FUTURE DEVELOPMENT OF NUTRIENT EMISSIONS AND RIVER LOADS IN THE DANUBE BASIN

J. van Gils, Delft Hydraulics, Delft, NETHERLANDS
H. Behrendt, Institute for Freshwater Ecology and Inland Fisheries, Berlin, GERMANY
A. Constantinescu, Danube Delta National Institute for Research and Development, Tulcea, ROMANIA
K. Isermann, R. Isermann, Bureau of Sustainable Agriculture, Hanhofen GERMANY
M. Zessner, Institute for Water Quality and Waste Management, TU Vienna, AUSTRIA

Abstract: The Danube is the second largest river of Europe, and its catchment covers substantial parts of 13 European countries. The river discharges into the Black Sea, which is a water body extremely sensitive to eutrophication problems. Mismanagement of nutrients in the Danube Basin has led to severe ecological problems, both in the catchment and in the receiving marine waters. In the 1990s, the Danube River nutrient loads have decreased, partly due to the collapse of the central and eastern European economies following 1989. The project "Nutrient Management in the Danube Basin and its Impact on the Black Sea" (EU 5th Framework Programme, acronym *daNUbs*, 2001-2004) aims at developing scientifically sound recommendations for nutrient management in the Danube River Basin. A number of scenarios for the future development of the nutrient emissions and the Danube River nutrient loads play a key role in *daNUbs*. The present paper describes these scenarios and formulates the conclusions towards the future nutrient management. The key conclusions are that there is a substantial risk for the river nutrient loads to increase again up to pre-1989 levels, but that this risk can be mitigated by a sound environmental policy, in which adequate control of point sources is the most important element.

Introduction

The Danube is one of the large rivers flowing into the Black Sea. The catchment has a population of 82 Million, which is 43 % of the total population within the Black Sea basin. The Danube is about 2900 km long, and its catchment of just over 800,000 km^2 covers 33 % of the Black Sea basin. It is the second largest river basin on European territory (after the Volga). Its average discharge of about 6500 m^3/s, contributes about 55% to the freshwater discharge of the Black Sea. The Danube presents an extreme case of a transboundary catchment, covering 18 different states. River basin management is further complicated by the presence of extreme (for European standards) socio-economic gradients in the basin. International co-operation in water management issues dates back to the early 1990s. In 1998 the Danube River Protection Convention (DRPC) became the vehicle for joint river management, with the International Commission for the Protection of the Danube River (ICPDR) as the operational body. All Danube countries have adopted the European Water Framework Directive as the legislative framework for integral water management. The ICPDR is responsible for the international co-ordination of this effort.

Mismanagement of nutrients in the Danube Basin has led to severe ecological problems: the deterioration of groundwater resources and the eutrophication of rivers, lakes and especially the Black Sea (Lancelot et al. 2002 and references therein, van Gils et al. 2004). These problems are directly related to social and economic issues (e.g. drinking water supply, tourism and fishery as impacted sectors; agriculture, nutrition, industry and waste water management as drivers). In order to recommend proper management for protection of the water system in the Danube Basin and the Black Sea, an interdisciplinary analysis of the Danube catchment, the Danube River system and the mixing zone of Danube river in the North-western Black Sea needs to be carried out. This is the key objective of the project "Nutrient Management in the Danube Basin and its Impact on the Black Sea" (EU 5th Framework Programme, acronym *daNUbs*, 2001-2004). The project makes use of an integrated suite of mathematical models, covering a "chain of effects" including the natural and socio-economic features of the basin, the resulting nutrient emissions to the surface waters, in-stream transformation, storage and losses, conveyance of nutrients towards the Danube Delta and the Black Sea and the oceanopgraphical and ecological processes on the North-western shelf of the Black Sea.

The suite of models mentioned above is used to analyse a number of scenarios for the future development of the nutrient issue in the Danube Basin and in the Black Sea. This paper presents and discusses the results from this assessment.

Materials and Methods

General

Figure 1 presents the overall lay-out of the daNUbs research project (*daNUbs*, 2005). The centre part of this figure represents the sequence of mathematical models.

The first step in the quantitative assessment is carried out by the model MONERIS (**MO**delling **N**utrient **E**missions in **RI**ver **S**ystems). The model is based on data regarding the river flow and the water quality as well as on digital maps and extensive statistical information based on geographical information systems (GIS). It uses semi-empirical relations to calculate the yearly averaged nutrient emissions to the surface waters, distributed over different pathways, as well as the in-stream retention in the small scale surface water network. The application to the Danube Basin has been validated on the basis of historical data (Schreiber et al., 2005, Behrendt et al., 2005).

The **D**anube **W**ater **Q**uality **M**odel (DWQM) is based on the advection-diffusion equation, and it was developed and applied to estimate the in-stream nutrient loads and the storage and losses in the Danube River and its main tributaries (*daNUbs*, 2005 Deliverable D5.9). It is based on data regarding the yearly point and diffuse emissions to the surface water from MONERIS as well as on daily hydrological data for different stations in the Danube basin. It disaggregates the yearly averaged fluxes calculated by MONERIS to daily concentrations, and it disaggregates the total nutrients to the different species in the aquatic nutrient cycles. Eventually, it calculates the nutrient fluxes towards the Danube Delta.

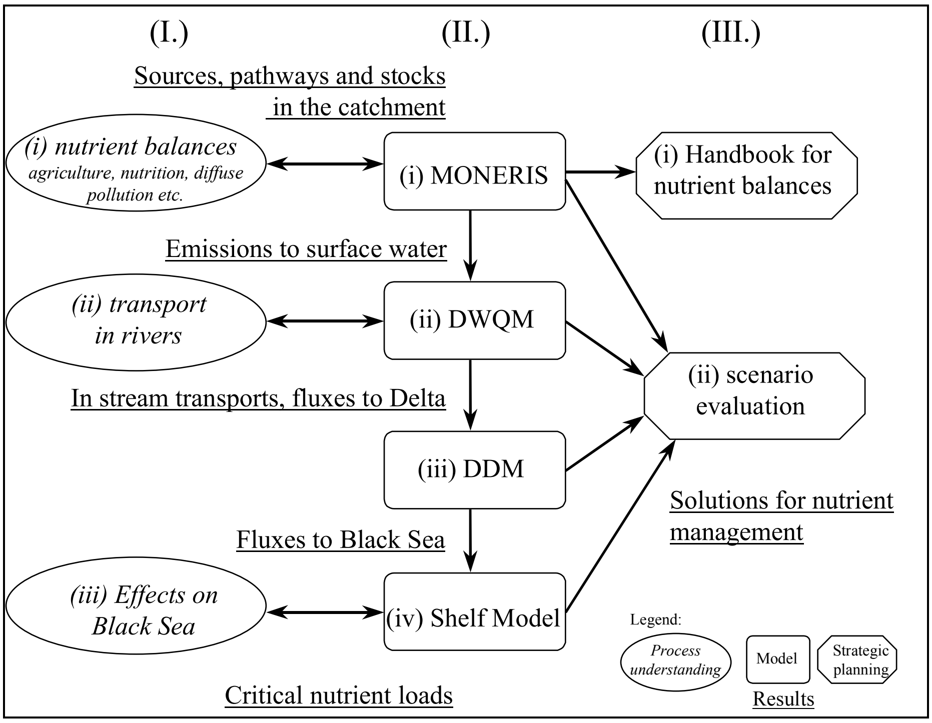

Figure 1: Graphical presentation of research elements of the *daNUbs* project.

The **D**anube **D**elta **M**odel (DDM) is of a similar nature as the DWQM, and has the specific objective to quantify storage and losses of nutrients in the Danube Delta as well as the resulting fluxes towards the Black Sea (Constantinescu & Bakkum, 2002).
Finally the Shelf Model, consisting of a hydrodynamic model and an ecology model, deals with processes and impacts on the North-western shelf of the Black Sea.

Description of scenarios for future development

Five different scenarios have been developed regarding the socio-economic factors controlling nutrient emissions and Danube River loads. They concern the "nutrition system" including agriculture with plant and animal nutrition, human nutrition as well as waste and waste water management. The system consists of 7 actors, being agriculture (producers), feed industry, households (consumers), food industry, waste and waste water management, trade and policy. The developed scenarios feature different degrees of economical, ecological and social sustainability, according to criteria of efficiency, consistency and sufficiency. The scenarios are described in detail by Isermann (*daNUbs,* 2005, Deliverables D3.1, D3.2 and D3.3).

The basic intentions of the scenarios can be summarised as follows. Scenario 1 is the continuation of the present situation in waste water management and agricultural production ("Business as usual scenario"). Changes are only due to an expected change of population in the Danube Basin and long term effects of N retardation in soils and groundwater, which delay the effects of changes in agricultural practice on the emissions to surface waters. Scenario 2 describes a situation with a high agricultural productivity as it was the case in the 1980s in the whole Basin and a development in waste water management according to requirements of the urban waste water directive for normal areas ("worst case scenario"). Scenario 3 describes the same situation with application of best available practice in agriculture and requirements for sensitive areas in waste water treatment ("best available technique scenario"). Scenario 4 describes a situation were reduction measures especially in agriculture are further extended including restriction of animal production based on a minimum requirement to supply the local population with healthy nutrition (0.1 AU/(inh.a)) and far reaching erosion abatement ("sustainability/green scenario"). Scenario 5 describes a situation with an expected development in agriculture and a determination of treatment requirements in waste water treatment based on appropriate ambient water quality protection ("policy scenario"). Scenarios 1 to 3 can be characterised as being not sustainable, while Scenario 4 is considered strongly sustainable and Scenario 5 weakly sustainable.

Modelling nutrient emissions

The emission model MONERIS uses spatially and temporally varying input data regarding the natural system and the human activities in the Danube Basin (Schreiber et al., 2005). This comprises among other factors:

- Soil map
- Meteorological data
- Land use
- Population and degree of urbanisation
- Connection to sewer systems and degree of waste water treatment
- N surplus on agricultural soils
- P accumulation in soils
- Atmospheric deposition

It uses this information to calculate the emissions of N and P to the surface water, by (semi-) empirical formulas. Seven different pathways are distinguished: (1) point sources (waste water treatment plants, industry, and agro-industry), (2) overland flow, (3) ground water flow, (4) tile drainage, (5) erosion, (6) urban systems and (7) atmospheric deposition.

The Danube River basin is represented by a schematisation consisting of 388 sub-catchments of more or less homogeneous characteristics (Figure 2). The average size of these sub-catchments is about 2,000 km^3. The application of MONERIS to the Danube Basin has been validated on historical data (Behrendt et al, 2005).

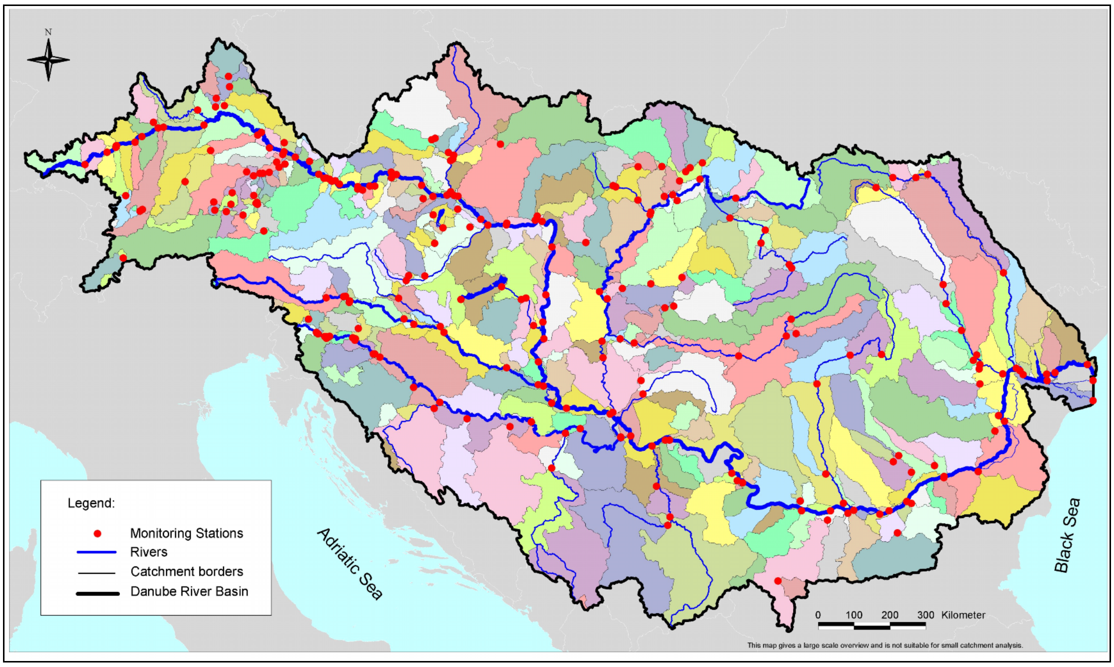

Figure 2: **Overview of the schematisation of the Danube Basin in MONERIS.**

Translation of scenarios to input for numerical emission modelling

In order to quantify effects of different scenarios on the emissions to surface waters and the discharge via Danube River to the Black Sea it is necessary to translate the assumptions into numerical parameters as input for emission modelling. The main input parameters for the MONERIS emission model and for calculation of the nitrogen surplus in agriculture as input parameter into MONERIS, that were varied between the different scenarios are presented in Table 1 as basin wide averages. The different parameters on country level are presented in the Annex. The following describes how different values for parameters in different scenarios were derived.

Population

For the actual situation (2000) data on population and the distinction between urban and rural population form FAO-statistics (FAOSTAT, 2004a) have been taken. The values for scenarios 1-5 are forecasts for 2015 from the same source. For countries which are only partly situated within the Danube Basin, the relations between the urban and rural population and the trends in population development in the Danube Basin have been assumed to be the same as for the total country.

Waste Water Management

The specific P-emissions to the sewers consist of a part from population (1.65 g P/(inh.d)) and a part from industry (1.0 g P/(inh.d)) which have been assumed to be constant for all scenarios except scenario 4, where reduction of specific emissions from these sources by source abatement (industrial production, urine separation) have been assumed. In addition a part of specific P-emissions stems from the use of detergents. For scenario 1 the assumed amount of P in detergents has been kept constant as compared to the actual situation. For scenario 2 the amount of P in detergents in Austria and Germany remains unchanged, but in the rest of the Danubian countries a situation like in the 1980s has been assumed. For scenarios 3 to 5 a reduction of P in detergents to about 0.35 g P/(inh.d) as it is the situation in Austria and Germany has been assumed for all countries. The specific N emissions were not considered as variable.

Table 1: Input parameters to the nutrient emission scenarios, presented as basin averages.

		2000	**Sc 1**	**Sc 2**	**Sc 3**	**Sc 4**	**Sc 5**
Total population (Danube catchment)	M inh.	82.1	77.2	77.2	77.2	77.2	77.2
Urban population (Danube catchment)	M inh.	57.6	54.2	54.2	54.2	54.2	54.2
Rural population (Danube catchment)	M inh.	24.5	23.0	23.0	23.0	23.0	23.0
Specific emissions of P	gP/cap/d	3.6	3.6	4.6	3.0	2.5	3.0
Population connected to sewer systems	%	61	62	80	80	78	80
Population connected to treatment plants	% of total pop.	47	48	80	80	78	80
Pop. conn. to mechanical treatment plants	% of total pop.	6	6	0	0	0	0
Pop. conn. to treatment plants with C removal	% of total pop.	22	21	56	17	17	39
Pop. conn. to treatment plants with N/P removal	% of total pop.	20	21	24	63	61	41
Overall efficiency of N-removal by treatment	% of WWTP flow	49	51	45	70	70	56
Overall efficiency of P-removal by treatment	% of WWTP flow	57	58	52	77	77	63
Surface specific livestock	AU/AA	0.46	0.46	0.72	0.72	0.19	0.51
Per capita livestock	AU/cap	0.24	0.24	0.38	0.38	0.10	0.27
Use of mineral N-fertilisers	kgN/haAA/y	31	31	65	49	22	43
Efficiency of use of N in agriculture *	%	148	148	176	161	150	165
N surplus on agriculture areas	kgN/haAA/y	27	27	58	46	21	39
Reduction of tile drainage	% of area	0	0	0	20	20	10
Development of deposition of NHx	% of 2000 values	100	101	119	100	74	106
Erosion abatement **	% of arable land	0	0	0	50	100	0

* N input (fertiliser, deposition, N-fixation) in relation to N-in harvested crops.

** Minimum tillage, mulch techniques, i.e. mulch seeding; intercropping.

The connections to sewers are assumed to stay constant in scenario 1. In scenarios 2, 3 and 5, as approximation to the requirements from urban waste water directive, it was assumed that the total urban population and 30 % of the rural population are connected to sewer systems unless this percentage is already higher now. No additional connections to waste water treatment plants are assumed in scenario 1. In all the other scenarios the waste water collected in sewer systems is treated biologically as it is required in the EU urban waste water directive. In scenario 2 only carbon removal (including 30 % N and 35 % P removal) is applied unless the treatment level is already higher now. Scenarios 3 and 4 assume N (80 %) and P (87 %) removal in all towns with more than 10,000 inhabitants. In scenario 5 based on results from EU/AR102A/91 (1997) on the dilution capacity of receiving waters in different Danubian countries nutrient removal was assumed for treatment plants discharging to receiving waters with a dilution capacity at low flow of less than 2 m^3/(pe.d) (pe: population equivalent). For other treatment plants, biological treatment with carbon removal only was assumed.

Agriculture

In general for all scenarios it was assumed, that the agricultural area remains unchanged. Production reductions result in reduced intensity of production per area but not in a reduction of the agricultural area under production. As for waste water management scenario 1 is a prolongation of the actual situation. For scenario 2 the same productivity (animal and plant production) and N-efficiency of plant production (N input (fertiliser, deposition, N-fixation) in relation to N in harvested crops) for Austria and Germany as in 2000 and for the other countries in the Danube Catchment as in the end of the 1980s was assumed. Scenario 3 has the same agricultural production, but an increased N-efficiency in plant production based on application of best practice by 10 % in Austria and Germany and 20 % in the other countries as compared to scenario 2. In scenario 4 the animal production is reduced to 0.1 AU/(inh.a).

Crop production is assumed according to the needs for food for the population and fodder for the animal stock. The N-efficiency was assumed to be 150 %, assuming a best available practice on a relative low level the intensity of production. For scenario 5 predicted agricultural production for the year 2015 according to FAOSTAT (2004) was assumed. For the N-efficiency the value was set to 167 % an average value for EU15. The values for mineral fertiliser application and N-surplus were calculated based on these assumptions.

Changes in NH_x emissions to the air can be achieved by better storage and spreading. Further changes in life stock lead to changes in NH_x emissions and consequently NH_x deposition. The variation of the NH_x deposition due to changes of livestock are calculated from the relation between NH_x -deposition (EMEP, 2002) and the animal units for the individual countries within the time periods 1985, 1990, 1995 and 2000. These regressions were used to calculate the NH_x deposition for the numbers of animal units within the scenarios.

For phosphorus it was assumed that the surplus on soil in future anyway will not be that high that it leads to significant changes in the P-content in top soil and thus will not have significant influence on the emissions to surface waters. P-emissions to surface waters from agriculture will mainly be influenced by the level of erosion abatement (use of minimum tillage, mulch techniques like mulch seeding, intercropping). In scenarios 3 and 4 two different levels of application of erosion abatement in the basin have been applied.

Modelling transport and retention, and export to the Black Sea

In order to allow the impact assessment in the surface water, the fate of the emitted nutrients in the surface waters needs to be assessed. Typically, the load of nutrients leaving a catchment through the outflowing river water is significantly smaller than the emissions to the surface water. The surface water is able to remove and/or store a fraction of the emitted nutrients. The research carried out in the *daNUbs* project has demonstrated that this is indeed the case in the Danube River basin, and that most of the retention of nutrients is taking place in the small surface waters which are not explicitly included in the DWQM (*daNUbs* 2005, Deliverable D5.9). For phosphorus, the 200 km backwater area of the Iron Gates dams presents an exception: due to net sedimentation of particulate phosphorus, this area is a "point sink" which stores an estimated 40% of the incoming phosphorus. The retention of nutrients in the small surface waters is calculated by empirical formulas in each of the 388 sub-catchments distinguished by MONERIS. The formulas calculate the loads coming out of the small scale river network, expressed as total N, total P and DIN (Schreiber et al., 2005).

Figure 3: **The schematisation of the Danube River and its main tributaries in the DWQM**

Both the emissions mentioned above and the retention in the smaller surface waters are calculated as constant values for a period of several years (the project works with 5 year periods). The DWQM (Figure 3) operates on much smaller time scales. It calculates the transport and retention of nutrients in the Danube River and its main tributaries on a daily basis, thus allowing a detailed impact assessment in the Danube Delta and the North-western Shelf of the Black Sea. To this end, the DWQM *disaggregates* the 5-year average nutrient loads coming out of the small surface water network on the basis of the day-to-day variation of the river hydrology. The DWQM also *disaggregates* the pools of N and P in a number of species which are related to its detailed representation of the nutrient cycling in the surface waters.

The Danube Delta Model (Figure 4(a)) is an integral application of hydraulic modelling and GIS processing. Like the DWQM, the DDM uses a commercial one-dimensional open-channel dynamic numerical modelling system, capable of solving the equations that describe unsteady water flow and water quality.

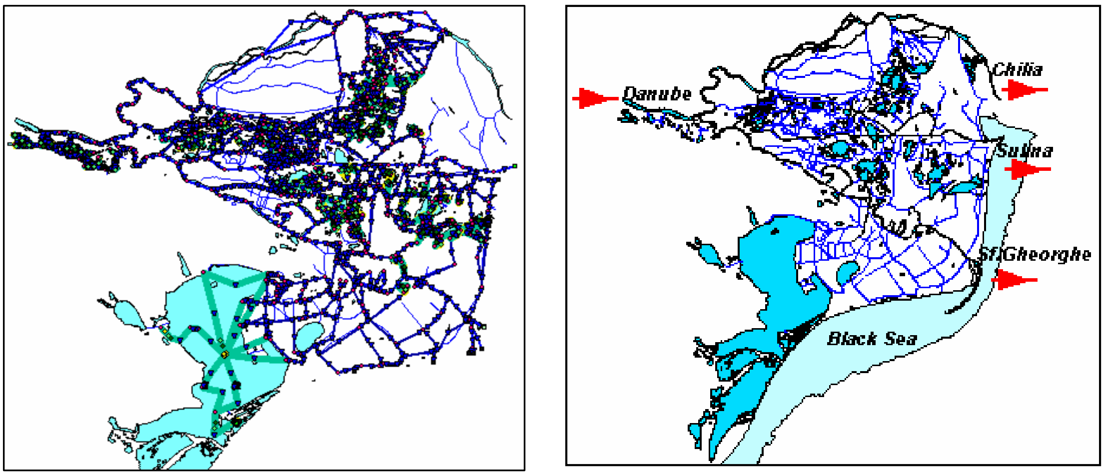

Figure 4: (a)the Danube Delta Model **(b) Outflow to the Black Sea**

The water quality model used by the DWQM and the DDM is suitable to quantify the transformation, storage and loss processes of the nutrients N, P and Si. The DDM is specifically designed to predict the nutrient removal in the aquatic complexes and their transport from the catchments to the Black Sea. The most important nutrient loss process that has been taken into account is the loss of N to the atmosphere by denitrification. Retention of phosphorus is mainly related to storage in the sediments by net sedimentation. To be able to make a distinction in biochemical processes in reed beds (standing and floating reed) and open water bodies these parts are separated in the hydrological model (Figure 5).

Both the DWQM and the DDM distinguish the following state variables: dissolved oxygen, inorganic nutrients (NH_4, NO_3, Si, dissolved and particulate PO_4), dissolved organic N, inorganic suspended matter, algae and detritus (C, N, P, Si).

The DDM has been calibrated using nutrient removal coefficients for each aquatic complex based upon weight factors between open water and reed beds of each of the complexes and depending on a function based upon the water level at Tulcea. Also the model include the meteorological conditions as wind, precipitation and evaporation that play a significant role especially in the dry period and can not be ignored from a hydrological and water quality point of view (Constantinescu & Bakkum, 2002).

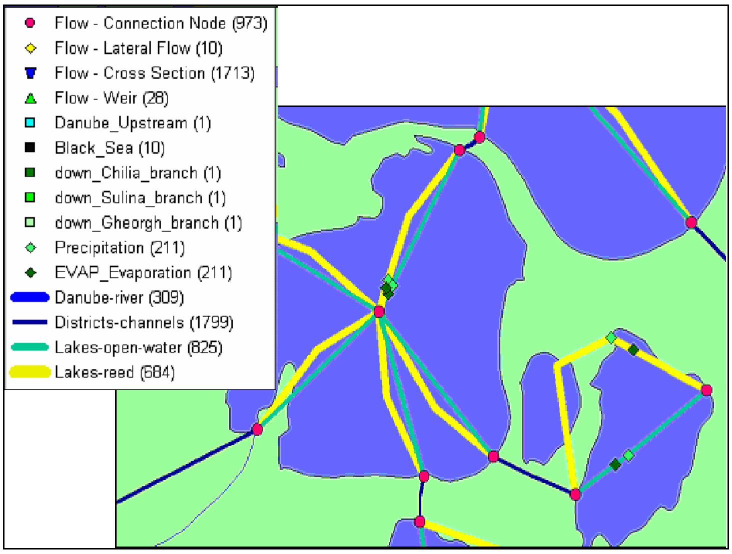

Figure 5: **Modelling principle for reed beds versus open water and evaporation and precipitation.**

Results and Discussion

The results of the analysis will be presented in terms of the emissions to the surface water, in the form of the Danube River loads and in terms of the loads towards the Black Sea (after passage of the Danube Delta).

Nutrients emissions

The calculated nutrient emissions are presented in Figure 6. The figure shows the total emissions of N and P for the scenarios 1 to 5. The total emissions are subdivided over the pathways on one hand, and over the sectors on the other hand.

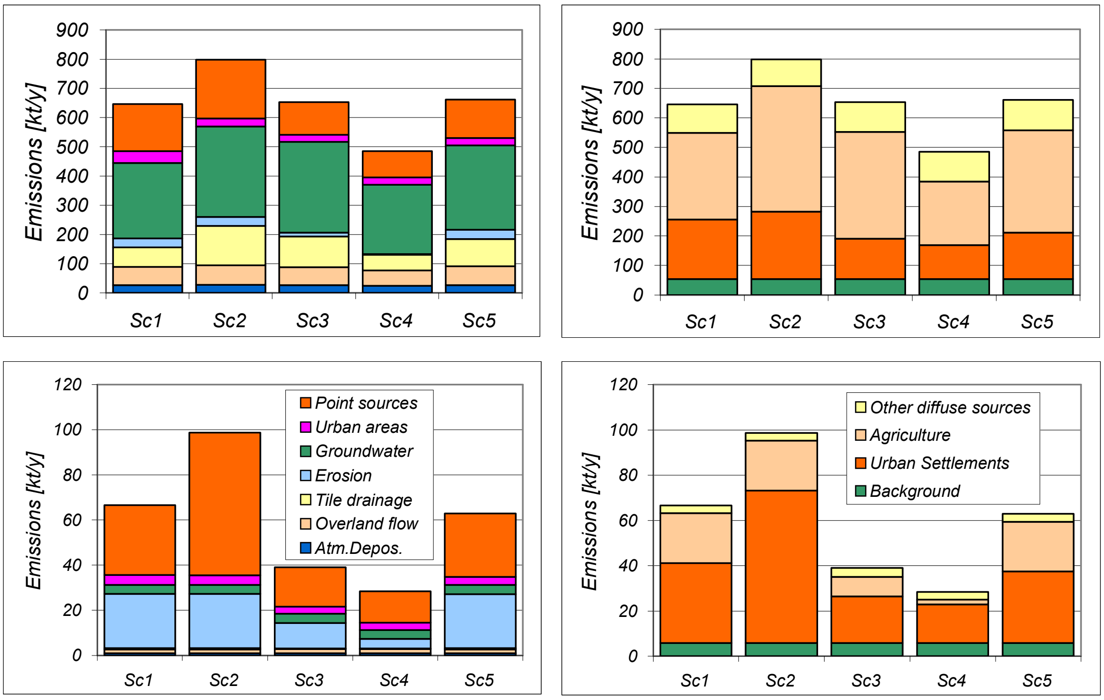

Figure 6: **Calculated emissions of nitrogen (top) and phosphorus (bottom) for the Scenarios 1 to 5, distributed over pathways (left) and over sectors (right).**

The emissions in scenario 2, which includes implementation of the Urban Waste Water Directive for normal areas, are substantially higher than those in scenario 1, especially for P. For P this is the result of the increased emissions from the urban sector only, while for N the agriculture sector and the urban sector are both responsible. Scenario 3 shows a decrease in the emissions from the urban sector, due to the implementation of the Urban Waste Water Directive for sensitive areas. For N, this decrease is still compensated by increasing agriculture emissions despite the implementation of BAP, while for P the agriculture emissions show a decrease as well, due to erosion abatement measures. Scenario 4 is a more extreme variant of scenario 3, including a drastic reduction of agriculture production corresponding to a reduced animal protein intake of the local population (healthy nutrition). Contrary to scenario 3, scenario 4 is sufficient to reduce the N emissions from agriculture to a level below that of scenario 1. Scenario 5 has similar emission levels as scenario 1.

For P, the division over the sectors is similar in both scenarios, while for N an increase in the emissions from agriculture is compensated by a decrease in the urban sector.

Scenario 2 demonstrates that the emissions of N and P may increase in the period up to 2015 to a level that resembles the emissions in the 1980s, if the expected economic development in the middle and lower Danubian countries proceeds without proper environmental control measures. Scenario 5 for phosphorus and scenarios 3 and 5 for nitrogen demonstrate that such control measures can only be realised by proper domestic waste water management.

Transport and retention, export to the Black Sea

River loads towards the Danube Delta

The calculated Danube River nutrient loads upstream of the Danube Delta for the scenarios 1 to 5 are shown by Figure 7. The loads clearly reflect the variation of the emissions between the different scenarios. If we compare the emissions (Figure 6) to the river loads (Figure 7), we can see the effect of retention: about 40% for N and about 70% for P.

The scenario 2 is clearly a *worst case* scenario, with a load of P 40% higher than in the year 2000 and a load of N 15% higher than in the year 2000. This situation strongly resembles the situation before the economic changes in the middle and eastern part of the basin in the late 1980s. The other scenarios show similar or smaller loads than those of today.

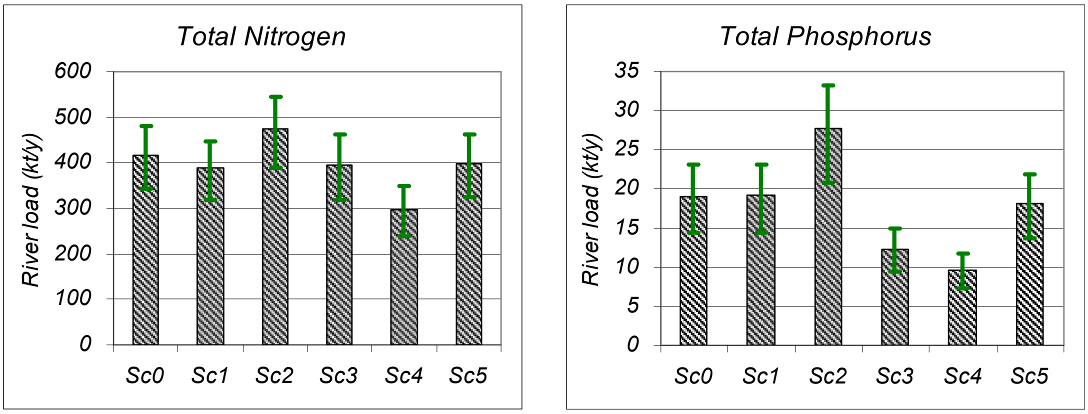

Figure 7: Calculated Danube River loads towards the Danube Delta, for the scenarios 1 to 5. The figures show the variability of the loads, induced by differences in the river hydrology.

Figure 7 also shows the impact on the Danube River loads of differences in the river hydrology as they have been observed in the recent past. A period of relatively low discharges, as observed in 1989-1992, causes lower diffuse emissions and a higher retention capacity of the surface water system. A period of relatively high discharges, as observed in 1998-2000, causes higher diffuse emissions and a lower retention capacity of the surface water system. As a result, the estimated river loads may vary considerably due to these hydrological variations. For N, the hydrology induced variation of the loads is of the same order as the differences between the scenarios. This implies that the year to year loads depend as much on hydrology as on the development of the emissions. For P, the hydrology induced variability of the loads is relatively smaller, but still significant.

Disaggregation: concentrations of nutrient species

The impact assessment for the Black Sea is done by models which operate with atmospheric data of a high spatial and temporal resolution. Such data is only available for 2003. For this reason, the loads calculated by MONERIS have been disaggregated for a period of 4 years including 2003. Figure 8 provides examples. On the left, Figure 8 shows the concentration of total N and total P as a function of time. The concentration of total N shows a clear seasonal variation controlled by the annual temperature variation, with high concentrations in the winter and low concentrations in the summer (this is line with field data).

For total P, the variability is controlled by other factors, such as the river hydrology. The high concentration of total P in 2003 is caused by the extremely low river discharge. On the right, Figure 8 shows the subdivision of phosphorus over the different species. This graph clearly demonstrates the variable ratio between PO4 and particulate/organic phosphorus.

The calculations with the DWQM have resulted in daily time series for the concentrations of all state variables at the entrance to the Danube Delta.

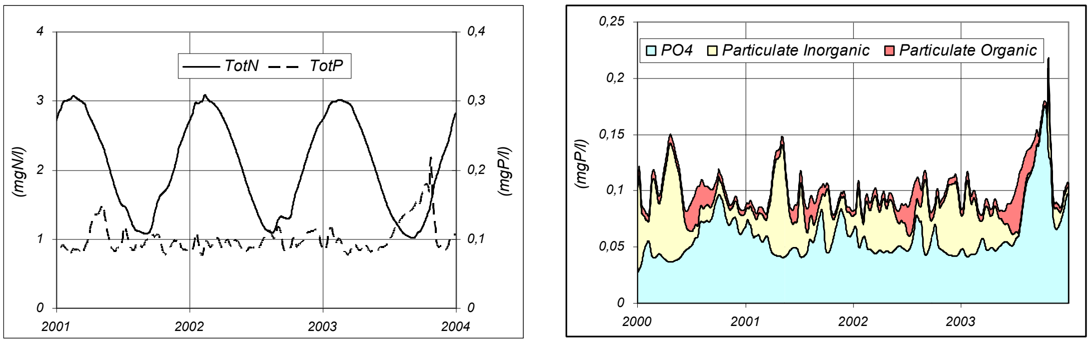

Figure 8: **Examples of the disaggregation over time (left) and over the different nutrient species (right). The examples concern the station Reni, upstream of the Danube Delta.**

Impact of the Danube Delta

The transport of water and nutrients towards the Black Sea proceeds mainly through the main Danube delta branches Chilia, Sulina and Sf.Gheorghe (Figure 4(b)). The water budget shows that the Danube delta aquatic complexes in between these main branches receive on average substantially less than 10% of the discharge upstream of the Danube Delta (Figure 9). The yearly averaged inflow to the Delta aquatic complexes ranges from 3.5% to 4.9% of the Danube discharge over 2000-2003. The daily inflow to the Delta aquatic complexes ranges from less than 1% to about 10% of the Danube discharge, over the same period.

The nutrient balances for the Danube Delta calculated for 2000-2003 are presented in Table 2. The annually averaged retention inside the Danube Delta aquatic complexes in relation to the River Danube load is about 2.3% for N, 2.4% for P and 1.2% for Si. Consequently, the Danube Delta turns out to be of negligible importance for the assessment of the different scenarios. Even if the average impact of the Delta is small, there is considerable variation over the year: the momentaneous impact of the Delta various between 25% retention and 15% remobilisation.

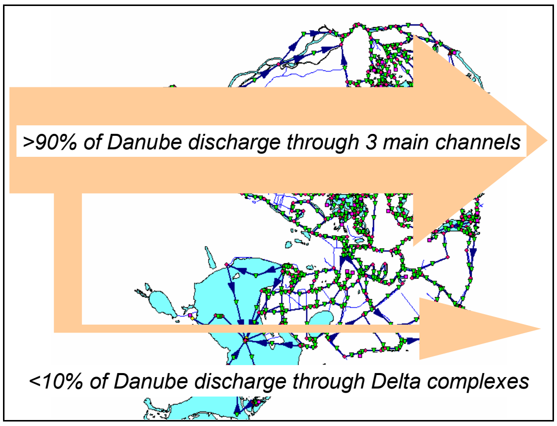

Figure 9: **Water balance of the Danube Delta**

Table 2: Balance of the nutrients in the Danube Delta (simulation 2000-2003)

	Export to the Black Sea			Losses/storage in the Danube Delta		
Year	**Nitrogen**	**Phosphorus**	**Silica**	**Nitrogen**	**Phosphorus**	**Silica**
	(kt/year)	(kt/year)	(kt/year)	(kt/year)	(kt/year)	(kt/year)
2000	483	24	473	13.84	0.62	9.06
2001	455	21	493	10.66	0.53	5.78
2002	501	22	527	12.13	0.59	7.69
2003	374	15	366	6.47	0.28	0.87
average	*453*	*20*	*465*	*10.78*	*0.50*	*5.85*

Conclusions and Recommendations

The scenario analysis demonstrates that a reduction of the river nitrogen load by 7% is “under way” via the delayed response of the ground water emissions to the reduction of the nitrogen surplus on agricultural soils after 1989.

The implementation of the Urban Waste Water Directive without the requirements for additional nutrient removal for sensitive areas will lead to a substantial increase of the point sources emissions of both nitrogen and phosphorus, due to expected increase of people connected to sewer systems. Furthermore, the nitrogen and phosphorus emissions from agriculture are bound to increase in view of the expected economic development in the central and eastern European countries. For nitrogen, the introduction of Best Agricultural Practices will probably not be sufficient to avoid such an increase. A decrease of the nitrogen emissions from agriculture can only be expected if the human nutrition patterns undergo a distinct change, which will allow a substantial reduction of the animal density to about 0.1 Animal Unit per inhabitant per year. This distinct change in nutrition patterns is the only condition that can cause a substantial reduction of the total nitrogen emissions as compared to the present situation. A decrease of the phosphorus emissions from agriculture can also be brought about by erosion abatement measures.

Consequently, there is a substantial risk that the emissions of nitrogen and phosphorus, and therefore the river loads of both nutrients may increase in the period up to 2015 to a level that resembles the emissions in the 1980s, if the expected economic development in the middle and lower Danubian countries proceeds without proper environmental control measures. A drastic change of the human nutrition patterns is one way to avoid this risk, but this is probably not easily realised. Another, probably more feasible way, to do it is by implementing a selective additional nutrient removal at WWTP’s.

The annual river loads of nitrogen and phosphorus are not determined by anthropogenic factors alone; also the river hydrology plays a decisive role. The hydrology induced natural variability of the river loads is of the same order as the differences between the analysed scenarios (which vary the anthropogenic factors). The impact of the river hydrology on the day-to-day variations of the nutrient concentrations is also very strong.

References

Behrendt H., J. van Gils , H. Schreiber and M. Zessner (2005): Point And Diffuse Nutrient Emissions And Loads In The Transboundary Danube River Basin. II. Long term changes. Arch. Hydrobiol. Suppl. Large Rivers, (submitted).

Constantinescu A., Bakkum R. (2002): Danube Delta Hydrological and Water Quality Model, 21st Conference of the Danubian Countries on the Hydrological Forecasting and Hydrological Bases of the Water Management, Bucharest, 2-6 September 2002.

daNUbs (2005): "Nutrient Management in the Danube Basin and its Impact on the Black Sea", Final Report, Institute for Water Qualtiy and Waste Management, Vienna University of Technology, Austria, March 2005.

EMEP (2002): http://www.emep.int/index_data.html

EU/AR102A/91 (1997): Nutrient Balances for Danube Countries – Final Report, Institute for Water Quality and Waste Management, Vienna University of Technology and Department of Water and Wastewater Engineering, Budapest University of Technology in the framework of the Danube Applied Research Programme.

FAOSTAT (2004) Commodity Balances, Livestock and Fish Primary Equivalent, 2004 and Crops Primary Equivalent, 2004 (last updated 30 June 2003) [retrieved 14.7.2004] in IFIP (2004) Socio economic analyses, draft deliverable D9.2 of the project daNUbs, EVK1-CT-2000-00051 by the Energy, Environment and Sustainable Development (EESD) Programme of the 5th EU Framework Programme.

FAOSTAT (2004a): http://faostat.fao.org/faostat/form?collection=Population.LTS&Domain=Population&servlet=1&hasbulk=&version=ext&language=EN.

Lancelot C., J. -M. Martin, N. Panin and Y. Zaitsev (2002): The North-western Black Sea: A Pilot Site to Understand the Complex Interaction Between Human Activities and the Coastal Environment, Estuarine Coastal and Shelf Science, Volume 54, Pages 279-283.

Schreiber, H., Behrendt, H., Constantinescu, L.T., Cvitanic, I. Drumea, D., Jabucar, D., Juran, S., Pataki, B., Snishko, S. & Zessner, M. (2005): Point and diffuse nutrient emissions and loads in the transboundary Danube river basin – a modelling approach. Arch. Hydrobiol. Suppl. Large Rivers, (submitted).

Van Gils, J., Behrendt, H., Constantinescu, A., Lazlo, F. & Popescu, L. (2004): Changes of the nutrient loads of the Danube since the late eighties: An analysis based on long term changes along the whole Danube and ist main tributaries. *Wat. Sci. Tech.*, (in print).

Acknowledgements:

The results presented come from the project "Nutrient Management in the Danube Basin and its Impact on the Black Sea" (daNUbs) supported under contract EVK1-CT-2000-00051 by the Energy, Environment and Sustainable Development (EESD) Programme of the 5th EU Framework Programme. Details on the project can be found on the project homepage: http://danubs.tuwien.ac.at/.

Annex: Input parameters to the nutrient emission scenarios.

The annex below provides country specific data for the emission explaining factors used in the MONERIS application to the Danube Basin. All data listed in Table 1 are included in this annex. The reduction of tile drainage as well as the erosion abatement are not further specified, since these are applied homogeneously over the whole catchment area.

For every variable a representative basin average or basin total is included. In case of an average value, the weighing factor for the averaging procedure is indicated.

Total population (Danube catchment)

Country	2000	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
	M inh.	M inh.	M inh.	M inh.	M inh.	M inh.
Germany	9.72	9.68	9.68	9.68	9.68	9.68
Austria	7.70	7.59	7.59	7.59	7.59	7.59
Czech Republic	2.77	2.64	2.64	2.64	2.64	2.64
Slovak Republic	5.01	5.01	5.01	5.01	5.01	5.01
Hungary	10.94	9.69	9.69	9.69	9.69	9.69
Slovenia	1.74	1.62	1.62	1.62	1.62	1.62
Croatia	3.01	2.77	2.77	2.77	2.77	2.77
Bosnia i Herzegovina	3.14	3.31	3.31	3.31	3.31	3.31
Serbia and Montenegro	9.12	8.84	8.84	8.84	8.84	8.84
Romania	20.84	19.29	19.29	19.29	19.29	19.29
Bulgaria	4.25	3.47	3.47	3.47	3.47	3.47
Moldova	0.89	0.85	0.85	0.85	0.85	0.85
Ukraine	2.95	2.42	2.42	2.42	2.42	2.42
Total	82.09	77.19	77.19	77.19	77.19	77.19

Urban population (Danube catchment)

Country	2000	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
	M inh.	M inh.	M inh.	M inh.	M inh.	M inh.
Germany	8.85	8.82	8.82	8.82	8.82	8.82
Austria	5.75	5.67	5.67	5.67	5.67	5.67
Czech Republic	2.19	2.09	2.09	2.09	2.09	2.09
Slovak Republic	3.35	3.35	3.35	3.35	3.35	3.35
Hungary	8.01	7.09	7.09	7.09	7.09	7.09
Slovenia	0.99	0.92	0.92	0.92	0.92	0.92
Croatia	2.08	1.91	1.91	1.91	1.91	1.91
Bosnia i Herzegovina	1.78	1.88	1.88	1.88	1.88	1.88
Serbia and Montenegro	5.52	5.35	5.35	5.35	5.35	5.35
Romania	13.34	12.35	12.35	12.35	12.35	12.35
Bulgaria	3.10	2.53	2.53	2.53	2.53	2.53
Moldova	0.45	0.43	0.43	0.43	0.43	0.43
Ukraine	2.18	1.79	1.79	1.79	1.79	1.79
Total	57.59	54.18	54.18	54.18	54.18	54.18

Rural population (Danube catchment)

Country	2000	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
	M inh.	M inh.	M inh.	M inh.	M inh.	M inh.
Germany	0.86	0.86	0.86	0.86	0.86	0.86
Austria	1.95	1.92	1.92	1.92	1.92	1.92
Czech Republic	0.58	0.55	0.55	0.55	0.55	0.55
Slovak Republic	1.66	1.66	1.66	1.66	1.66	1.66
Hungary	2.94	2.60	2.60	2.60	2.60	2.60
Slovenia	0.75	0.70	0.70	0.70	0.70	0.70
Croatia	0.93	0.86	0.86	0.86	0.86	0.86
Bosnia i Herzegovina	1.36	1.43	1.43	1.43	1.43	1.43
Serbia and Montenegro	3.60	3.49	3.49	3.49	3.49	3.49
Romania	7.50	6.94	6.94	6.94	6.94	6.94
Bulgaria	1.16	0.94	0.94	0.94	0.94	0.94
Moldova	0.44	0.42	0.42	0.42	0.42	0.42
Ukraine	0.77	0.63	0.63	0.63	0.63	0.63
Total	24.50	23.01	23.01	23.01	23.01	23.01

Specific emissions of P

Country	2000	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
	gP/cap/d	gP/cap/d	gP/cap/d	gP/cap/d	gP/cap/d	gP/cap/d
Germany	2.98	2.98	3.00	3.00	2.50	3.00
Austria	2.95	2.95	3.00	3.00	2.50	3.00
Czech Republic	3.43	3.43	5.12	3.00	2.50	3.00
Slovak Republic	3.13	3.13	5.12	3.00	2.50	3.00
Hungary	3.37	3.37	5.12	3.00	2.50	3.00
Slovenia	3.82	3.82	5.12	3.00	2.50	3.00
Croatia	4.14	4.14	5.12	3.00	2.50	3.00
Bosnia i Herzegovina	5.12	5.12	5.12	3.00	2.50	3.00
Serbia and Montenegro	5.12	5.12	5.12	3.00	2.50	3.00
Romania	2.89	2.89	5.12	3.00	2.50	3.00
Bulgaria	4.85	4.85	5.12	3.00	2.50	3.00
Moldova	4.05	4.05	5.12	3.00	2.50	3.00
Ukraine	4.65	4.65	5.12	3.00	2.50	3.00
Average (total pop.)	3.58	3.57	4.65	3.00	2.50	3.00

Population connected to sewer systems

Country	2000	Scenario 1	Scenario 2	Scenario 3	Scenario 4*	Scenario 5
	%	%	%	%	%	%
Germany	95.0	95.0	95.0	95.0	95.0	95.0
Austria	86.0	86.0	86.0	86.0	86.0	86.0
Czech Republic	74.6	74.6	85.4	85.4	83.3	85.4
Slovak Republic	54.0	54.0	76.8	76.8	73.5	76.8
Hungary	56.8	56.8	81.2	81.2	78.5	81.2
Slovenia	74.2	74.2	74.2	74.2	74.2	74.2
Croatia	43.2	43.2	78.3	78.3	75.2	78.3
Bosnia i Herzegovina	43.5	43.5	69.7	69.7	66.7	69.7
Serbia and Montenegro	56.0	56.0	72.4	72.4	69.2	72.4
Romania	46.0	46.0	74.8	74.8	73.4	74.8
Bulgaria	68.0	68.0	81.0	81.0	78.3	81.0
Moldova	56.0	56.0	65.6	65.6	60.7	65.6
Ukraine	53.0	53.0	81.7	81.7	79.1	81.7
Average (total pop.)	61.5	61.8	79.7	79.7	77.9	79.7

Population connected to treatment plants

Country	2000	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
	% of total pop.	% of total pop.	% of total pop.	% of total pop.	% of total pop.	% of total pop.
Germany	94.3	94.3	95.0	95.0	95.0	95.0
Austria	86.0	86.0	86.0	86.0	86.0	86.0
Czech Republic	64.8	64.8	85.4	85.4	83.3	85.4
Slovak Republic	48.8	48.8	76.8	76.8	73.5	76.8
Hungary	34.8	34.8	81.2	81.2	78.5	81.2
Slovenia	51.2	51.2	74.2	74.2	74.2	74.2
Croatia	35.0	35.0	78.3	78.3	75.2	78.3
Bosnia i Herzegovina	19.2	19.2	69.7	69.7	66.7	69.7
Serbia and Montenegro	44.1	44.1	72.4	72.4	69.2	72.4
Romania	28.1	28.1	74.8	74.8	73.4	74.8
Bulgaria	38.0	38.0	81.0	81.0	78.3	81.0
Moldova	25.2	25.2	65.6	65.6	60.7	65.6
Ukraine	11.8	11.8	81.7	81.7	79.1	81.7
Average (total pop.)	46.8	47.6	79.7	79.7	77.9	79.7

Pop. connected to mechanical treatment plants

Country	2000	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
	% of total pop.	% of total pop.	% of total pop.	% of total pop.	% of total pop.	% of total pop.
Germany	0.9	0.9	0.0	0.0	0.0	0.0
Austria	1.0	1.0	0.0	0.0	0.0	0.0
Czech Republic	0.7	0.7	0.0	0.0	0.0	0.0
Slovak Republic	2.4	2.4	0.0	0.0	0.0	0.0
Hungary	3.9	3.9	0.0	0.0	0.0	0.0
Slovenia	2.0	2.0	0.0	0.0	0.0	0.0
Croatia	21.0	21.0	0.0	0.0	0.0	0.0
Bosnia i Herzegovina	18.2	18.2	0.0	0.0	0.0	0.0
Serbia and Montenegro	13.7	13.7	0.0	0.0	0.0	0.0
Romania	4.5	4.5	0.0	0.0	0.0	0.0
Bulgaria	12.2	12.2	0.0	0.0	0.0	0.0
Moldova	0.0	0.0	0.0	0.0	0.0	0.0
Ukraine	1.4	1.4	0.0	0.0	0.0	0.0
Average (total pop.)	5.8	5.7	0.0	0.0	0.0	0.0

Pop. connected to biol. treatment plants with C removal

Country	2000	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
	% of total pop.	% of total pop.	% of total pop.	% of total pop.	% of total pop.	% of total pop.
Germany	7.2	7.2	8.2	8.2	8.2	8.2
Austria	17.8	17.8	7.7	7.7	7.7	7.7
Czech Republic	32.3	32.3	43.5	32.7	31.9	17.1
Slovak Republic	22.4	22.4	39.2	17.7	16.9	53.8
Hungary	26.8	26.8	71.5	17.3	16.7	65.0
Slovenia	49.1	49.1	74.2	29.8	29.8	59.3
Croatia	14.0	14.0	78.3	31.4	30.2	54.8
Bosnia i Herzegovina	1.0	1.0	69.7	13.9	13.3	41.8
Serbia and Montenegro	30.4	30.4	72.4	21.6	20.7	43.4
Romania	23.6	23.6	74.8	15.0	14.7	44.9
Bulgaria	25.8	25.8	81.0	17.2	16.6	40.5
Moldova	25.2	25.2	65.6	23.7	21.9	39.4
Ukraine	10.4	10.4	81.7	43.8	42.4	49.0
Average (total pop.)	21.5	21.3	56.1	17.2	16.7	39.0

Pop. connected to biol. treatment plants with N/P removal

Country	2000	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
	% of total pop.	% of total pop.	% of total pop.	% of total pop.	% of total pop.	% of total pop.
Germany	86.1	86.1	86.8	86.8	86.8	86.8
Austria	67.1	67.1	78.3	78.3	78.3	78.3
Czech Republic	31.8	31.8	41.8	52.7	51.4	68.3
Slovak Republic	23.9	23.9	37.6	59.2	56.6	23.0
Hungary	4.2	4.2	9.7	63.9	61.8	16.2
Slovenia	0.0	0.0	0.0	44.3	44.3	14.8
Croatia	0.0	0.0	0.0	46.9	45.0	23.5
Bosnia i Herzegovina	0.0	0.0	0.0	55.8	53.4	27.9
Serbia and Montenegro	0.0	0.0	0.0	50.7	48.5	29.0
Romania	0.0	0.0	0.0	59.8	58.7	29.9
Bulgaria	0.0	0.0	0.0	63.8	61.6	40.5
Moldova	0.0	0.0	0.0	41.9	38.8	26.2
Ukraine	0.0	0.0	0.0	37.9	36.6	32.7
Average (total pop.)	19.6	20.6	23.7	62.5	61.2	40.7

Overall efficiency of N-removal by treatment

Country	2000	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
	% of inflow to WWTP	% of inflow to WWTP	% of inflow to WWTP	% of inflow to WWTP	% of inflow to WWTP	% of inflow to WWTP
Germany	78.7	78.7	78.7	78.7	78.7	78.7
Austria	65.1	75.0	75.0	75.0	75.0	75.0
Czech Republic	54.3	54.3	54.5	60.8	60.8	70.0
Slovak Republic	53.5	53.5	54.5	68.5	68.5	45.0
Hungary	33.8	33.8	36.0	69.3	69.3	40.0
Slovenia	29.2	29.2	30.0	59.9	59.9	40.0
Croatia	18.0	18.0	30.0	59.9	59.9	45.0
Bosnia i Herzegovina	11.0	11.0	30.0	70.0	70.0	50.0
Serbia and Montenegro	23.8	23.8	30.0	65.1	65.1	50.0
Romania	26.8	26.8	30.0	70.0	70.0	50.0
Bulgaria	23.6	23.6	30.0	69.4	69.4	55.0
Moldova	30.0	30.0	30.0	61.9	61.9	50.0
Ukraine	27.6	27.6	30.0	53.2	53.2	50.0
Average (pop. sewer)	48.6	51.1	45.2	69.6	69.7	55.9

Overall efficiency of P-removal by treatment

Country	2000	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
	% of inflow to WWTP	% of inflow to WWTP	% of inflow to WWTP	% of inflow to WWTP	% of inflow to WWTP	% of inflow to WWTP
Germany	89.5	89.5	89.5	89.5	89.5	89.5
Austria	83.1	83.1	83.1	83.1	83.1	83.1
Czech Republic	60.3	60.3	60.5	67.1	67.1	76.6
Slovak Republic	59.5	59.5	60.5	75.0	75.0	50.6
Hungary	39.0	39.0	41.2	75.9	75.9	45.4
Slovenia	34.2	34.2	35.0	66.1	66.1	45.4
Croatia	23.0	23.0	35.0	66.1	66.1	50.6
Bosnia i Herzegovina	16.0	16.0	35.0	76.6	76.6	55.8
Serbia and Montenegro	28.8	28.8	35.0	71.5	71.5	55.8
Romania	31.8	31.8	35.0	76.6	76.6	55.8
Bulgaria	28.6	28.6	35.0	76.0	76.0	61.0
Moldova	35.0	35.0	35.0	68.2	68.2	55.8
Ukraine	32.6	32.6	35.0	59.1	59.1	55.8
Average (pop. sewer)	57.3	58.2	51.6	76.9	77.0	62.7

Development of deposition of NHx

Country	2000	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
	% of 2000 values	% of 2000 values	% of 2000 values	% of 2000 values	% of 2000 values	% of 2000 values
Germany	100.0	100.0	100.0	79.5	53.4	97.4
Austria	100.0	100.0	100.0	83.2	59.3	107.2
Czech Republic	100.0	100.0	130.9	106.9	71.2	100.3
Slovak Republic	100.0	100.0	128.9	107.7	77.9	101.5
Hungary	100.0	101.0	122.6	105.2	81.5	110.4
Slovenia	100.0	74.0	102.8	82.3	55.0	105.8
Croatia	100.0	132.0	114.6	101.1	84.9	104.5
Bosnia i Herzegovina	100.0	120.0	118.9	103.4	85.2	124.3
Serbia and Montenegro	100.0	83.3	122.4	102.5	72.1	106.4
Romania	100.0	100.0	129.3	107.8	73.7	100.2
Bulgaria	100.0	100.0	131.8	113.2	85.0	103.0
Moldova	100.0	104.1	127.9	110.0	85.3	111.1
Ukraine	100.0	96.0	119.7	102.3	74.2	102.8
Average (no weights)	100.0	100.8	119.2	100.4	73.7	105.7

Weighing factors for agriculture data

Country	Country population	Agriculture area
	1000 inh.	1000 ha
Germany	22681	2593
Austria	8102	3416
Czech Republic	10269	1177
Slovak Republic	5391	2353
Hungary	10012	6186
Slovenia	1990	405
Croatia	4446	1708
Bosnia i Herzegovina	3977	1369
Serbia and Montenegro	10555	5369
Romania	22480	13662
Bulgaria	8099	3093
Moldova	4283	953
Ukraine	49688	2435
Total	161973	44721

Per capita livestock

Country	2000	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
	AU/cap	AU/cap	AU/cap	AU/cap	AU/cap	AU/cap
Germany	0.28	0.28	0.28	0.28	0.10	0.27
Austria	0.35	0.35	0.35	0.35	0.10	0.40
Czech Republic	0.22	0.22	0.41	0.41	0.10	0.22
Slovak Republic	0.18	0.18	0.35	0.35	0.10	0.19
Hungary	0.18	0.18	0.32	0.32	0.10	0.24
Slovenia	0.28	0.29	0.30	0.30	0.10	0.31
Croatia	0.16	0.16	0.25	0.25	0.10	0.19
Bosnia i Herzegovina	0.14	0.14	0.24	0.24	0.10	0.27
Serbia and Montenegro	0.26	0.26	0.43	0.43	0.10	0.31
Romania	0.27	0.27	0.49	0.49	0.10	0.27
Bulgaria	0.18	0.18	0.41	0.41	0.10	0.20
Moldova	0.18	0.18	0.33	0.33	0.10	0.22
Ukraine	0.29	0.29	0.53	0.53	0.10	0.35
Average (population)	0.24	0.24	0.38	0.38	0.10	0.27

Surface specific livestock

Country	2000	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
	AU/AA	AU/AA	AU/AA	AU/AA	AU/AA	AU/AA
Germany	1.29	1.29	1.29	1.29	0.47	1.24
Austria	0.80	0.80	0.80	0.80	0.23	0.92
Czech Republic	0.53	0.53	0.98	0.98	0.24	0.53
Slovak Republic	0.40	0.40	0.78	0.78	0.22	0.42
Hungary	0.29	0.29	0.52	0.52	0.16	0.39
Slovenia	1.13	1.14	1.19	1.19	0.40	1.23
Croatia	0.26	0.26	0.41	0.41	0.16	0.30
Bosnia i Herzegovina	0.31	0.31	0.52	0.52	0.21	0.58
Serbia and Montenegro	0.45	0.45	0.73	0.73	0.17	0.53
Romania	0.41	0.41	0.75	0.75	0.15	0.41
Bulgaria	0.23	0.23	0.54	0.54	0.13	0.26
Moldova	0.30	0.30	0.55	0.55	0.17	0.37
Ukraine	0.34	0.34	0.63	0.63	0.12	0.42
Average (AA)	0.46	0.46	0.72	0.72	0.19	0.51

Use of mineral N-fertilisers

Country	2000	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
	kgN/haAA/y	kgN/haAA/y	kgN/haAA/y	kgN/haAA/y	kgN/haAA/y	kgN/haAA/y
Germany	117.06	117.06	117.06	102.15	64.22	112.00
Austria	35.00	35.00	35.00	19.43	28.19	50.86
Czech Republic	51.12	51.12	86.31	70.45	35.38	44.81
Slovak Republic	29.79	29.79	59.24	52.00	45.29	46.41
Hungary	44.04	44.04	82.70	67.73	16.59	61.24
Slovenia	69.00	69.00	77.12	52.65	80.93	53.78
Croatia	37.89	37.89	58.14	45.54	15.56	30.42
Bosnia i Herzegovina	14.20	14.20	40.91	29.15	26.89	28.48
Serbia and Montenegro	23.65	23.65	91.89	71.95	13.54	50.44
Romania	16.90	16.90	48.29	29.63	17.30	28.64
Bulgaria	19.82	19.82	77.15	62.79	7.69	20.56
Moldova	23.47	23.47	54.20	40.39	22.97	41.18
Ukraine	8.81	8.81	36.11	23.66	15.45	13.81
Average (AA)	31.33	31.33	64.70	48.66	22.41	42.85

Efficiency of use of N in agriculture

Country	2000	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
	%	%	%	%	%	%
Germany	155	155	154	150	150	165
Austria	167	167	167	152	152	165
Czech Republic	166	166	204	185	150	165
Slovak Republic	147	147	204	185	150	165
Hungary	136	136	176	160	150	165
Slovenia	185	185	178	162	154	165
Croatia	184	189	178	162	157	165
Bosnia i Herzegovina	157	160	178	162	150	165
Serbia and Montenegro	123	121	178	162	150	165
Romania	150	150	175	160	150	165
Bulgaria	144	144	170	155	150	165
Moldova	148	148	177	161	150	165
Ukraine	142	142	177	161	150	165
Average (AA)	148	148	176	161	150	165

N surplus on agriculture areas

Country	2000	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
	kgN/haAA/y	kgN/haAA/y	kgN/haAA/y	kgN/haAA/y	kgN/haAA/y	kgN/haAA/y
Germany	81.6	81.6	80.9	74.4	43.4	87.4
Austria	43.6	43.6	43.4	33.6	23.4	52.1
Czech Republic	47.4	47.4	97.3	79.9	30.1	44.9
Slovak Republic	26.5	26.5	75.0	61.7	31.3	39.8
Hungary	22.5	22.6	61.7	48.7	18.8	43.6
Slovenia	73.9	73.3	75.7	60.0	48.1	60.2
Croatia	34.1	35.9	46.2	36.6	18.8	27.7
Bosnia i Herzegovina	17.5	18.4	38.9	30.9	22.2	31.6
Serbia and Montenegro	13.3	12.4	69.9	55.4	16.7	41.1
Romania	22.8	22.8	52.1	41.1	19.3	31.5
Bulgaria	15.5	15.5	54.4	42.4	11.9	21.2
Moldova	20.0	20.0	47.6	37.7	18.9	33.4
Ukraine	13.4	13.4	39.6	31.3	14.1	22.0
Average (AA)	27.1	27.1	57.9	46.5	21.1	38.9