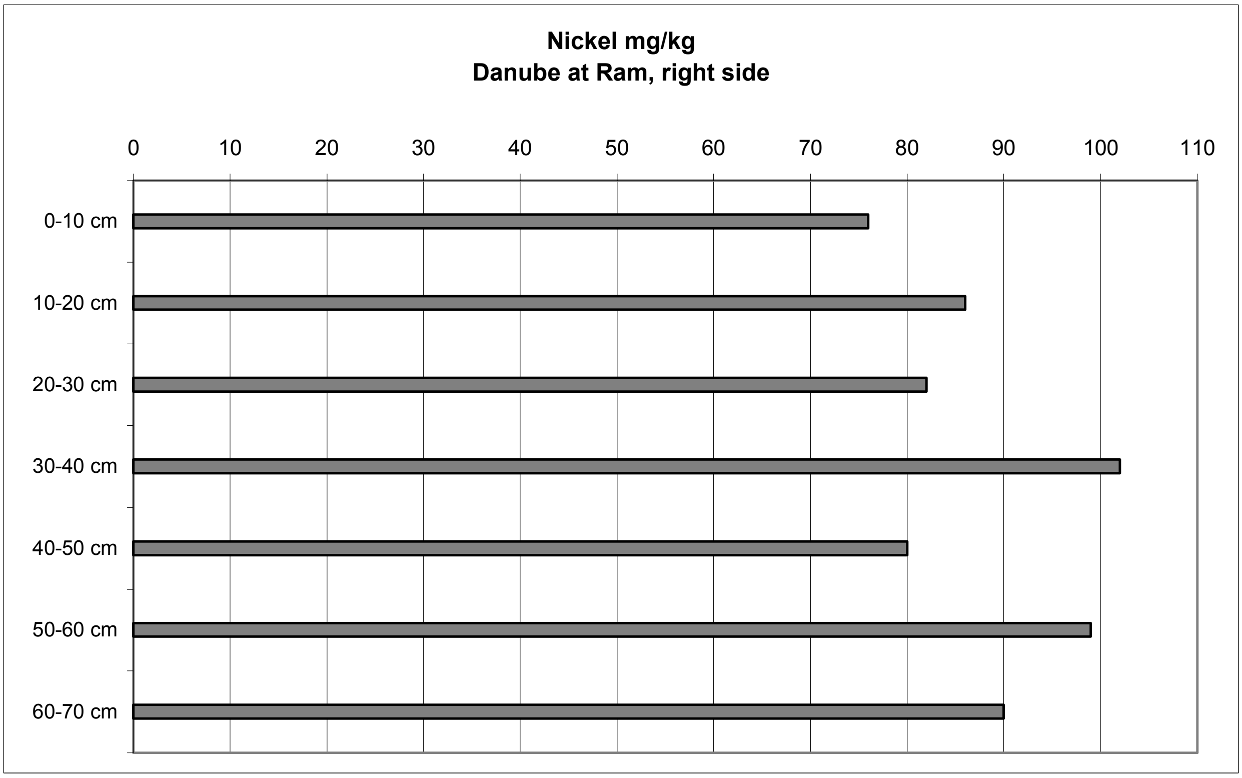


Figure 3.5.4./l.

4. CONCLUSIONS

- The behaviour of heavy metals along the longitudinal section of the Danube is characteristic. There is a continuous increase of the concentrations of them in the sediment samples along the river. Generally, it can be concluded that mercury, lead, chromium, nickel and copper were almost always in higher amount in the sediment than the mussel species. In contrast, cadmium was found in higher amount in mussels than in the sediment samples.

- Mercury was present only in very limited amounts both in the Danube and the tributaries and it was always in fewer amounts in the mussel species. Cadmium was characteristically in higher amount in the sediment of the lower Danube than in the upper sections. The navigable Bega Canal had the most polluted sediment by Cd. The amounts of lead, chromium and copper were increasing in the Danube sediment along the longitudinal section of the river. The concentration of Pb and Cr in mussel species were much less than in the sediment fraction. The longitudinal distribution of nickel in the Danube sediment was a bit different because a peak was observable downstream Belgrade and the Iron Gate section was characterized by double values than the upper stretch. The Ni content of the mussels in Pancevo (upstream left side) exceeded very much the measured levels of the sediment fraction. In Mohács section again more Ni was measured in a mussel species (*Anodonta anatine*) than in the sediment. The sediment samples of tributaries had always-bigger concentrations of Ni than mussel tissues. The sediment of River Timok was extremely contaminated by copper due to mining activity along the upper watershed.

- There were only two heavy metals (*Cd and Ni*) that had much bigger concentrations in mussels than in the sediment. Generally, the mussel species *Unio pictorum* and *Unio tumidus* accumulated the largest amount of different metallic compounds.

- Generally Cl-pesticides and PCB's were in higher amount in the tissues of living aquatic organisms (mussels) than in the river sediment samples. PAH's occurred in bigger amounts in sediment samples usually.

- 2,4 DDE was present in *no detectable amount* in the sediment phase of the Danube and the tributaries. However, the mussel samples contained significant amount of this compound at certain sampling sites. The distribution of DDD is highly similar because it was detected in negligible amount at one sediment sample. All of the three mussel species had relatively high concentrations of this pollutant in their tissues. It is very interesting that DDT is still present in the aquatic environment. Mussel tissues contain significantly higher amounts than the sediment samples.

- PAH-compounds refer to oil contamination that is originated mostly from river shipping. The sediment fraction contains almost every case much bigger concentrations than the mussel samples.

- PCB's usually occurred in smaller amounts than the detection limit. The distribution of different PCB compounds illustrates variable picture in sediment and mussel samples. PCB-52 concentrations are usually just above the detection limit. PCB-101 compound occurs in relatively low amount in the sediment, too. However, the different mussel species collected in the Danube and the tributaries always contain more PCB-101 compound than the corresponding sediment samples.

- PCB-118 concentrations were in the same order of magnitude in case of both the sediment and the mussel samples. Generally, the concentrations measured in the sediment fraction are dominating. The values of *Anodonta anatina* (2.8 ug/kg at Novi Sad upstream, left) and *Unio tumidus* (2.4 ug/kg at Kostolac and Sava, 7.4 ug/kg at Ostruznica) can be mentioned as examples representing the peak values measured in mussels among all sites.

- Altogether 38 macroinvertebrate samples were successfully collected in the sampling program. The number of sites is 27 where living mussel species were collected. Some sites contained more than one species, so altogether 53 mussel samples were analysed. The following species were collected during the sampling campaign: (**1**) *Anodonta anatina*, (**2**) *Unio tumidus* (**3**) *Unio pictorum* (**4**) *Unio crassus* (**5**) *Sinanodonta woodiana*, (**6**) *Pseudanodonta complanata* (**7**) *Anodonta cygnea.*

- The frequency of the large mussels is the following (in decreasing order): *Unio tumidus* (at 24 sites), *U. pictorum* and *Anodonta anatina* (18-18 sites), *Sinanodonta woodiana* (10), *Pseudanodonta complanata* and *Unio crassus* (4-4), *Anodonta cygnea* (1 site only).

- The group of *MOLLUSCA* (aquatic snails and mussels) represents the richest community of the Danube and the tributaries. Based on the faunal data the flowing stretch of the Yugoslavian Danube has similarly rich macroinvertebrate community as the upstream section in Hungary. The main difference is the main available substrate type: smaller sediment particles are predominantly present at many sites. The section of the Iron Gate I. reservoir shows a big mixture in rheophilous and stagnant water species. The same phenomenon was experienced during the BTF 1999 sampling mission already.

- The most diverse picture of the macroinvertebrate community structure was detected at Radujevac. Most of the Danubian rheophilous snail species are present in large individual number (*Theodoxus danubialis, T.fluviatilis, Fagotia acicularis, F. esperi, Amphimelania holandrii*). *Corbicula "fluminalis*" was detected also.

- The investigated Danube section is mainly belonging to b-mesosaprobe and a-b-mesosaprobe zones. The evaluation of the saprobic situation is not very clear i.e. the value of saprobic index upstream Pancevo is bigger than at downstream. The reason of that might be the effect of the wastewaters of Belgrade but it would need more detailed site-specific analysis.

- There were four localities investigated in 1999 in the framework of the BTF sampling mission: the vicinity of Novi Sad and Pancevo, the upper-middle section of the Iron Gate and the area of Kragujevac. It can be concluded that very similar taxonomic composition was experienced one year ago at these sampling locations. The vicinity of the industrial areas showed high degree of pollution that could be seen on the list of occurring taxa. All members of the macroinvertebrate fauna are characteristic to the eutrophic Middle and Lower Danube section, including the Iron Gate Reservoir.

- Based on the previous results of sediment core samples collected in the Iron Gate Reservoir during the BTF mission it can be concluded that there is no direct evidence of the effect of the war in heavy metal pollution. The vertical distribution of heavy metal compounds illustrate that the recent layer (the upper 10 cm) contains the least amount of the different metals at both, left and right sides. Generally, it can be concluded that the amount of cadmium, mercury and lead is approximately doubled in 30 cm depth comparing to the concentrations detected in the surface layer. There are no such big differences in copper, chromium and nickel, but the surface concentrations are always smaller than the amounts detected in deeper layers.

REFERENCE

- UNEP/Habitat BTF and ICPDR: Report on Assessment of Target Pollutants in the FRY Reach of the Danube River Basin, 1999