Summary of the Final Report

JOINT DANUBE SURVEY

MAY 2002

Information

ICPDR – International Commission for the Protection
of the Danube River / Permanent Secretariat
Vienna International Centre, D0412
P. O. Box 500, 1400 Vienna / Austria
Tel: 0043-1-260 60-5738, Fax: 0043-1-260 60-5895
e-mail: icpdr@unvienna.org, www.icpdr.org

An der schönen blauen Donau

Donau so blau,
Durch Tal und Au
Wogst ruhig du dahin,
Dich grüßt unser Wien,
Dein silbernes Band
Knüpft Land an Land,
Und fröhliche Herzen schlagen
An deinem schönen Strand.

(Franz von Gernerth)

Imprint

Owner: ICPDR– International Commission for the Protection of the Danube River / Permanent Secretariat, **Design and Production**: p:matter Vienna, e-mail: p_matter@hotmail.com; **Photos:** ICPDR and Bundesamt für Wasserwirtschaft, Austrian; **Editing/Proofreading:** Parole Language Services, Croatia; **Print:** Print Tech Ltd., Hungary

Foreword

The Danube River is a source of life for 83 million people living in its basin. For thousands of years the River has irrigated the fields along its course turning them into fertile farmland. It has fed the surrounding population on fish. As an important transportation route, the Danube has carried people and goods between different destinations along its 2,857-kilometer-long course. Its natural beauty has inspired poets, painters and composers. Like any valuable asset in the history of humankind, it has attracted conquerors and influenced the course of history.

The Danube is obviously not the only life-sustaining or awe-inspiring river in the world, but it is a uniquely "political" river since it connects 13 European countries, with smaller parts of its basin reaching into yet another four. No other river basin in the world is shared by so many nations. This international character of the Danube can be a double-edged sword. On the one hand, it carries the potential for generating political conflict when changes in the River caused by one country reach beyond that country's border. At the same time, it carries at least an equally large potential for promoting co-operation and encouraging consensus building since the success of any effort to manage and protect the River heavily depends, from the very early stage on, on the agreement between so many riverine states.

Recent history has been dominated by co-operation. The population of the Basin has proved to be committed to preventing the Danube from turning into the sewer of Central and Eastern Europe and ensuring that the River should keep its blue colour to continue to live up to the image created by Johann Strauss.

The Joint Danube Survey (JDS, the Survey) is only the most recent proof of this commitment.

From August to September 2001, two ships equipped with accommodation and research facilities sailed from Regensburg, Germany, down to the Danube Delta carrying scientists from different countries who collected and analysed samples of water, sediment and suspended solids to obtain homogeneous data on the chemical and biological status of the Danube and its main tributaries.

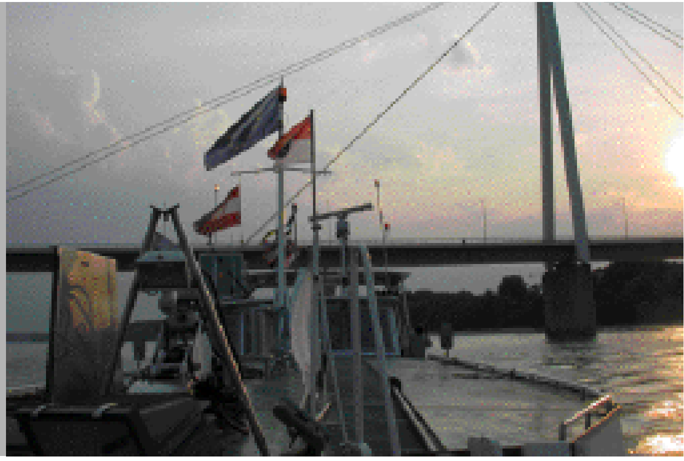
The Survey was made possible by the generous financial support of the German government and a large contribution from the Austrian government. In-kind contributions came from other Danube Basin countries and all riparian states contributed their scientific, logistical, managerial and other necessary expertise to make JDS a truly joint enterprise.

Once they are used as a basis for making adequate environmental decisions, the over 40,000 results generated by the Survey will bring us another step closer to a cleaner Danube.

Martina Motlova
President of the International Commission for the Protection of the Danube River

Contents

Institutional Background



The first legal/institutional framework for cooperation in protecting the Danube water environment through joint measures was established with the signing of the Bucharest Declaration in 1985. The next step, the adoption of the Convention on the Protection and Sustainable Use of the Danube River (Danube River Protection Convention, DRPC) in Sofia in 1994, was taken in response to the need to develop an international water protection strategy for the Danube River. With its entry into force on 22 October 1998, the DRPC became the key legal instrument for regulating cooperation and transboundary water management in the Danube River Basin. Its main objective is defined as protection and sustainable use of ground and surface waters in the Danube River. In 2001, Contracting Parties to the DRPC included Austria, Bulgaria, Croatia, the Czech Republic, the European Community, the Federal Republic of Germany, Hungary, Moldova, Romania, the Slovak Republic and Slovenia; Ukraine was a Signatory to the Convention and Bosnia-Herzegovina had an observer status. The Federal Republic of Yugoslavia had expressed its interest in acceding to the DRPC.

To facilitate the implementation of the Convention, the International Commission for the Protection of the Danube River (ICPDR) has been set up under the Convention as its main decision-making body. The present work and activities of the ICPDR are focussed on fulfilling all commitments ensuing from the current European Union (EU) water legislation and pertaining to sustainable ecological development in the Danube region. The EU Water Framework Directive (EU-WFD) in particular, adopted in 2000, stands out as an effective new legislative tool for safeguarding well-balanced life conditions for all communities sharing the Danube River.

Preparing the Joint Danube Survey

Preparations for the Joint Danube Survey involved clarifying Survey objectives and selecting teams of experts to fulfil them, selecting the parameters to be measured, identifying the sampling and analysis methods and choosing the sampling sites. These tasks were carried out by the Monitoring, Laboratory and Information Management (MLIM) expert group of the ICPDR.

The ICPDR Secretariat in Vienna, which managed the entire project, identified the facilities and equipment necessary to perform the tasks. The tiniest scientific details had to be thoroughly discussed in advance to make sure there were no delays once the actual Survey got under way. Similar strict and systematic preparation was necessary for the logistical support since a single piece of equipment that might not be on board when needed could have seriously undermined the work of the scientists.

A critical part of the role of the ICPDR involved enlisting from the very early stage the support of a range of local authorities in the countries contributing to the Survey - an important prerequisite for the entire expedition to run smoothly and on schedule.

The crew: (left to right) Birgit Vogel, Peter Woitke, Erich Poetsch, Haide Bernerth, Boyan Boyanovsky, Carmen Hamchevici, Peter Literathy, Jaroslav Slobodnik, Aleksandar Miletić, Bela Csanyi

Preparing the Joint Danube Survey

Objectives

Any satisfactory attempt to protect the environment against polluting substances must necessarily start with detailed and accurate information on the occurrence of those substances in the ecosystem. To collect such information, the ICPDR runs regular monitoring of the Danube River water quality in the frame of the Trans-National Monitoring Network. The results of the monitoring are evaluated and published every year. However, the regular monitoring covers a restricted range of parameters and the results are collected from different laboratories in all ICPDR countries, which may result in some discrepancies in the analysed data. In order to broaden the scope of monitoring by including in it as many polluting substances as possible and improve the comparability of water quality data, the ICPDR in 2000 decided to launch a scientific expedition – the Joint Danube Survey.

The main objective of the Survey was to make a thorough analysis of water, sediments, suspended solids and river flora and fauna in the Danube and its major tributaries. Collecting homogenous data sets produced by the best laboratories in the Danube River Basin would help to identify and confirm specific pollution sources. It was agreed that special attention would be paid to the screening of hazardous substances specified in the EU Water Framework Directive (EU-WFD). In addition, the joint research project was seen as an excellent opportunity for experts from all Danube River Basin countries to exchange their experience and to harmonise the different sampling procedures and methods of laboratory analysis used in their respective countries. Last but not least, the press conferences held in all Danube countries to inform the public about the objectives of the Survey helped to raise public awareness about pollution reduction and protection of natural ecosystems.

Preparing the Joint Danube Survey

Sites and samples

Since chemical and biological conditions of rivers are strongly impacted by landscape geomorphology, features such as discharge, slope, depth-width variations, substrate composition or sediment transport, which in particular affect the variety and quality of habitats for aquatic organisms, must be seriously considered in selecting sampling sites that would yield representative data.

In the case of the Danube River Basin, its landscape geo-morphology is characterised by a diversity of morphological patterns, which in turn is reflected in a broad spectrum of chemical and ecological variation from the source of the River to its mouth in the Black Sea. Taking this into account, the Danube was for the purposes of the Survey divided into three major reaches: (1) the Upper Danube reach from the source of the River to the Gabcikovo Dam at 1816 river km, which is characterised by frequent damming and very limited free-flow sections, (2) the Middle Danube reach from the Gabcikovo Dam to the Iron Gate Dam at 943 river km, a completely free-flow section, and (3) the Lower Danube reach from the Iron Gate Dam to the Danube Delta, another free-flow section. Each of the three major Danube reaches was further subdivided into three sub-reaches making a total of nine distinct geo-morphological reaches characterised by specific geo-morphological landscape features and anthropogenic impacts. These geo-morphological reaches are as follows:

Reach 1: Neu Ulm - Confluence with the Inn River (river km 2581-2255)
Alpine river character; anthropogenic impact by hydroelectric power plants

Reach 2: River Inn - Confluence with the Morava River (river km 2225-1880)
Alpine river character; anthropogenic impact by hydroelectric power plants

Reach 3: Morava River – Gabcikovo Dam (river km 1880-1816)
Anthropogenic impact by the construction of Gabcikovo Dam

Reach 4: Gabcikovo Dam – Budapest (upstream, river km 1816-1659)
Turning from an Alpine into a lowland river, the Danube flows through the Hungarian Highlands

Reach 5: Budapest (upstream) – confluence with the Sava River (river km 1659-1202)
As a lowland river, the Danube flows across the Hungarian Lowlands; anthropogenic impact by significant emissions of untreated wastewater in Budapest

Reach 6: The Sava River/Belgrade – Iron Gate Dam (river km 1202-943)
As a lowland River, the Danube breaks through the Carpatian and Balkan mountains; anthropoge-

nic impact by damming effects of Iron Gate hydroelectric power plant and significant emission input of untreated wastewater in Belgrade

Reach 7: Iron Gate Dam – Confluence with the Jantra River (river km 943-537)
As a lowland river, the Danube flows through the Walachian Lowlands (Aeolian sediments and loess); steep sediment walls of up to 150m characterise the River bank on the Bulgarian side

Reach 8: The Jantra River – Reni (river km 537-132)
Lowland river; alluvial islands between two Danube arms

Reach 9: Reni – the Black Sea / Danube Delta arms (river km 132 – 12)
The Danube splits into three Delta arms; characteristic wetland and estuary ecosystem; slopes decrease to 0,01 ‰

A total of 98 sampling sites were selected and distributed across the nine reaches, 74 on the main river and 24 on its major tributaries and arms of the Danube. Sampling at each of the 98 locations included five different sample types (water, sediment, suspended solids, mussels and biota,) each with different determinand list and to be taken at different sampling points: left, middle and right.

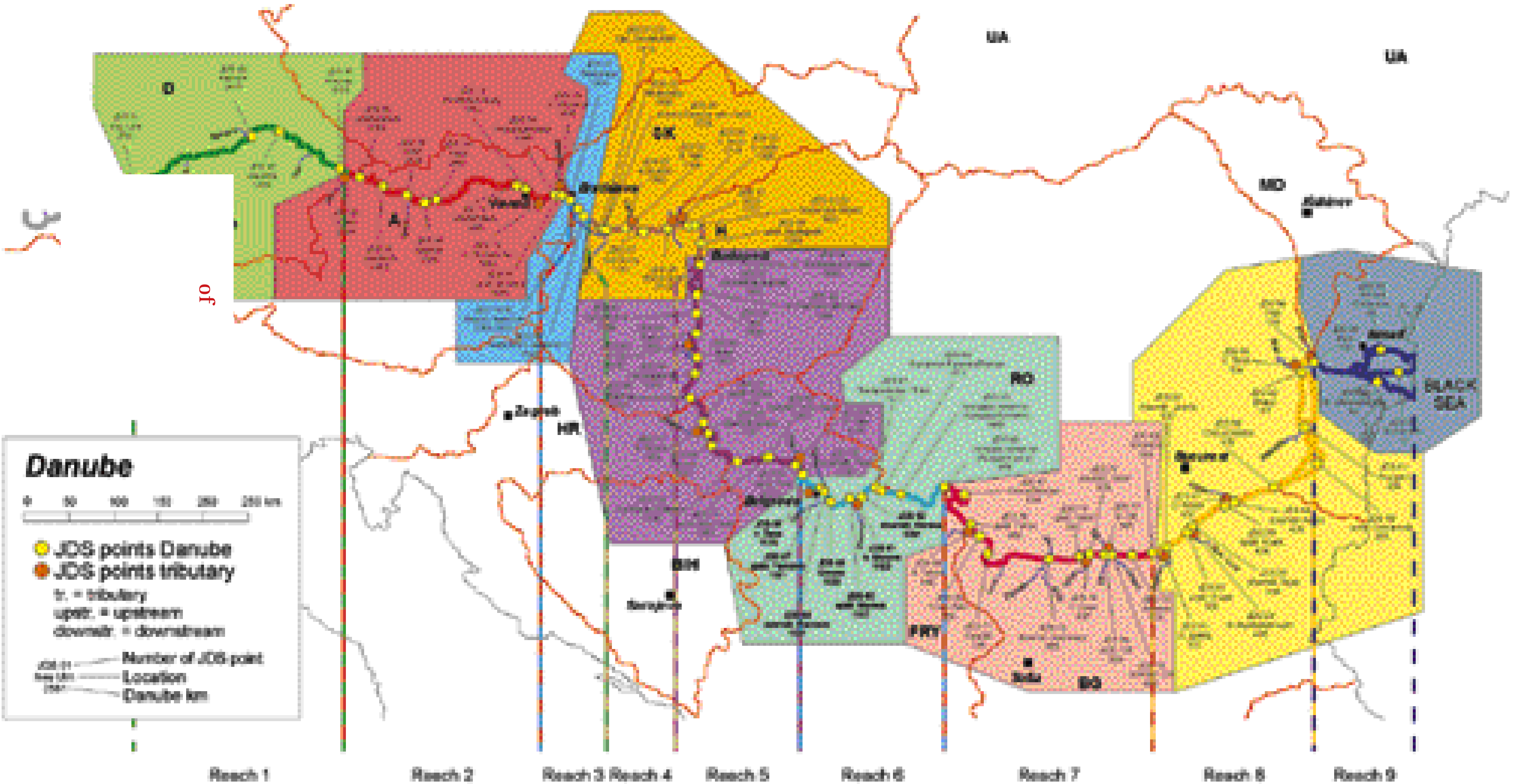
Facilities and equipment

Two ships, Argus from Germany and Szechenyi from Hungary, were selected as the expedition vessels. Argus, a laboratory ship from Hessen, was the centre of all scientific activities. A big grab mounted on the front deck of Argus was used for collecting boulders for the examination of fauna attached to it. The ship's large laboratory enabled on-board processing and immediate analyses of the collected samples that might otherwise deteriorate as a result of storage (e.g. for microbiological analysis). Other samples, those whose analysis required sophisticated instrumentation and special laboratory conditions, were sent to nine top laboratories in Germany, Austria, Slovakia and Hungary. Szechenyi, a prime Hungarian icebreaker – served as a support vessel for accommodation, storage and other logistic purposes.

Human resources

The Survey was performed by an international Core Team made up of ten scientists from the Danube countries with expertise in hydrobiology, microbiology and chemistry. The scientific Core Team was in each country accompanied and assisted by national experts, which set the stage for an exchange of experience between countries and contributed to a very careful examination of the River.

Figure 1: Geo-morphological reaches of the Danube coverd by the Survey



Findings of the Survey

As expected, the Survey yielded data necessary to determine the ecological and chemical status of the Danube River and its major tributaries. It is important to note that the Survey was for the most part deliberately conducted during a low water period, and that the observed concentrations of chemical pollutants consequently represent the worst-case scenario.

Ecological status of the Danube River

Besides being a good indicator of pollution, the aquatic community in a river also reflects changes in the river's hydro-morphology. The appearance and distribution of aquatic organisms in rivers are significantly influenced by flow conditions, temperature, transparency of the water, habitat/substrate conditions and variation as well as the chemical status of the aquatic environment. The planktonic and benthic communities, their species composition and frequency of the individuals are used as the basis for the assessment of the ecological status of rivers included in the EU Water Framework Directive.

Based on their preferred habitat, aquatic communities are commonly classified as follows:

- benthic macroinvertebrates (macrozoobenthos): small animals, which can be seen with the naked eye, living on the bottom sediment, widely used for the assessment of organic pollution (saprobity);
- phytobenthos: algae living attached to the bottom sediment or any other material (e.g. wood) in the river;
- macrophytes: aquatic plants (large algae, mosses, higher plants) whose plant mass is often used for the assessment of trophic status, changes in morphological structures and flow velocities;
- phytoplankton: microscopic algae living in the free-flowing or stagnant water phase, whose biomass is widely used for the assessment of eutrophication effects;
- zooplankton: microscopic small animals living in the free-flowing or stagnant water phase, used in combination with phytoplankton results for the assessment of trophic status.

All biological elements referred to in the EU Water Framework Directive for the assessment of ecological status (benthic invertebrates, phytobenthos, macrophytes, phytoplankton and zooplankton) were investigated during the Survey except for fish because that group of organisms would have required a different sampling method. Special emphasis was placed on the evaluation of organic pollution (saprobity) and eutrophication. In addition to the above-mentioned aquatic communities, microbiological parameters (total coliforms, faecal coliforms, faecal

Examples of the Danube biota

Findings of the Survey

streptococci and heterotrophic bacteria) were also analysed in the water.

More than 1000 aquatic species and higher-level organisms were identified during the Survey, specifically:
- 268 macrozoobenthos taxa
- 340 phytobenthos taxa
- 49 macrophyte species
- 261 phytoplankton taxa
- 120 zooplankton taxa

Based on the results obtained during JDS, the ecological status of the Danube is characterised by those biological groups.

Macrozoobenthos

The biological assessment of the benthic invertebrate fauna during JDS should take into account the fact that the Survey took place in August/September 2001 when a large number of aquatic insects had already emerged.

During the Survey, 268 species were detected in the benthic samples collected with the polyp grab of the ship Argus. When all the species from accessory light trap catches and from manual collections with a sweep net are added to this number, the total number of reported benthic invertebrate species climbs to nearly 300.

The highest number of species and higher-level organisms - an average of 40 - was found at the sampling stations in the Upper Danube reach. In the middle and lower reaches, the figures range from 30 to 10. The number of species is considerably influenced by the different grain size of the substrate and flow velocities in the Danube. The number of species for both banks matched only up to 60 %, and the biggest differences between the left and right banks could be observed in the middle and lower reaches of the Danube. The number of species in the tributaries was found to differ very slightly from that in the Danube.

The dominant groups of invertebrates show a varying distribution along the Danube. While the same species of crustaceans colonises the whole of the Danube, the number of insects was found to decrease significantly as one moved downstream. This is probably due to the fact that the Survey was - as was mentioned earlier - conducted during a low-flow period when life conditions are not optimal. Molluscs and detritivores dominate the middle and lower reaches.

Saprobity	Interval of saprobic indices	aprobiological water quality class	
oligosaprobic	< 1,25	I	(unpolluted)
oligosaprobic to ß-mesosaprobic	1,25 to 1,75	I-II	(low-polluted)
b-mesosaprobic	1,76 to 2,25	II	(moderately polluted)
b-mesosaprobic to a-meso-sapro-bic	2,26 to 2,75	II-III	(critically polluted)
a-mesosaprobic	2,76 to 3,25	III	(strongly polluted)
a-mesosaprobic to polysaprobic	3,26 to 3,75	III-IV	(very highly polluted)
polysaprobic	> 3,75	IV	(excessively polluted)

Table 1: Classification of the saprobiological water quality class (Austrian standard ONORM M 6232)

Findings of the Survey

Saprobity – Biological water quality class

Macroinvertrebrates (macrozoobenthos) in particular have for many years been widely used in Europe in assessing the organic pollution of rivers. In the Danube area, this assessment is mainly based on the saprobic system, which leads to a classification of water quality into seven biological water quality classes: four main and three in-between classes (see Table 1). Water quality class II (moderately polluted) indicates the general water quality objective.

The saprobity of the Danube varied between water quality class II (moderately polluted) and II/III (critically polluted). Taking into account that the saprobic index is also influenced by the habitat structure (for example, comparison of free-flowing stretches to impounded areas), the Danube showed good water quality (class II) all the way to Budapest.

Downstream of Budapest, where the Danube passes through the Hungarian Lowlands, water quality often decreased to class II-III, indicating significant organic pollution. Taking into account the high chlorophyll-A values as well as the extreme over-saturation with oxygen in this reach, secondary pollution caused by an elevated phytoplankton biomass, which usually leads to an increase in saprobity, was clearly recognisable.

Downstream of Belgrade to the Iron Gate reservoir, water quality varied between class II and II-III. Signs of pollution began to appear, and there were significant differences in the saprobity of the samples collected from the left and right banks of the Danube, which seemed to be due to the pollution effects of the discharging tributaries. Only the impounded reach upstream of the Iron Gate Dam showed saprobity values below the limit for water quality class II.

In the Lower Danube reach, especially downstream of big cities, discharges seemed to result in an increase in the level of destruents, bacteria and detritus feeders; even toxic effects seemed to exist. On the left bank of the Danube, for example at Vrbica/Smiljan, no invertebrates were present on rocks and pebbles, and the very fine-grained, reduced sediment was predominantly inhabited by a few oligochaetes and chironomids. Comparing the Upper and Lower Danube in terms of the sum of abundances, the lower section of the Danube was clearly marked by a significant decrease in biodiversity.
Arms and tributaries of the Danube were found to be more polluted than the River itself and even reached water quality class III (strongly

Macrozoobenthos sampling

polluted) or higher. The Moson-Danube arm and the dammed Rackeve-Soroksar arm were found to be critically polluted (water quality class II-III). The Schwechat, the Drava and the Tisza could be placed between class II and II-III. The mouths of the Vah, Velika Morava, Jantra, Siret and Prut tributaries are critically polluted (water quality class II-III). The Sio even reached water quality class III. No macroinvertebrates were found - probably due to toxic effects - in the Iskar, Olt and Arges tributaries which exceeded the limit of water quality class III and represented the worst quality conditions identified during the Survey.

Alien species

The building of the Main-Danube Canal and its opening in 1992 removed a natural biogeographical barrier which had for millennia separated the Rhine and the Danube and triggered an on-going, two-way fauna transfer between the two rivers. The competition between local and foreign aquatic animals (neozoa) for food and habitat has resulted in changes in macrozoobenthos diversity. Shipping encourages a fast dispersal of neozoans. For example, the mussel *Corbicula* was transported by ship from Europe and Egypt (the Nile) to North America and then returned to Europe around 1980. It migrated into the Danube in 1997 starting in the Rhine River, reached the Hungarian region by 1998/99 and was found in the Delta during JDS in 2001.

Phytobenthos

Phytobenthos is the totality of algae living on the surface of substrata in the river bed. The ecological niche of phytobenthos algae can be characterised by a long list of environmental variables (hydrology, substratum, light, water chemistry, temperature and other biota) showing river-type-specific variation ranges. In the long term, phytobenthos communities respond to environmental stress (e.g. abrasion, siltation, instability of substratum, seasonal and horizontal shade pattern, turbidity, hardness, nutrient content, diurnal and seasonal variations, grazing by zoobenthos, fish, shading by riparian vegetation) primarily by changes in species composition.

Altogether 340 phytobenthos species and higher-level organisms were identified in the Danube, its side arms and its main tributaries during the Survey.

The richest group was *Bacillariophyceae* with 264 identified species. This algal group, also called Diatoms, is well known for having a species-specific silicate structure. Dominating JDS samples were pennate-species of Diatoms, mainly genera of *Navicula*, *Nitzschia*, *Achnanthes*, *Amphora*, *Cocconeis*, *Cymbella*, *Diatoma*, *Fragillaria*, *Gomphonema*, *Gyrosigma*, *Pinnularia* and *Surirella*.

The number of species identified at the individual sampling sites varied in the range of 20-96 in the Danube and between 16-109 in the tributaries. Downstream of Koszloduy (river km 685), the number of phytobenthic species decreased significantly. This seemed to be due to the type of substratum (mud and sand). An extremely low number of species (20-39) was found in the Danube Delta.

Findings of the Survey

Macrophytes

The Danube River offers a broad diversity of abiotic habitat parameters such as different substrate types, flow types and transparency as a sound basis for the development of diverse macrophyte vegetation.

Altogether 49 different aquatic plant species were collected and identified during JDS, specifically:

- 14 moss species;
- 16 Spermatophyta (higher plants) - submerged Rhizophyte species;
- 9 floating leafed and free-floating plants;
- 6 species representing Amphiphytes
- 3 Helophyte species
- 1 species which belongs to the group of Characeae (Phycophyta).

During JDS Macrophyte evaluations, the impact of flow conditions became very clear because mosses, submerged Rhizophyte species, floating leafed and free-floating plants can serve as good indicators of flow conditions. Mosses prefer hard substrates (e.g. boulders) which dominantly characterise the Upper Danube reach (Austria, Germany). They represented a considerable share of the total plant mass in Reaches 1, 2 and 4.

Concerning plant mass, a clear dominance of higher plants (Spermatophyta), i.e. free-floating and floating leafed plants, was observed in the Danube. In general, submerged Macrophyte species prefer higher-flow velocities than do floating leafed or even free-floating species. The final dominance of these two plant groups is ultimately determined by light availability, which in turn is determined by transparency of the river water. Submerged species prefer habitat conditions marked by high transparency values. A dominant occurrence of submerged Rhizophytes due to high transparency values was found along Reach 3 (Gabcikovo reservoir) and Reach 7.

If transparency values are low, Macrophyte species, which grow on the water surface or very close to it, become the dominant species. Therefore, in the last two Reaches (8 and 9), where lower transparency values were recorded, floating leafed and free- floating aquatic plant species dominated the Macrophytes.

Besides being influenced by transparency, the occurrence and distribution of Macrophyte species is also crucially determined by nutrients. The majority of the plant species collected during JDS are indicators of eutrophic (high amount of nutrients) conditions and others such as Ceratophyllum demersum, Potamogeton crispus and Zannichellia palustris are common signals of significant nutrient loads. The species group of Characea (Phycophyta) usually serves as an indicator of oligotrophic (low in nutrients) habitats providing high transparency values. Such preferred conditions obviously occur in some parts of the Iron Gate reservoir where this specific group could be found.

Plankton

Plankton communities are expected to develop only in large rivers with the exception of their upper section. Development of riverine plankton is based on the following conditions: necessary water depth and flow (average minimum

Findings of the Survey

flow 200-300 m^3/s), a given flow velocity (max. 0,4 m/s), turbulence, suspended solids contents, required length of the river section and stagnant waters hydraulically connected to the main arm.

Phytoplankton

The development of phytoplankton biomass depends on the concentrations of nutrients and their availability, light conditions, flow velocity (residence time) and the "grazing" effect of zooplankton and benthic filter-feeding animals. An increase in the nutrient concentration in water usually results in an increase in algal (or plant) biomass. Phytoplankton biomass (mg/l) and/or chlorophyll-A concentrations are commonly used as variables to characterise the trophic status of a water body along with concentrations of plant nutrients (phosphor and nitrogen), oxygen saturation and transparency.

Qualitative and quantitative algological investigations were carried out during JDS to produce an overview of the longitudinal variation in species composition and characterise the eutrophication status of the River. Altogether 261 phytoplankton species were found during JDS in the plankton of the Danube and its tributaries. The longitudinal variations in phytoplankton biomass were also related to the variation in the number of species.

The increase in species abundance in the middle and most eutrophicated part of the Danube was caused mainly by the increasing number of coccal forms of green algae (Chlorococcales) as might have been expected in an eutrophic environment. In general, high values of biomass/chlorophyll-A indicated eutrophic conditions in the middle Danube reach particularly downstream of Budapest.

Concerning the tributaries, the highest concentrations of phytoplankton biomass were found in the Iskar, the Velika Morava, the Ipoly, and the Sio, where high eutrophic status was usually accompanied by high nutrient concentrations and oxygen-hypersaturation. Despite the fact that the Jantra, the Russenski Lom, the Arges, the Siret and the Prut were also found to have high concentrations of nutrients or biodegradable organic matter, the phytoplankton biomass was found to be low, probably due to retarding or toxic effects. In contrast, a high concentration of phytoplankton biomass was observed in the Drava, despite the low concentration of nutrients.

Zooplankton

Zooplankton communities can only develop in rivers exceeding the length of about 500-700 km, because the growth of the species requires a certain time period such as 3-7 days for Rotatoria, one week for Cladocerans and one month for Copepods. Temperature is particularly important in the case of Rotatoria. If the river flow is high and water level fluctuations are large without the necessary depth, zooplankton will be destroyed due to frictions against the bank, riverbed and plants. Suspended solids could damage zooplankton species. Qualitative and quantitative composition of zooplankton could be highly influenced by the effects of the confluence of a species-poor canal and water diversion devices and closures.

Findings of the Survey

Altogether 120 species (79 Rotatoria, 27 Cladocera and 14 Copepoda) forming the zooplankton community were identified in the Danube and its tributaries during the Survey.

The number of zooplankton species found at JDS sampling sites varied between 4-26 in the Danube and 6-30 in its main tributaries. A gradual increase in the number of species was observed in the Danube downstream towards the Delta.

The occurrence of many rare species was recorded especially in the German, Austrian, Slovak and Hungarian part of the Danube. The biggest abundance of species was found in the Hungarian and Yugoslavian section of the River.

The abundance of individual zooplankton communities varied widely between 280 – 1,380,000 ind/m^3 in the Danube and 1,140 – 799,000 ind/m^3 in its main tributaries. The lowest individual numbers were measured along the German, Austrian, Romanian and Bulgarian river stretches. The highest individual numbers were registered downstream of Budapest and in the Yugoslavian part of the Danube near Novi Sad, as well as between the points of confluence with the Tisza and the Sava rivers. These results are not in accordance with the results of previous investigations where maximal individual numbers were observed further downstream on the Romanian-Bulgarian-Ukrainian river stretch and in the Danube Delta. In many cases, an impact of tributaries on the Danube was observed in the form of a change in the composition of species and an increase in zooplankton density in the Danube downstream of the confluence.

From the longitudinal variation in phytoplankton biomass and zooplankton density shown in Figure 2 it can be seen that the peak in phytoplankton biomass was followed by maximum values in zooplankton density in the Middle Danube reach. That the decrease in phytoplankton was associated with an increase in zooplankton density is most likely due to the grazing effect of zooplankton.

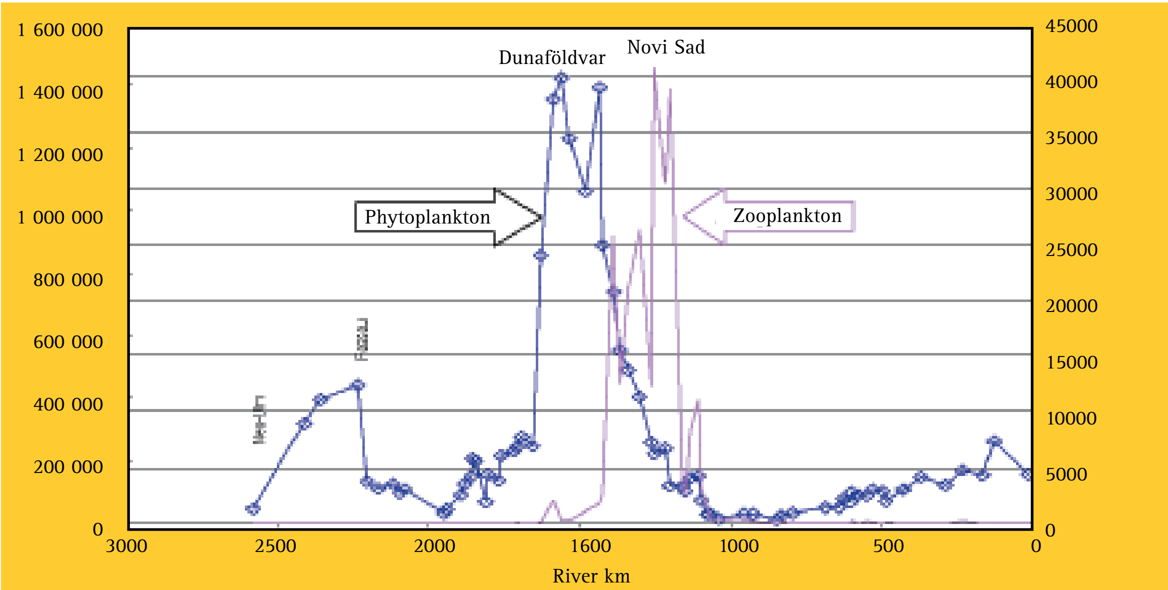


Figure 2: Variation in phytoplankton biomass and zooplankton population density along the Danube River found during JDS.

Microbiology

Microbial communities represent a fundamental part of aquatic ecosystems. They degrade organic matter thus contributing to the self-purification process in rivers. Bacteria are ideal sensors because of their fast response to changing environmental conditions. Total coliforms, faecal coliforms and faecal streptococci are very good indicators for the assessment of faecal pollution mainly caused by raw and treated sewage and diffuse impacts from farmland and pastures, also indicating the potential presence of pathogenic bacteria, viruses and parasites. The concentration of heterotrophic bacteria usually shows correlation to organic pollution.

For monitoring the quality of river water intended for the abstraction of drinking water, irrigation and bathing, the examination of these microbiological standard parameters is made obligatory by legislation. (e.g. EU Surface and Drinking Water Directive 75/440/EEC; WHO Guidelines for the Safe Use of Wastewater and Excreta in Agriculture and Aquaculture, 1989; EU Bathing Water Directive 76/160/EEC).

Since Danube countries normally use different methods of microbiological analysis, JDS offered a unique opportunity to obtain comparable results from Neu Ulm (Germany) to the Black Sea. For the first time, standard microbiological determinands were analysed on board by using uniform methodology for all sampling sites.

The evaluation of microbiological results showed pollution to reach the highest values in the tributaries (the Russenski Lom, the Arges, the Siret and the Prut in particular) and in the side

Findings of the Survey

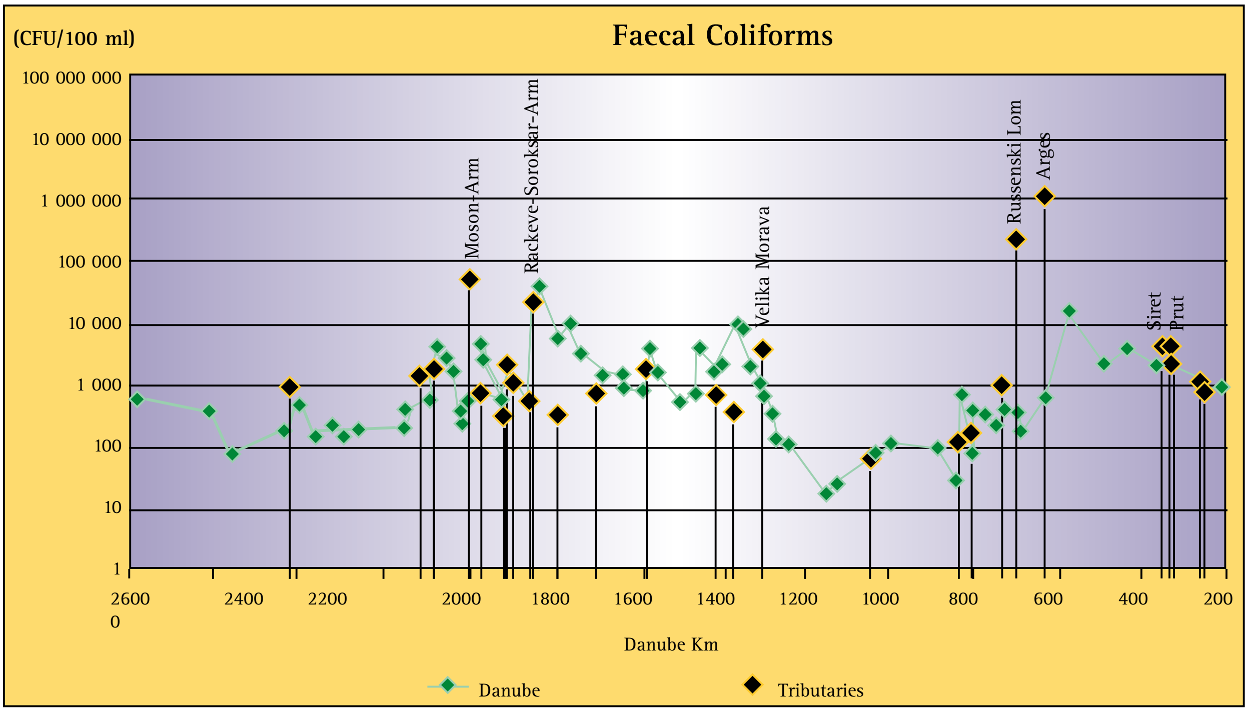


Figure 3: Variation of faecal coliforms along the course of the Danube River (small columns represent tributaries)

arms (the Moson arm, the Rackeve-Soroksar arm). Lower bacterial values could be observed in the Upper Danube reach as well as in and downstream of the Iron Gate reservoir. Higher levels of faecal pollution were found in the middle part of the Danube, particularly downstream of major cities (Budapest, Beograd) as far as 1.100 river km and again in the Lower Danube from 500 river km to the Danube Delta.

On-board analysis is under way

Figure 4: Microbiological classification of the Danube River and its major tributaries; CC=colony count TC=total coliforms, FC=faecal coliforms, FS=faecal streptococci

Tributary right bank	CC/ml	TC/100ml	Danube sampling site	FC/100ml	FS/100ml	Tributary left bank
	3800	2300	JDS 1 Neu Ulm; km 2581	610	100	
	1200	1300	JDS 2 Kelheim; km 2412	380	40	
	580	780	JDS 3 us dam Geisling (Rb); km 2358	80	5	
	1400	1800	JDS 4 us dam Kachlet (P); km 2230	210	15	
JDS 5 Inn; km 2221	1700	3800	Tributary	920	10	
	1900	2000	JDS 6 Jochenstein; km 2200	500	150	
	660	750	JDS 7 us. dam Aschach; km 2165	160	35	
	750	1000	JDS 8 us dam Abwinden-A; km 2120	230	80	
	360	750	JDS 9 Wallsee; km 2095	160	35	
	680	850	JDS 10 us dam Ybbs-P.; km 2061	310	60	
	620	2300	JDS 11 us. dam Greifenst.; km 1950	220	35	
	1100	1350	JDS 12 Klosterneuburg; km 1943	400	40	
JDS 13 Schwechat; km 1913	31000	4900	Tributary	1500	210	
	1100	2000	JDS 14 Wildungsmauer; km 1895	620	60	
	3500	11800	JDS 15 us Morava (Hainb); km 1881	4000	195	
	3800	2700	Tributary	2000	310	JDS 16 Morava; km 1880
	3600	6100	JDS 17 Bratislava; km 1868	3900	500	
	3500	6800	JDS 18 Gabcikovo res. km 1856	2800	100	
	2200	7700	JDS 19 Gabcikovo reserv.; km 1852	2800	210	
	2200	6500	JDS 20 Gabcikovo reserv.; km 1846	2100	170	
	820	1500	JDS 21 Ásványráró; km 1812	290	30	
	2200	1200	JDS 22 Bap (Dunakiliti); km 1812	420	30	
	5800	1200	JDS 23 Medvedov; km 1806	580	30	
JDS 24 Mosoni Arm-end; km 1794	34000	280000	Arm	51000	2200	
	3900	14800	JDS 25 Komarno/K.; km 1768	4200	30	
	1900	2400	Tributary	780	100	JDS 26 Vah; km 1766
	4900	3000	JDS 27 Iza / Szony; km 1761	2700	70	
	3400	1400	JDS 28 St. / Esztergom; km 1719	620	40	
	21000	1100	Tributary	380	250	JDS 29 Hron; km 1716
	13000	16000	Tributary	2100	3500	JDS 30 Ipoly; km 1708
	4400	8800	JDS 31 Szob; km 1707	2300	70	
	3400	6000	JDS 32 us Szentendre I.; km 1692	1300	30	
JDS 33 Szent I. Arm-start; km 1683	8300	4600	Arm	1200	220	
	3300	1600	JDS 34 D71 us. Budapest; km 1659	520	30	
JDS 35 Szent I. Arm-end; km 1658	1100	1500	Arm	580	70	
	7600	54000	Arm	23000	770	JDS 36 Rack. Arm-start; km 1642
	4900	61800	JDS 37 ds. Budapest; km 1632	41000	900	
	310	590	Arm	350	34	JDS 38 Rack.-S Arm-end; km 1586
	2800	11000	JDS 39 Tass; km 1586	6600	180	
	12000	33000	JDS 40 Dunaföldvár; km 1560	5800	2200	
	5200	11000	JDS 41 Paks; km 1533	3400	140	
JDS 42 Sio; km 1497	1300	2000	Tributary	730	50	
	4100	7900	JDS 43 Baja; km 1481	1600	40	
	3800	3700	JDS 44 Hercegszanto; km 1434	1600	30	
	2800	5300	JDS 45 Batina; km 1429	1000	70	
	1900	9500	JDS 46 us. Drava; km 1384	900	30	
JDS 47 Drava; km 1379	110000	8200	Tributary	2000	220	
	25000	14000	JDS 48 ds. Drava (Erdut/B); km 1367	3800	220	
	19000	7300	JDS 49 Dalj; km 1355	1700	50	
	3100	1700	JDS 50 Ilok/Backa Palanka; km 1300	560	10	
	8500	1900	JDS 51 us. Novi Sad; km 1260	740	20	
	15000	11000	JDS 52 ds. Novi Sad; km 1252	4400	450	
	23000	4100	JDS 53 us Tisa (Stari S.); km 1216	1900	120	
	350	4000	Tributary	690	60	JDS 54 Tisa; km 1215
	11000	7600	JDS 55 ds Tisa/us Sava; km 1202	2200	310	
JDS 56 Sava; km 1170	1200	1100	Tributary	360	50	
	18000	39000	JDS 57us Pancevo/ds Sava; km 1159	9200	1900	
	12000	31000	JDS 58 ds. Pancevo; km 1151	6000	1200	
	4800	6900	JDS 59 rodus; km 1132	2100	120	
	3400	5200	JDS 60 us. Velika Morava; km 1107	1100	10	
JDS 61 Velika Morava; km 1103	1700	7200	Tributary	3600	90	
	1100	6600	JDS 62 ds. Velika Morava; km 1097	700	60	
	550	5800	JDS 63 Stara Palanka-Ram; km 1077	340	10	
	3800	1400	JDS 64 Banatska P./B.; km 1071	140	30	
	240	880	JDS 65 Irongate res.(G.M.); km 1040	120	20	
	1300	60	JDS 66 Irongate res.(T/O); km 954	20	10	
	520	120	JDS 67 Vrbica / Simijan; km 924	20	10	
	2800	240	JDS 68 us Timok (R./Q.); km 849	60	20	
JDS 69 Timok; km 845	1100	280	Tributary	70	50	
	920	290	JDS 70 Pristol/Novo Selo H.; km 834	80	5	
	340	290	JDS 71 Calafat; km 795	110	5	
	4700	550	JDS 72 ds. Kozloduy; km 685	100	20	
	6600	650	JDS 73 us. Iskar (Bajkal); km 641	30	10	
JDS 74 Iskar; km 637	220	360	Tributary	120	70	
	1400	4200	JDS 75 ds. Iskar; km 630	700	190	
	670	130	JDS 76 us. Olt; km 606	90	35	
	1300	320	Tributary	190	160	JDS 77 Olt; km 605
	1200	1300	JDS 78 ds. Olt; km 603	390	50	
	880	650	JDS 79 ds Turnu-M./Nikopol; km 578	350	70	
	1100	1900	JDS 80 ds. Zimnicea / S.; km 550	340	100	
JDS 81 A11 Yantra; km 537	1500	4200	Tributary	660	280	
	1900	3000	JDS 82 ds. Jantra; km 532	400	180	
	1400	2900	JDS 83 us. Ruse; km 498	360	1400	
JDS 84 Russenski Lom; km 498	1400000	960000	Tributary	340000	310000	
	1500	1000	JDS 85 ds. Ruse / Giurgiu; km 488	190	40	
	3100	1900	JDS 86 us. Arges; km 434	560	120	
	1400000	3600000	Tributary	1100000	120000	JDS 87 Arges; km 432
	520	2800	JDS 88 ds. Arges (Oltenita); km 429	640	130	
	54000	75800	JDS 89 Chiciu / Silistra; km 375	17000	5400	
	3500	5500	JDS 90 ds. Cernavoda; km 293	2400	150	
	5400	11800	JDS 91 Giurgeni; km 235	4300	950	
	3100	5300	JDS 92 Braila; km 167	2200	120	
	12000	22000	Tributary	4400	2000	JDS 93 Siret; km 154
	29000	12000	Tributary	3500	2500	JDS 94 Prut; km 135
	6200	4800	JDS 95 Reni; km 132	2300	1800	
JDS 96 Sf. Gheorghe Arm; km 64	3800	4000	Arm	1200	50	
	2900	2500	Arm	610	120	JDS 97 Vilkova - Kilia Arm; km 58
	4800	4200	JDS 98 Sulina - Sulina Arm; km 15	950	60	
	1	1	class I	1	1	
	500	500		100	50	
	501	501	class II	101	51	
	10000	10000		1000	100	
	10001	10001	class III	1001	101	
	100000	100000		10000	1000	
	100001	100001	class IV	10001	1001	
	750000	1000000		100000	10000	
	750001	1000001	class V	100001	10001	

Findings of the Survey

Chemical status of the Danube River

The Joint Danube Survey generated results concerning quality status of the water column characteristic for the time period of the Survey particularly in terms of general variables and nutrients. The identification of selected pollutants such as heavy metals, volatile organic hydrocarbons, polar pesticides and pharmaceuticals provided information on direct pollution inputs and helped detect pollution hot-spots. The latter was also supported by GC/MS screening.

Chemical pollution characteristics of the sediment and aquatic organisms usually reflect long time exposure to pollution. In JDS, the analysis of sediment samples was extended to include a wide range of pollutants, while mussels were analysed only for selected pollutants such as heavy metals, polyaromatic and chlorinated hydrocarbons. Some of the specific, EU-WFD priority pollutants were analysed for the first time in the Danube. The GC/MS screening provided additional information on chemical pollution by revealing compounds beyond those originally targeted.

General characteristics

Conductivity measurements in the Danube and its main tributaries demonstrated the salt content of the different water bodies. A significant effect observed in the Upper Danube reach involved the dilution of the Danube water with the Inn which is marked by low salinity. The increasing salt content in the Middle Danube reach was caused by the Tisza and the Sava rivers.

The pH values and dissolved oxygen concentrations in the water varied in accordance with the increased primary productivity and degradation of the organic pollution load. This occurred particularly in the Middle Danube reach. The algal blooming increased both the pH values and the dissolved oxygen concentration, as was discussed earlier under the characterisation of phytoplankton. Downstream from the high primary production section, both the pH value and the dissolved oxygen content of the water significantly decreased, most likely due to the biodegradable organic pollution from the major cities (Budapest and Belgrade) and from the load of natural organic matter (plankton).

In general, the concentration of suspended solids was below 50 mg/l, which was to be expected given the relatively low flow regime. The suspended solids concentration exceeded 150 mg/l in two tributaries (the Siret and the Prut). General characteristics of the bottom sediment included grainsize distribution. Because sediment-associated pollutants were determined in a less-than-63-µm fraction, it was important to demonstrate its percentage in the original sediment sample. According to the measurements, most of the samples contained more than 20% of this fine fraction in the sediment. Therefore, this fraction can be considered as a representative part of the sediment to be analysed for pollutants.

Nutrients

Different forms of nitrogen and phosphorus were measured in water, suspended solids and bottom sediment samples.

Findings of the Survey

Ammoniacal and nitrite-nitrogen concentrations in the water column were slightly increased in the lower part of the Middle Danube reach, following the decreasing trends in the pH value and dissolved oxygen content. The organic nitrogen content of suspended solids was related to the algal bloom. The organic nitrogen content in the bottom sediment was relatively constant along the entire Danube reach. Elevated values were found in the tributaries.

As one moved downstream the River, both ortho-phosphate-P and total-P showed a slight increase in the water along the Danube. In the case of suspended solids, total-P concentration followed the same trend as in the case of the organic nitrogen. However, high concentrations were measured in the Danube samples upstream of its confluence with the Inn, but were significantly lower downstream of the confluence as a result of mixing with the Inn water. In the case of the bottom sediment, total-P concentration showed no variation along the course of the Danube or in the tributaries, except for the Arges tributary.

The dissolved silica content of the water was significantly low along the Middle Danube section, where high algal blooms were observed. This was mainly due to the uptake of silica by the algae, in particular diatoms. Downwards from this section, the dissolved silica concentration increased again most likely originating from the decomposition of the algal and other organic detritus.

Sampling suspended solids

Heavy metals

A variety of elements (aluminium, arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, zinc) was determined in water samples, sediments, suspended solids and mussels of the Danube and some of its tributaries. A strong correlation between the heavy metal content in suspended solids, sediments and mussels indicates the applicability of these matrices for monitoring purposes. Data evaluation was carried out using heavy metal quality targets for sediments and suspended solids. Except for some restricted areas and tributaries, contamination of the Danube by chromium, lead and mercury is rather low. However, some hotspots were detected at the same site as during earlier surveys (e.g. Cousteau survey; Phare AR/105 research study). All other metals showed elevated concentrations in at least one of the investigated matrices, particularly in the lower

stretch of the Danube (downstream of the Sava river confluence).

A serious contamination of the Danube water and several of its tributaries with heavy metals such as copper, nickel and particularly arsenic, was observed. The concentrations of arsenic exceeded the quality target at almost all sampling stations. Tributaries with the highest excess in heavy metal concentrations in water included the Rusenski Lom, the Iskar and the Timok.

In sediments, concentrations of arsenic, cadmium, copper, nickel, zinc and lead (in tributaries only) were found to be above quality targets at more than one-third of the sampling points. A comparison of the heavy metal content

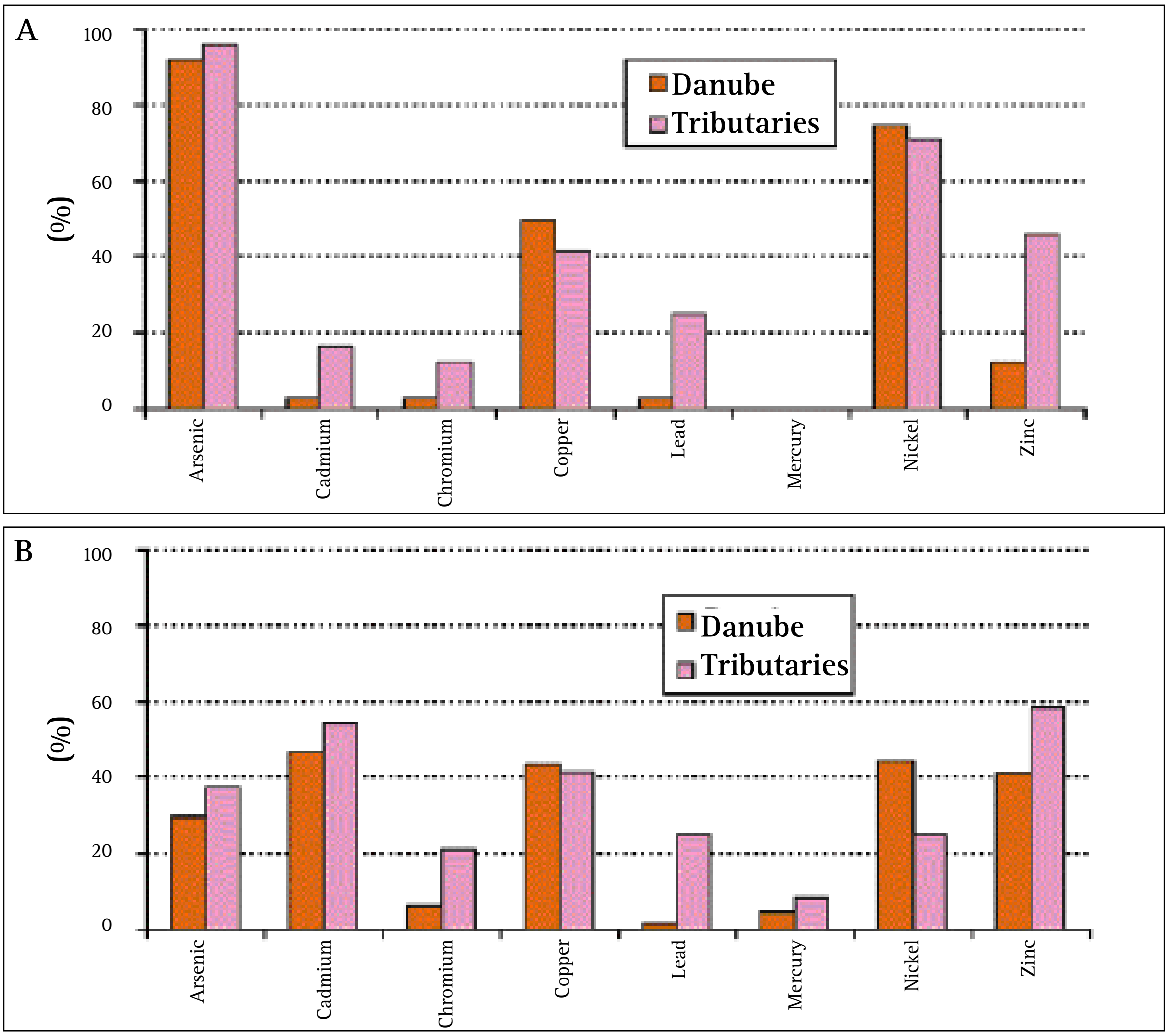


Figure 5: Number of JDS samples (in %) with heavy metal concentrations exceeding quality targets for water (A) and sediments (B)

Findings of the Survey

in sediments and suspended solids shows a similar pollution pattern indicating arsenic, cadmium, copper, nickel and zinc as the elements of highest concern. Based on a comparison with the background concentrations, the Iskar (cadmium, lead and zinc) and the Timok (arsenic and copper) tributaries were identified as specific contamination sources.

Despite a significant decrease in arsenic, chromium, mercury, lead, nickel and zinc in core sediment samples of the Iron Gate, their surface concentrations are still well above quality targets.

Organic pollutants

The presence of organic compounds in water is a direct consequence of natural processes in the environment as well as of various anthropogenic activities in the industrial, agricultural and municipal sectors. While the occurrence of organic compounds of a natural origin, which are part of the nature's life cycle, usually does not pose any remarkable problems to the environment, the presence of organic micropollutants has an adverse impact on the quality of the natural world. To prevent this undesirable phenomenon, the most dangerous substances are covered by legislation. Based on the established quality standard, a number of priority pollutants are regularly monitored in all European river basins. In the frame of the Trans-National Monitoring Network (TNMN) that covers the Danube River Basin, seven organic micropollutants are analysed monthly in water in the selected profiles. Another 15 organic micropollutants are on the TNMN Determinand List for sediments. This limited number of compounds is considered as an absolute minimum necessary to be monitored regularly in the Danube River Basin. To enlarge the information on the organic contamination in the Danube and its tributaries, some additional groups of organic micropollutants were selected as target compounds to be analysed in the Joint Danube Survey samples.

Aggregate characteristics

UV absorbance at 254 nm showed very slight variations in the Danube water. A similar feature was observed in humic substances. Higher values of both parameters were found in the tributaries. The correlation between UV absorbance and humic substances indicated that the major part of the dissolved organic matter was of natural origin.

Total organic carbon (TOC) in suspended solids followed a trend similar to the variation in phytoplankton. High TOC values were measured in the samples containing high algal biomass. In the bottom sediment, higher concentrations were measured in the lower part of the Middle Danube reach as well as upstream of the Inn confluence. This was similar to the profile of total-P.

Total extractable matter (TEM) in suspended solids correlated with the TOC values. In the case of the bottom sediment, the TEM concentration demonstrated an increasing trend as one moved downstream towards the Danube Delta. This was probably caused by the accumulation of hydrophobic organic pollutants, particularly petroleum-related compounds, in the bottom sediment.

Petroleum hydrocarbons

Earlier surveys and monitoring results had

demonstrated significant oil pollution in the Danube River Basin. Therefore, special attention was paid to identifying oil pollutants in water, suspended solids, bottom sediment and in biota samples. The interpretation of the results of the analysis of petroleum-related pollutants is difficult due to the fact that there is no single analytical method available, and each method has its own information content. In JSD, three methods were used for the general characterisation of the total petroleum hydrocarbon contamination: GC/FID, UV absorption and fluorescence. GC/MS method was used to determine one of the most important group of Petroleum hydrocarbons, the polyaromatic hydrocarbons (PAHs).

In water samples, the analysis was carried out with the single fluorescence method, which allowed the type of oil pollution to be characterised. Most of the samples contained mainly light petroleum hydrocarbons (e.g. monoaromatics). However, some samples were highly contaminated with heavier petroleum products.

In the suspended solid and bottom sediment samples, the highest values were found in the Middle Danube reach. This correlates with the results of the earlier studies. The Lower Danube reach was generally more contaminated than the Upper Danube reach.

Concerning PAHs, their concentration levels in the sediment were usually lower than the sediment quality target; 2 mg/kg concentrations were exceeded in 17 samples only and none of the samples reached 20 mg/kg. The sediment core samples varied in terms of their content of the 16 PAH compounds, but they also remained below 2 mg/kg in most of the core samples. The concentration of PAHs in mussels showed an increasing trend as one moved downstream to the Danube Delta. The highest concentrations were measured in mussels collected from tributaries in the Middle Danube reach.

Volatile organic chlorohydrocarbons (VOCs)

In general, the contamination of the Danube and its main tributaries with VOCs is very low. This is important for the waterworks along the Danube because VOCs are relevant in drinking water production. The low VOC concentrations can also be explained by the fact that the samples were taken in the summer, which is characterised by high air and water temperatures. The water quality target values were only exceeded by 1,2-dichloroethane in several sites in Hungary.

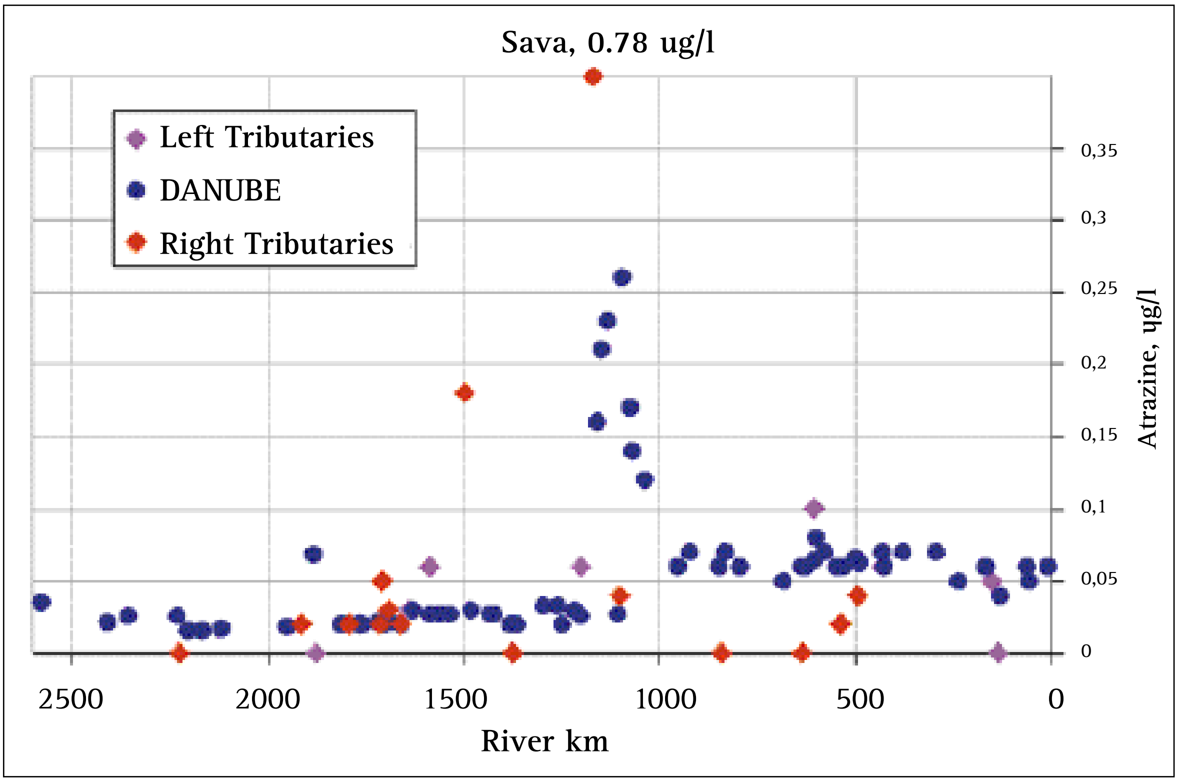


Figure 6: Atrazine concentrations in the Danube and its tributaries

Polar pesticides

Of all 23 pesticides under investigation, only Atrazine and Desethylatrazine could be found along the Danube in the average concentrations of around 0,05 µg/l. It was only in a few samples that the quality target set by the Rhine Commission (0,1 µg/l) was exceeded. The few higher-Atrazine results were mainly found in the tributaries. The maximum value for Atrazine was found in the Sava River (0,78 µg/l) and it affected the Danube River downstream of its confluence with the Sava.

Other WFD priority pollutants

63 suspended matter samples and 187 sediment samples (including 26 core samples) from the Danube River and its major tributaries and arms were analysed for the WFD compounds para-tert-octylphenol, 4-iso-nonylphenol, di[2-ethylhexyl]phthalate, penta-chlorophenol, penta-bromodiphenyl ether and tributyltin. Penta-bromodiphenyl ether and penta-chloro-phenol were not found in the samples under investigation, while tributhyltin was present only in low concentrations. Para-tert.-octylphenol was found only in bottom sediments; significant concentrations of 4-iso-nonylphenol and di[2-ethylhexyl]phthalate were found in bottom sediments as well as in suspended solids (from a few µg/kg up to more than 100 mg/kg), indicating the rele-

vance of these compounds as an indicator of industrial pollution of solid materials in the Danube River. Most of the elevated concentrations of nonylphenol were found in the Yugoslavian section of the Danube. This may be caused by the use of alkylphenol-containing surfactants in this region.
Sediment core samples usually show decreasing concentrations of WFD compounds from old to new sediment layers.

Pharmaceuticals

The samples that originated from the Danube River itself all showed relatively low concentrations of the pharmaceuticals investigated. Diclofenac and Naproxen were present in each sample, Clofibric acid, Ibuprofen, Isopropylphenazone and the metabolite of metamizol were found in almost all samples. The relatively constant "background level" in most of the samples was about one half of that found in the Elbe River in two sampling campaigns in 1999 and 2000. Three tributaries showed significantly higher amounts that can presumably be assigned to wastewater discharges. The impact of contaminant loads in the tributaries on concentrations in the Danube River could not be assessed directly because no samples were taken for the analysis of pharmaceuticals immediately upstream and downstream of the confluence with tributaries. A comparison of the flow data of the tributaries (the Iskar: 13.50 m^3/s; the Jantra: 9.50 m^3/s; the Arges: 9.99 m^3/s) and those of the Danube River (4170 – 4490 m^3/s in that region) shows that, because of the dissolution of the tributaries' load, no significant effect on the concentrations in the Danube can be expected.

GC-MS analysis

A special detection task involved the search for unknown organic compounds, which are not included in the regular monitoring programmes and were not directly searched for during the Survey. By using a state-of-the-art gas chromatographic-mass spectrometric technique, scientists were able to identify 96 organic compounds in the Danube water. The most ubiquitous compounds involved phthalates, fatty acids, aliphatic chlorohydrocarbons and sterols. In addition to these compounds, the following groups were observed: aliphatic and aromatic hydrocarbons, phenols, hydroxy- and keto- aliphates and aromates, benzothiazoles and other sulphur and nitrogen-containing compounds, organophosphates and a limited number of herbicides. The results of the GC/MS screening also confirmed several results of the target analyses.

Mussels in the Danube shore near Paks, Hungary

Conclusions and Lessons Learned

With all its major objectives achieved, the Joint Danube Survey has produced a number of tangible results.

It has produced a reliable and consolidated picture of the Danube and its major tributaries in terms of water quality. For the first time, comparable data about the entire course of the River have been provided on over 140 different parameters: biological and chemical pollutants, aquatic flora and fauna and bacteriological indicators. In addition to ensuring data comparability, JDS - the most comprehensive Danube survey carried out so far - has supplemented the earlier fragmented picture by yielding information on a wider range of water quality parameters. Since in the very selection of the studied parameters Survey planners were guided by the need to comply with the EU Water Framework Directive, the data and information yielded by JDS meet the requirements of the Directive in terms of ecological and chemical surface water status characterisation.

The collected data show the Danube to boast a high degree of biodiversity since more than 1,000 aquatic species and higher-level organisms were identified during the Survey, and specifically:

- 268 macrozoobenthos taxa
- 340 phytobenthos taxa
- 49 macrophyte species
- 261 phytoplankton taxa
- 120 zooplankton taxa

The Danube's biodiversity has increased since the opening of the Main-Danube Canal in 1992 because the removal of the natural bio-geographical barrier that had for millennia separated the Rhine and the Danube has allowed the river fauna to migrate between the two rivers.

The organic pollution (saprobity) of the Danube varied between water quality class II (in the Austrian classification scheme this means moderately polluted) and II/III (critically polluted). Many arms and tributaries were found to be more polluted than the main stream and some of them even reached water quality class III (strongly polluted, e.g. the Sio River). In some tributaries (e.g. the Iskar, Olt and Arges) no macroinvertebrates at all were found – a clear indication of an even higher level of organic pollution.

A high correlation of phytoplankton biomass and chlorophyll-A concentration was observed during the Survey. High concentrations of biomass/chlorophyll-A were found in the Hungarian stretch of the Danube downstream of Budapest, which indicates elevated eutrophication in this reach of the Danube River. The overproduction of biomass can lead to a variety of problems ranging from anoxic waters (through decomposition) to toxic algal blooms, a decrease in biodiversity and habitat destruction. The algal blooming observed during the Survey increased both the pH values and the dissolved oxygen concentration in the Middle Danube reach. Comparing longitudial variations in phytoplankton biomass with the density of zooplankton in the Danube, peak phytoplankton biomass values were found to be followed by maximum values in zooplankton density as one moved down the River. That the decrease in phytoplankton was associated with an increase in zooplankton density is probably due to the filtering effect of zooplankton.

Conclusions and Lessons Learned

The highest values in microbiological pollution were observed in the tributaries (the Russenski Lom, the Arges, the Siret and the Prut in particular) and the side arms (the Moson Arm, the Soroksar Arm).

Specific heavy metal pollution hot-spots were detected. At most sampling stations, the concentrations of arsenic in the Danube River water exceeded the values set by the German quality target. The biggest excesses in terms of heavy metal concentrations in water were observed in the Rusenski Lom, the Iskar and the Timok tributaries. An analysis of sediments revealed elevated levels of cadmium, lead and zinc in the Iskar River and of arsenic and copper in the Timok River, which makes the two tributaries serious contamination sources.

Navigation along the Danube is the main source of oil pollution observed during the Survey. The highest values of petroleum hydrocarbons in sediments and suspended solids were found in the Middle Danube reach.

The maximum value of Atrazine herbicide (0,78 µg/l) was found in the Sava River. It adversely affected the Danube River downstream of its confluence with the Sava.

Significant concentrations of harmful chemical pollutants (4-iso-nonylphenol and di[2-ethylhexyl]phthalate) featuring on the EU Water Framework Directive List of Priority Pollutants, were found in bottom sediments as well as in suspended solids. Their concentration ranged from a few µg/kg up to more than 100 mg/kg. Most of the elevated concentrations of nonylphenol were found in the Yugoslav section of the Danube. This may be caused by the use of alkylphenol-containing detergents in this region. These compounds were monitored in the Danube River for the first time during the Survey.

The Survey provided a framework for harmonising sampling, sample preparation and analytical methods used in different Danube countries - all thanks to the cohesive team-work of the Core Team and their effective cooperation with national scientific teams.

As yet another important benefit, the jointly collected samples analysed on board and in the national laboratories provided a unique opportunity for scientists to compare their results and improve the quality of their analytical work and the monitoring results.

Last but not least, the close contact that JDS researchers established and nurtured during the Survey with country representatives, the media, the local experts and the public, created a forum for raising public awareness about pollution reduction policies and activities in the Danube River Basin.

Lessons learned from the Joint Danube Survey should serve as a basis for future activities. In particular, we have learned that:

- The Danube Trans-National Monitoring network needs to be improved by including the relevant priority pollutants into the set of monitored parameters and by revising the biological monitoring system;

- Sediment quality targets should be established;
m Methodologies for the characterisation of the

Conclusions and Lessons Learned

ecological status, required by the EU-WFD, should be redefined;

- Regular surveys should be organized to obtain comparable data sets over a given time span.

The Danube experts involved in the Survey have agreed that a set of specific publications with more detailed evaluation of data should follow the JDS Report. This should support the general focus of the ICPDR towards the implementation of the EU Water Framework Directive.

In conclusion, a word about cooperation as a critical prerequisite for all joint projects: cooperation is certainly a means to an end rather than an end in itself. However, it is reasonable to expect that the spirit of cooperation generated during the Joint Danube Survey will not remain confined to scientific research but that it will spill over to inspire the Danube countries' further joint activities in combating environmental pollution and preserving natural ecosystems. If this happens, indeed, then the Danube will rise from a passive subject of research to an active agent of change in the region.