Strategic and economic aspects of municipal wastewater treatment in the Danube Basin

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Abstract: Aspects of municipal wastewater management in the Danube Basin are discussed with particular focus to the needs of Central and Eastern European transition countries of much lower infrastructure and economic development than Germany and Austria. The present situation of infrastructure development and nutrient emissions are discussed, which cover countries, point- and non-point sources, retentions and loads carried by the Danube to the Black Sea. Removal rates and costs of seven state-of-the-art technologies are outlined which are one of the important tools of nutrient emission reduction in the Basin. Development needs are evaluated under the assumption of approaching infrastructure levels of Germany and Austria, and nutrient emission reduction goals of the North-East Black Sea. Capital and annualized costs are estimated and the issue of affordability is addressed by analyzing different strategies and conditions of financing. Two indicators are used: total annual cost per GDP and head specific total annual cost related to the net household expenditure. The second one can be critically high which under the present modest economic growth can be balanced primarily by the increase of the implementation period of investments. The paper is completed by Hungarian strategic experiences of the past fifteen years in wastewater management, implementation and financing.

Keywords: Affordability; Black Sea; Danube; economic aspects; municipal wastewater treatment; nutrient emissions.

INTRODUCTION

Municipal wastewater treatment issues are handled in the developed world with detailed legislation and advanced methodologies of design, operation, economic evaluation, environmental and public health assessments, and others. Large numbers of technological alternatives are available depending on the combination of physical, chemical, aerobic and anaerobic biological (ASM and biofilm), membrane and other processes. Also, increasing number of changing and sometimes conflicting concepts such as sustainability, prevention, precaution, equity, ethics, cost-effectiveness etc. are accounted for which lead to new evaluation methods (ecological footprint, life cycle assessment, various multi-criteria evaluations and others). Thus, why are we addressing aspects of municipal wastewater treatment in the Danube Basin?

Interrelated reasons are many-fold. First, the Danube Basin (about 820 000 km²) including thirteen countries¹ (minor portions of five other countries also belong to the watershed) is probably the most international river basin of the World where more than 82 million people live (Fig. 1). It is a huge area where transboundary pollution management is crucial. Oxygen depletion and high ammonia levels often occur in smaller tributaries and nitrate contamination of groundwater is also a major issue. The quality of the main Danube is acceptable, but nutrient levels are high and signs of eutrophication are apparent. Nutrient loads and their consequences are recognized as one of the most severe problems of the river Danube catchment area, the Danube Delta and the Black Sea. In other words, local water quality problems and regional eutrophication should be handled simultaneously, a difficult and somewhat conflicting issue which calls for a basin-wide nutrient emission reduction programme (similarly to the Baltic Sea).

¹ Before the separation of Serbia and Montenegro.
Second, such specific strategy is not yet available. Its legal framework is defined by three elements. (i) the Danube River Protection Convention (DRPC) being an instrument of transboundary management and collaboration. Its executive agency is the International Commission for the Protection of the Danube River (ICPDR). (ii) The new unified water policy of the European Union, the Water Framework Directive\(^2\) (WFD) approved in 2000 which builds on already existing so-called daughter directives (related to drinking water quality, integrated pollution prevention and control, and others), which - contrasted to the past - lay equal emphasis on water bodies, small and large alike. Many of the Danubian countries implement now the EU WFD. (iii) The urban wastewater treatment daughter directive\(^3\) (UWWD).

Third, the basin incorporates a large number of significantly different countries in terms of water infrastructure, economic and social developments. Germany and Austria are highly advanced countries of the EU-15. The next cluster is formed by earlier and present accession countries of the EU (the Czech Republic, Slovakia, Hungary and Slovenia, Romania, Bulgaria and Croatia). Finally, Bosnia-Herzegovina, Serbia and Montenegro (separated in 2007), Moldova and Ukraine belong to the non-accession country group. To the last two clusters countries of various transition levels belong.

Fourth, our interest here is the “downstream” transition region where huge infrastructure developments are anticipated in the future. A number of important questions should be addressed. What are the cost implications? Are they affordable? How to realize financing? What is the time span of the implementation, not forgetting that developed countries spent 30-40 years to reach the present high level of service? In relation to these questions the literature offers rather contradicting conclusions. For instance, the final report of the large EU 5 R+D study, daNUbs (Nutrient Management in the Danube Basin and its Impact on the Black Sea, Kroiss, 2005) recommends on an affordability basis to start immediately with the application of sensitive area requirements with nutrient removal in treatment plants in the Basin with more than 10 000 PE. In a strong contrast a UNDP/GEF study states that “a comprehensive programme for installation on new wastewater collection systems and technically advanced treatment systems from own resources or commercial loans is not reasonable near term strategy for most municipal water and wastewater utilities even when coupled with an aggressive programme of tariff and effluent charge reform” (Morris and Kis, 2004).

And finally, how to combine local and regional water quality goals or in a different formulation, national and regional strategies? How should riparian countries enhance collaboration in nutrient and wastewater management? How to improve knowledge transfer (i) between the two country clusters and (ii) within the transition region? How to utilize good experiences and to avoid failures already recognized? The objective of the present paper is to discuss some of the above questions, on the basis of the literature and own experiences.

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\(^2\) The EU WFD is based on sustainability, integration, subsidiarity and cost recovery. The basic unit of the EU WFD is the river basin, “the area of land from which all surface runoff flows through a sequence of streams, rivers and possibly lakes into the sea at a single river mouth, estuary or delta.” Thus, the whole Danube catchment forms a basin. The principal goal of the EU WFD is to ensure the “good status” of waters (for surface waters, status refers to the worst ecological and chemical quality, where the first depends on biological quality, hydrology, morphology, physical, and general chemical elements and others). Major tool of the implementation of the EU WFD is the river basin management plan defining programmes of measures. The concept of the DRPC is identical to that of the EU WFD.

\(^3\) Which applies for settlements above 2000 PE and distinguishes normal and sensitive areas (to be identified by individual countries which should be protected from nutrients due to eutrophication or water supply reasons). For sensitive areas the requirements are as follows: 2 mgP/l and 15 mgN/l for the 10 000-100 000 PE range, and 1 mgP/l and 10 mgN/l above 100 000 PE (and at least 80 % and 70 % - 80 % P and N removal rate, resp. for the two clusters). Below 2000 PE regulation should be specified solely on the national level.
WASTEWATER MANAGEMENT AND NUTRIENT EMISSIONS TODAY
Fig. 2 demonstrates the present level of sewerage and wastewater treatment in riparian countries⁴ so that the contribution of various technologies (mechanical, biological and biological with nutrient removal) is also illustrated (van Gils et al., 2005). We see an unbalanced infrastructure development in transition countries: average level of public water supply (not shown) is about 70 %, the connection to the sewer network is 53 %, while treatment is only 34 %. Sanitation service is extremely poor which leads to pollution of surface and subsurface waters and public health risks. About 20 % of wastewaters collected is discharged into surface waters without any treatment (sludge management is even further neglected). Service level is gradually decreasing from upstream to downstream in the Basin. Sewage treatment is below 30 % in some of the countries and downstream to Hungary nutrient removal is absent. Reconstruction needs are high everywhere. From the figure it is evident that development needs are huge, which include rural areas where 34 % of the transition region’s population lives (in five countries the ratio is close to 40 %, see Fig. 1) and service level is often below 5 % - 10 % (GWP, 2000).

As noted, wastewater management in the Danube Basin has also strong nutrient management implications. On the basis of two comprehensive European R+D studies completed in the course of the past decade (Somlyódy et al, 1999 and Kroiss, 2005) and other studies (see e.g. Somlyódy, 2002) we have a significantly improved knowledge on nutrient emissions and pathways, on nutrient impacts on receiving waters and ecosystems including the North-Western Black Sea, and on management strategies.

⁴ Countries approximately follow an upstream-downstream sequence as used by the literature.
Fig. 3 demonstrates P emissions of countries (1998-2000 average) on the basis of the daNuBs study (Kroiss, 2005). A number of additional information is also presented: point and non-point source\(^5\) contribution, non-controllable natural background emission and finally “immission” loads carried by the Danube which reach the Black Sea (Schreiber et al, 2003, Behrendt et al, 2004, Kroiss, 2005). Emissions were estimated by using the empirical MONERIS model (Behrendt et al, 2004). N and P retention due to denitrification, adsorption, sedimentation \textit{etc.} by small rivers and lakes, as well as the main river and larger tributaries were calculated by MONERIS and the Danube Water Quality Model\(^6\) (van Gils et al, 2005).

From the figure it can be seen that (i) on the Danube Basin level point sources form 35 \% and 20 \% of the total P and N emissions, resp., thus they are important elements of nutrient control, (ii) relatively small portions, 9 \% and 24 \% of P and N emissions, resp. are of non-controllable background origin, (iii) retention is high for P: only 34 \% of all emissions reach the Black Sea, while the same ratio is 62 \% for N, (iv) countries exhibit a large variability in terms of their emissions which depends on country size, level of wastewater management, land use and agricultural pattern, and many other factors.

From the viewpoint of regional emission reduction strategy at least three factors play distinct roles. First, retention coefficients is mentioned which can be estimated with large uncertainty, only. Low retention of a sub-basin or a country (high transfer coefficient) means that the actions planned would have large impacts on the Black Sea. High specific runoff

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\(^5\) Which is largely of agricultural origin.

\(^6\) Country load data are not expressing the present 20 \% - 30 \% P retention of the Iron Gate.
(or hydraulic load) leads to such situations (e.g. in Germany, Austria and Slovenia, while Hungary is characterized by high retention). Also, retention is small in the Danube7 and its large tributaries, and high in smaller streams (Schreiber et al., 2003). Second, the limiting principle is referred to, in which respect views are not completely clear. In the Danube Delta and some areas of the North-Western Black Sea P is considered as the limiting nutrient, while in off-shore waters mainly N, with the overall statement that P is probably more important (Kroiss, 2005). Exact target levels for the Danube load to the Black Sea have not yet been set. However, it is important to note that since the early nineties there has been a significant load reduction (to the level of the seventies) which led to positive ecosystem changes. Thus, the conclusion is that any increase must be avoided and further reductions to the level of the sixties should be preferably achieved (P and N emission levels were around 50 kt/a and 450 kt/a, resp. while the P and N loads of the Danube were approximately 20 kt/a and 250 kt/a, resp., Behrendt et al., 2004, Kroiss, 2005).

**COST OF WASTEWATER MANAGEMENT**

Costs and cost-effectiveness are crucial elements of wastewater related decisions. On the design level, obviously detailed estimates are derived by knowing the raw wastewater composition, effluent criteria, processes to be employed and local conditions. On the level of regional planning and scenario assessment, average cost figures of state-of-the-art technologies are used. In the course of the past fifteen years the literature produced a large number of such estimates where the motivation came from development needs of the CEE region (Henze and Odegaard, 1994, Somlyódy and Shanahan, 1997, Zessner et al., 1998). Here, these estimates were somewhat refined by recent Hungarian studies and practical applications. A summary is given in Fig. 4.

Figure 4. Removal rates and costs of technologies

Figure 4 applies to 100 000 PE and shows removal rates (for typical raw municipal wastewater composition) as well as investment and OMR costs of six technologies relative to advanced treatment with P and N removal (BNP): mechanical-, chemically enhanced primary-, high and low load biological treatment (M, CEPT, BHL and BLL), high and low load biological treatment with P removal (BHL P and BLL P). BOD5, NH4-N, TN and TP removal rates of BNP are 95 %, 95 %, 80 % and 95 %, resp. For large wastewater treatment plants the figure offers two multi-phase development paths: CEPT → BLLP → BNP and BHL → BLLP → BNP which idea can be used to the development of cost-effective strategies if budget is limited.

For investment and OMR costs of BNP treatment and sewerage (100 000 PE) broad range of estimates can be found. Investment cost values valid for Germany and Austria are assumed to

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7 An exception is the Iron Gate (see before).
be around 250 €/PE and 2500 €/PE, resp. (see e.g. Schoeneberg, 1988, Pechner, 1994), while related OMR costs are about 12 €/PE and 24 €/PE (Schönback et al, 2005). Cost levels in middle and downstream riparian countries are approximately 30 % - 50 % less for wastewater treatment\(^8\) while due to the higher contribution of civil engineering work the difference is higher for sewerage (a typical value for Hungary is 800 €/PE). The well-known effect of scale on the cost of treatment and sewerage is widely discussed in the literature (Somlyódy and Shanahan, 1997, Zessner et al, 1998, Kroiss, 2002). Thus, it is solely mentioned that (i) due to high specific costs solutions in small rural settlements deserve special attention and (ii) costs of treatment towards small PE values grow faster that that of the collection network.

**STRATEGIC DISCUSSION**

**Are development needs affordable?**

The upper part of Fig. 5 shows development needs under the assumption that collection and treatment is developed up to 80 % in transition Danubian countries. In this case all the urban areas and at least 30 % of the rural ones would be connected to the sewer network (the level corresponds to the Hungarian target for 2015). This would represent a longer term goal close to the level of Germany and Austria (treatment of all the presently collected wastewaters is also presented in the figure as a short term goal, see zero gap development). Our impression for the first glance is that investment needs are tremendous.

![Figure 5. Development needs and economic disparity in the Danube Basin](https://iwaponline.com/wpt/article-pdf/3/3/wpt2008054/383992/54.pdf)

The lower part of the figure demonstrates head specific GDP in €/cap/a and at purchase power parity (PPP, both for 2005). There is a strikingly increasing economic disparity towards middle and downstream countries: as contrasted to about 30 000 €/cap/a GDP of Germany and Austria, values below 1000 €/cap/a are not rare. High development needs are associated with low GDP and this reverse trend clearly shows the serious economic and financial problems of these riparian countries on how to proceed and to respond to a common Danube Basin wide nutrient emission reduction strategy.

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\(^8\) For instance, in Hungary wages, civil engineering and material costs are lower, while machinery is on the same level as in Germany or Austria. Components of OMR costs (personal, electricity, materials, maintenance and management) show lots of similarities (Palkó, 2000).
But, is the situation really so striking? Using the development and cost figures of the present paper, investment needs are around 40 billion €, i.e. on an average we are somewhere in the range of 500 €/cap - 1000 €/cap, which corresponds to earlier literature data of the CEE region (GWP, 2000). The comprehensive, modeling based scenario analysis of the daNUbs study (Schönback et al., 2005) allows drawing more detailed conclusions. Accordingly, the per capita head specific expenditure of transition countries is between 200 €/cap and 1100 €/cap.

Are the above values high or not? The answer is not easy and requires assumptions. The common methodology is to calculate the head specific total annual cost (TAC)\(^9\) and relate it to (i) the per capita GDP expressed by purchase power parity (PPP) and (ii) the total net household expenditures. Thus, two indicators are resulted in, the tolerable upper values of which are about 1 % and 3 %. In the first case the underlying hypothesis is that budget is not limiting: keeping in mind social needs, governmental and/or EU level interventions ensure infrastructure development. TAC is generally calculated by assuming 25 y and 50 y economic life for wastewater treatment plants and sewer networks, resp. and 3 % to 5 % real discount rate (the daNUbs study uses 3 %, while EU project proposals ask for a value of 5 %). For the second indicator the total annual cost is derived from actual conditions of financing.

Analysis of the first indicator led to favorable ratios: by using daNUbs study outputs countries are in the 0,1 % - 0,7 % GDP range (most of them are close to 0,5 %) and thus there are no difficulties, at least not in theory. However, the second affordability indicator seems to be more critical. The literature already reports about high values for some of the countries between 2 % - 3 % or above (see e.g. GWP, 2003 and note that uncertainties of these estimates are high) which will increase in the future. In Hungary it is estimated that the present affordability ratio is close to 2 % on an average which is in the top range of the related OECD list. Assuming the planned (relatively small) water supply and wastewater management developments (to meet requirements of the UWWD and to protect groundwater), as well as the missing reconstruction needs and subtracting the gain in sewage fee, a nation wide average increase to 3,5 % is anticipated, a very high value if cost recovery is assumed (see also later). In rural areas the indicator may reach 5 %, while - without social subsidies - the poorest 10 % of the population would face a burden above 10 %. Thus, the situation is far from being easy.

If money is not sufficiently available, loans should be borrowed. In this respect many alternative financial sources exist. However, conditions of lending money - relatively high interest rate and short return period - may result in a drastic change in the second indicator, which is non-acceptable. For instance, in Hungary infrastructure loans and bonds can be obtained for a 20 year return period starting from the operation of the facility and 5 % - 8 % interest rate. Depending on the above conditions, increase of the fee can range between 25 % and 200 % for new developments, even if only 10 % is used as an alternative source. Thus, loans are affordable only for smaller developments in regions with higher income. If affordability is constraining, we have a few tools, only: to increase the GDP\(^10\) and the family income and/or to stretch the implementation period of investments, to focus more on cost savings, cost-effectiveness and financing. All these show that EU funding is the key element of the

\(^9\) For the first case TAC = CRF·IC + OMRC, where CRF is capital recovery factor being a function of the discount rate and the economic life, IC is investment cost and OMRC is operation, maintenance and repair cost (it is noted that sometimes the annualized capital cost is used for the purpose of the indicator). For the second indicator TAC largely depends on lending conditions.

\(^10\) In order to speculate on future head specific tariffs it is worthy to mention that according to EUROSTAT the population weighted average GDP growth rate in 2004 in the transition region of the Basin was about 5 % (it ranged between 3.8 % and 7 %), which is 3.0 % and 2.5 % higher than for the EU-15 region, and Austria and Germany, resp. The average inflation rate was about 7% (the range was 2.0 % - 12 %). The unfavorable figure is primarily due to the economic performance of H, RO and MD (no data are available for SM).
desired developments. Even if it is there, an additional question for the transition portion of the Danube Basin is whether the region and individual countries are prepared to absorb efficiently the huge investments in question.

The difference in assumptions to derive the two affordability indicators offers the explanation for the contradiction referred to in the Introduction: for the first indicator a convention is employed while the second one is closely related sustainable operation of utilities. This was studied in eight riparian countries by Morris and Kis (2004). They found serious problems in five of the countries (CR, BH, RO, BU and MO): among other things high water loss up to 70 %, high risk index characterized by low operation reliability and severe financial conditions, and frequent non-payment. Additionally, they recognized the operation of about 3000 utilities. This large number raises serious institutional and regulatory issues (for comparison note that in England and Wales roughly the same number of people is served by 37 utilities). We aim at balancing nutrients on various scales, but this can be achieved only, if financing is also balanced and conditions of sustainable operation are there.

Which wastewater management strategy to chose?

It is a complex issue major elements of which we try to discuss in a conceptual manner. We use Figure 6(a) and (b) which illustrate the Basin wide investment cost as a function of the Danube P load to the Black Sea (the present level is 23.5 kt/a). The scheme was prepared on the basis of Figures 2-5 and results of the daNUbs study (Kroiss, 2005) such that order of magnitudes of variables is properly demonstrated. As can be seen, two opposite processes influence the mouth load: (i) expensive sewer development up to 80 % leads to an increase (i.e. cost-effectiveness is negative) and (ii) wastewater treatment results in a reduction depending on the technology choice (BLL or BLLP). The combination of the two actions offers a number of strategies: (i) Point I refers to sewer development alone, (ii) Points II and II’ indicate sewer development + biological treatment (BLL) for new constructions, with and without closing the existing treatment gap (I and II’ represent past, open-cycle, non-sustainable strategies, see Figs. 2 and 5), (iii) Points III and III’ demonstrate the same for P removal (BLLP) which reduces the Danube load by about 20 %. As can be seen, a positive cost-effective ratio can be gained by the last case, only when P removal is logically introduced also for the presently collected, but untreated wastewaters.

Figure 6(a) evidently leads to the recommended strategy and sequencing which is illustrated in Fig. 6(b): (i) close the existing gap first which is the most cost-effective step (0-1), (ii) develop sewerage and treatment BLLP (1-2-3) and (iii) do actions such that on each level (national, sub-basin, municipality etc.) the P cycle is closed as much as possible (see 1-3 and its saw tooth elements). Obviously, gradients of saw tooth pieces characterizing lower level policies depend on a number of factors: present infrastructure, cost figures, retentions and others. It is crucial to stress that from the viewpoint of cost-effectiveness retention (of natural science origin) plays an equally important role than costs (of economic origin).

The daNUbs project analyzed several scenarios more in detail (Kroiss, 2005, Schönback et al, 2005). The baseline or reference scenario assumes that existing facilities are operated without extension. All the other (uniform) strategies suppose sewer network development up to 80 % (Fig. 5) and at least biological treatment of all the collected wastewaters. They are different depending whether the normal or sensitive area assumption of the urban wastewater directive is applied or BNP treatment as the best available technology (BAT) is considered everywhere. Conclusions can be summarized as follows: (i) in total about 70 % of costs are associated to the sewer network and thus the cost impact of technology selection is relatively small (Fig. 6): it is less than 30 % of the total investment cost or 7 €/cap/a (see also Fig. 4). (ii) The most expensive strategy is the most cost-effective in terms of cost per nutrients removed at the mouth of the Danube (€/kg P and €/kg N). In fact, the UWWD normal area policy leads to a significant increase of P and N loads, and negative cost-effectiveness ratios (sewer development and increased loads are not compensated by treatment), but also the sensitive area strategy results in an increase in the N load. In contrast, the BAT scenario leads to a favorable P and N load reduction of 6,7 kt/a...
and 36.2 kt/a (see Fig. 3). (iii) The incremental investment cost can be relatively high for individual countries (e.g. about a billion € for Romania). Thus, the issue is which policy instrument to use to do more than the local policy would require (emission trading was considered earlier by ICPDR as a vehicle, ICPDR, 2000).

![Figure 6. Danube Basin wide strategies and cost-effectiveness](image)

Until now we discussed elements of cost-effective regional emission reduction policies. This may not be equivalent to that of sub-basin or national policies which have differing ambient water quality goals and cost-effectiveness can be also interpreted differently. Here a few, perhaps self-evident recommendations can be given: (i) treat all the wastewaters collected at present and upgrade existing plants (see also before), (ii) start to solve problems of high density urban areas where dilution rate is small, (iii) avoid the development of expensive sewer network for small settlements wherever possible and try to use alternative sanitation, (iv) as an element of realizing the good status of waters according the EU WFD, define ambient water quality criteria (usually for BOD5, DO, NH4-N, NO3-N, PO4-P etc.), and use models for strategy development and priority setting which also include diffuse sources, (v) set criteria carefully for small rivers to avoid increased loads and deteriorated water quality as a result of sewer development, (vi) be cautious with N removal in the vicinity of (small) lakes which is not only expensive, but it may result in undesired N limitation, (vii) select technology and its potential phased development for large plants in the light of Fig. 4 and budget available, (viii) schedule carefully actions, in the light of financing and affordability.
Technology selection requires a few further considerations. First, about 25% and 35% of respective capital and O&M costs of 100,000 PE plants are unrelated to the process applied (for example workshops, buildings, laboratories, mechanical pre-treatment etc., see Kroiss, 2002, Lindtner, 2004). Second, as seen from Fig. 4 removal leads to very little additional cost, thus it is worth applying. Third, nitrification is frequently needed (e.g. for small dilution capacity cases) and N removal with positive regional impacts has only a small incremental effect on the annual cost or the sewage fee. Fourth, as shown by the Austrian benchmarking study (Kroiss, 2002, Lindtner, 2004), cost variability of existing comparable plants is much larger than what is demonstrated by Fig. 4. In other words, local conditions and the implementation of plants play a decisive role. Lastly, it would make sense to develop a model based comprehensive strategy which considers local and Basin wide criteria simultaneously (see e.g. Somlyódy, 1996).

Implementation and financing experiences

In the course of the past fifteen years most of the transition countries of the Danube Basin performed huge developments. We use Hungary as an example where since 1990 the length of the sewer network was increased by 150% and connection grew from 44% of the total population to 57%. The development of wastewater treatment was even higher (and till 2015 there will be a further growth by about 8 million PE). Investments of the past five years were above 1.5 billion € which will be expanded by utilizing increasing sources of the Cohesion Fund of the EU without which - as noted - affordability can not be maintained (till 2015 about 3 billion € will be spent). As it looks at present subsidy or grant will cover 70% of the developments (85% EU and 15% state budget), while 30% will be the contribution of local governments. Half of it will likely be collected from the users while the other may come from the local governments’ budget and loans.

Past developments addressed a number of problems and lessons which are probably typical also to the region. First, the impact of the tariff increase by about two orders of magnitudes in the course of the past two decades is mentioned, which led to a 50% (or more) reduction in water consumption and the amount of wastewater generated. This was further aggravated by disconnections from the public water supply network in smaller towns and settlements, and the non-willingness to be connected to freshly constructed sewerage (which is now handled by a high soil disposal fee). The consequence was that the earlier hydraulically overloaded plants became underloaded and the raw wastewater got dense with high NH4-N concentrations (not rarely close to 100 mg/l) and a low C:N ratio unfavorable from the viewpoint of denitrification. At the same time large reactor volumes could be disengaged which - in principle - offers a broad range of upgrading possibilities. The above tendency - which is still going on - unfortunately was not all the time recognized at new designs and for this reason many plants suffer now from related problems. Thus, the importance of technological flexibility, wastewater characterization, design skills and the use of advanced methods are stressed. Second, the impact of unclear legislation is referred to. EU or national standards? was a question for a long period time. Additionally, site specific standards can be set even today which has been not all the time done correctly. All these fuzziness led several poorly designed plants and the import of too many different - often outdated - technologies into the country (financial promises contributed significantly). Thirdly and consequently, the mistrust born is noted: to avoid failures, a single prime contractor is often looked for who offers full warranty, not necessarily focusing on the technology choice. Fourthly and perhaps most importantly, in several CEE countries the need for a strong “wastewater industry” and culture has not yet been sufficiently recognized, which has been a major barrier from the viewpoint of future developments.

Fifth, issues of financing are addressed which in the nineties were characterized by changes of the crucially important institutional system, the creation of new laws and regulation, and scarcity of funding. The basis was a complicated multi-channel and

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11 Problems appear primarily in lakes’ regions (where often tight N standards are set) and in flatlands where it may be unclear what the final receiving water is.
multi-priority (water, environment, regional development etc.) subsidy system (which seemed to be unavoidable in the transition period) where application is social security entitled. Difficulties associated can be summarized as follows: (i) There was no strategy developed how the system will function. (ii) Too many priority goals have been formulated under permanently changing rules. Thus, budget for individual goals got frequently limited which led to the selection of cheap solutions and the design of oversized capacities. At the same time unrealistically high total subsidies (close to 90%) could be also realized. (iii) Securing own sources, borrowing money and the constraint of pre-financing led to huge dilemmas on one hand, but rich settlements often received unjustified advantages, on the other hand. (iv) The system offered opportunities for a cluster of settlements (examples exist mostly in the < 2000 PE range) to apply jointly, with success. This then sometimes resulted in unrealistic regional wastewater systems. (v) Funding of the increase of OMR cost and reconstruction were often ignored. The latter one was mostly of political origin: local governments avoided to include depreciation into the sewage fee being already high.

In summary, the above subsidy based system (under revision now) together with the permit procedure to be applied is extremely complicated with too many actors and sometimes irrational scheduling. It is not transparent enough and does not motivate cost savings. Moreover, it offers little time and space to involve good professional knowledge.

CONCLUSIONS
(i) The specific features of wastewater management in the Danube Basin - a huge area - stem from two factors. First, local water quality goals and Black Sea related regional nutrient emission reduction targets should be met jointly in a complicated transboundary setting. Second, the Basin incorporates a large number of significantly different (EU, accession and non-EU) countries in terms of water infrastructure, economic and social development.

(ii) Development needs are huge in middle and downstream transition countries. The long term assumption is that 80% of the population will be connected to the collection network and wastewater treatment such that at the same time P and N loads of the Black Sea will be reduced. Needs increasing downstream are associated with strikingly growing economic disparity indicating the seriousness of the economic problem.

(iii) The total investment cost of the above development is around 40 billion € or 200 €/cap - 1100 €/cap (70% is associated to the sewer network), depending on transition countries. Affordability is a serious issue even if budget is warranted by governments under favourable conditions which are typical for water infrastructure development. Already high water related family expenses can be doubled. On the average it may exceed 3% - 4% of the net family expenditure which is considered limiting. Rural areas and people in the low income range would be in a much worse situation. Commercial loans would lead to non-tolerable burdens. Under the present modest economic growth the affordability constraint can be met primarily by the increase of the planned implantation period of investments.

(iv) Priority should be given to upgrade treatment to the existing level of sewerage. New sewerage construction is recommended to be avoided in small settlements and postponed as long as economy does not allow it (unless hygienic reasons or drinking water protection require it). For new plants apply technologies with P, or if nitrification is needed with P and N removal (or consider phased development for large plants). The related increase within the total annual cost is relatively small, while the regional impact is large. Further arguments are that (a) the cost variability of existing plants of comparable sizes is larger than the
portion depending on the technology choice, and (b) implementation mistakes may have a dominating impact independently of the technology.

(v) Our final goal is to balance and close nutrient cycles on various scales of the Danube Basin. However, it should be realized that this can be achieved only, if financing is also balanced and conditions of sustainable operation of utilities are there.

(vi) Within the transition region of the Danube Basin, many sided experiences of the more developed countries should be utilized (“east to east” knowledge transfer) which are related to institutions, legislation, financing, implementation, pricing and its impacts, design, operation, and others. They may help to recognize problems at an early stage and to avoid failures.

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