Nutrient Management in the Danube River Basin

Mihaela Popovici

Abstract The EU Water Framework Directive requires that EU Member States implement the necessary measures within their river basin districts to achieve good status of water bodies by 2015. Nutrient pollution is a priority challenge in the Danube River Basin District, interlinking the freshwater with the marine environment – approximately 65% of the Danube River length was categorised as being *at risk* due to nutrient pollution. Eutrophication is of major concern in the Danube Region and especially in the receiving Western Black Sea. The ecological situation in the Black Sea has improved considerably in the last decade (reduced eutrophication, disappearance of anoxic conditions, regeneration of zoo-benthos and phytoplankton); however, the improvement was only partly due to the effect of measures like nutrient removal at wastewater treatment plants (WWTPs) or the ban of P-containing laundry detergents, as it was also to a considerable part due to the economic crises in Danube countries. The nutrient loads are thus still well above the levels of the 1960s; current evidence shows the need to develop newer solutions and to prepare nutrient management strategies to effectively reduce nutrients in the Danube River systems. The assessment of measures related to farming practices and land use management undertaken until end of 2012 provided information on declining trends of nitrogen surplus in all member states in the DRB. The measures related to farming practices and land use management consist most commonly of technical measures to reduce negative impacts caused by agriculture, such as input reduction measures, measures addressing diffuse pollution concerning both fertiliser and pesticide use, livestock farming-oriented measures focusing on the reduction of impacts from animal rearing, the use of manure as a fertiliser, changes in crop production practices as well as improving drainage systems.

Keywords Common agricultural policy, MONERIS, Nitrates directive, Nutrients

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Abbreviations

AEM	Agri-environmental measures
BAP	Best agricultural practices
BAT	Best available techniques
BSC	Black Sea Commission
CAP	Common Agricultural Policy
CIS	Common Implementation Strategy for the Water Framework Directive
CP	Contracting Party
daNUbs	Nutrient Management in the Danube Basin and its Impact on the Black Sea
DPRP	Danube Pollution Reduction Programme
DRB	Danube River Basin
DRBD	Danube River Basin District
DRBMP	Danube River Basin Management Plan
DRP	Danube Regional Project
DRPC	Danube River Protection Convention
DRS	Danube Region Strategy of the European Commission
EU	European Union
EUSDR	EU Strategy for the Danube Region
FAO	Food and Agricultural Organisation of the United Nations
FAOSTAT	Database of the Food and Agriculture Organisation of the United Nations
GAEC	Good Agricultural and Environmental Condition
GEF	Global Environment Facility
GEP	Good Ecological Potential
GES	Good Ecological Status
GIS	Geographical Information System
HMWB	Heavily Modified Water Body
ICPDR	International Commission for the Protection of the Danube River

MONERIS	Modelling Nutrient Emissions into River Systems
MoU	Memorandum of Understanding
MS	EU Member State
N	Nitrogen
NAP	National Action Plan
ND	Nitrates Directive (Directive 91 /676/EEC)
NSP	National Strategy Plan
NVZ	Nitrate Vulnerable Zone
OM	Ordinary Meeting
P	Phosphorus
POM	Programmes of Measures
RBD	River Basin District
RBM	River Basin Management
RBMP	River Basin Management Plan
RBN	River Basins Network
RDP	Rural Development Programme
RDR	Rural Development Regulation
SMR	Statutory Management Requirement
SWG	Standing Working Group
SWMI	Significant Water Management Issue
UNDP	United Nations Development Programme
UWWTD	Urban Waste Water Treatment Directive (Directive 91/271/EEC)
WFD	Water Framework Directive (Directive 2000/60/EC)
WWTP	Waste Water Treatment Plant

1 Introduction

1.1 Need for Nutrient Management in the Danube River Basin

The Danube River Basin is Europe's second largest river basin, with a total area of 801,463 km^2. It is the world's most international river basin as it borders 19 countries. The ecosystems of the Danube River Basin (DRB) are highly valuable in environmental, economic, historical and social terms, but they are subject to increasing pressure and serious pollution. The Danube River and its catchment provide drinking water, industrial and agricultural water supply, hydroelectric power generation, navigation, tourism, recreational opportunities and fisheries. These intensive uses have created severe problems of water quality and quantity and drastically reduced biodiversity in the basin. The pollution ends up in the Black Sea and affects a very large area.

In order to address these problems, the Danube countries have taken and are taking several actions on the national and international level. A central element in this respect is the implementation of the EU Water Framework Directive (WFD),

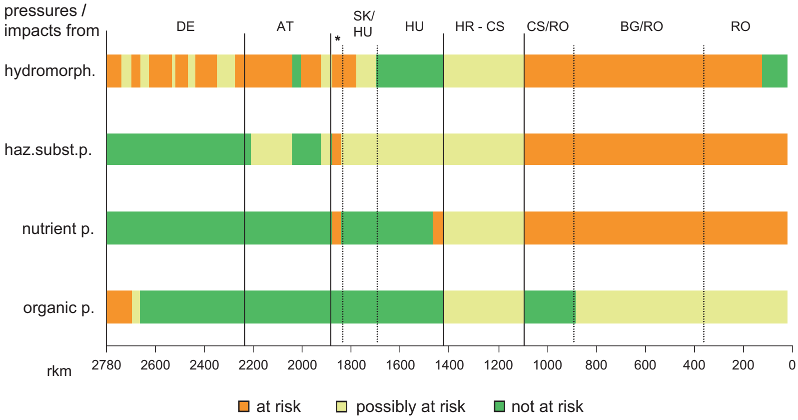


Fig. 1 Results of the risk analysis for the entire Danube River length [1] (*asterisk*: SK territory)

with the Joint Programme of Measures (JPM) incorporated in the Danube River Basin Management Plan. This JPM addresses the Significant Water Management Issues (SWMIs) in the DRB, through several technical measures needed to reduce the negative influence of human activities on the water quality. For each SWMI, visions and operational management objectives have been developed based on shared values with a long-term perspective. Overall, the visions and management objectives reflect the joint approach among all Danube countries and support the achievement of the WFD objectives in the DRB. When addressing pressures at the basin-wide scale, it is clear that cumulative effects may occur, and addressing these issues effectively requires the application of a basin-wide perspective and close cooperation between countries.

Figure 1 illustrates the results of the Danube Basin Analysis (DBA), prepared in line with the requirements of the WFD Art. 5 in 2005, according to the categorised pressures for the entire length of the Danube River itself. 58% of the Danube River length was categorised *at risk* due to organic pollution, 65% due to nutrient pollution and 74% due to hazardous substances. 93% of the Danube River was *at risk* or *possibly at risk* of failing the WFD environmental objectives because of hydromorphological alterations. In conclusion, large parts of the Danube River are subject to multiple pressures. For the entire DRBD, the distribution of pressures is similar.

Nutrient pollution is a priority challenge in the DRBD, interlinking the freshwater with the marine environment – approximately 65% of the Danube River length was categorised *at risk* due to nutrient pollution. While efforts to control nutrient enrichment over the past 30 years yielded some positive results, although the nutrient loads are still well above the levels of the 1960s, current evidence shows the need to develop newer solutions and to prepare nutrient management strategies to effectively reduce nutrients in the Danube River systems.

As a result of considerable investment in upgrades of sewage treatment plants especially in the upper basin, the phosphorus levels have markedly improved throughout most of the river system, although levels remain slightly above the levels of 1960s. Elimination of phosphorus in detergents in some countries and the adoption of best agricultural practices also contributed to reductions in total pollutant load in the Danube River systems and the Black Sea. Nitrogen levels have also improved, but they are still well above the level of 1960s.

Elevated loads of nutrients can enter the river through diffuse sources such as agricultural runoff and urban stormwater and point source discharges from sewage treatment plants. To date, nutrients have been reduced and managed through a range of programmes and initiatives; however much of the river systems remain stressed. Unless well managed, nutrient sources could continue and intensify in the future, with potential increases associated with population growth, agricultural intensification and further urbanisation within the DRBD.

The Danube River Basin Management Plan published in 2009 [2] is a significant first step towards achieving the good water status of water bodies that WFD requires, setting clear and ambitious targets for environmental improvement through the reduction of nutrients pollution in the Danube River systems.

As there is a wide range of factors influenced or affected by nutrient pollution, including the economic considerations, legal requirements or diverse stakeholder interests (such as fishing, drinking water, conservation, forestry and agricultural), the measures set within the Joint Programme of Measures will not be sufficient to achieve the environmental objectives of the WFD at the basin-wide level by end 2015 and need to be further addressed by a basin-wide strategic and coordinated approach.

The ICPDR's basin-wide vision for nutrient pollution is the "balanced management of nutrient emissions via point and diffuses sources in the entire Danube River Basin District that neither the waters of the DRBD nor the Black Sea are threatened or impacted by eutrophication".

Therefore, the countries efforts are focussing on achieving the management objectives related to nutrient pollution agreed in the DRBMP in relation to the Danube impact on the eutrophication of the Black Sea, and thus, the hydrological connection of the Danube River Basin with the Black Sea is of a central consideration.

The Black Sea eutrophication problem can be addressed and benefited by actions taken throughout the Danube River Basin, even in areas not responsible for the largest nutrient inputs to the river system. Actions taken for local reasons unrelated to the Black Sea – to improve water quality upstream in the DRB – will deliver benefits downstream as well.

1.2 Policy Context

Nutrient removal is required to avoid eutrophication in many Danube River Basin surface waters and the Black Sea North Western Shelf, in particular taking into account the character of the receiving coastal waters as a *sensitive area* under the

UWWTD [3]. The nutrient loads discharged from the DRB are an important factor responsible for the deterioration and eutrophication of parts of the Black Sea ecosystem.

The Danube countries committed themselves to implement the Memorandum of Understanding adopted by the International Commission for the Protection of the Black Sea (ICPBS) and the ICPDR in 2001 and agreed that "the long-term goal is to take measures to reduce the loads of nutrients discharged to such levels necessary to permit Black Sea ecosystems to recover to conditions similar to those observed in the 1960s".

The ministers of the Danube countries expressed their commitment in the Danube Declaration adopted at the Ministerial Meeting, February 16, 2010 (Danube Basin: Shared Waters – Joint Responsibilities), with regard to nutrient pollution that – "due to the measures made operational until 2012 – the nitrogen and phosphorus emissions to surface waters in 2015 will be about 12%, respectively 25%, lower compared to the average of the years 2000–2005. The load to the Black Sea will reach a level below the present state but still about 40% above that of the 1960s for nitrogen and about 15% for phosphorus".

The integration of the EU Nitrates Directive [4] with the Water Framework Directive [5] is central to ensure the legal alignment of the National Action Plans and River Basin Management Plans/Programmes of Measures. Furthermore, the integration of environmental concerns in the EU Common Agricultural Policy (CAP) was identified as one of the main priorities of the CAP. Agri-environment, as a key element of this integration, became a compulsory element of the EU Rural Development Programmes from the 2000–2006 programming period. Additionally, the CAP and Rural Development are important in minimum budget allocation for agri-environmental measures that are identified in RBMPs/POM.

The strategic approach to rural development was strengthened in the programming period 2007–2013. Strategic guidelines, which were defined at the EU level, set the overarching priorities of the EU Rural Development policy. Taking the guidelines into account, member states were required to develop a National Strategy Plan, which defined the action of the European Agricultural Fund for Rural Development (EAFRD) Period: 2014–2020 at the MS level. The National Strategy Plan also served as a reference for the development of the national/regional Rural Development Programme, the main instrument through which the rural development strategy is delivered at national or regional level. Agri-environment provides relevant tools to address a wide diversity of farming practices and a broad number of challenges in the EU.

The "Health Check" fine-tunes CAP reform to make the Single Payment Scheme more effective, efficient and simple, to adapt market instruments to meet new market opportunities and to respond to new and ongoing challenges (climate change, bioenergy, water scarcity, biodiversity).

Water plays a central role when it comes to adaptation, as it is vital for several economic sectors. Therefore it is essential to adapt the integrated river basin solutions to extreme events such as floods and drought and manage the resulting impacts on water supply, water quality and ecosystems. In the examination of the implications of measures proposed in the ICPDR Joint Programme of Measures, it is important to identify win–win and no-regret solutions.

To meet the overall binding target for the European Union of 20% renewable energy by 2020 and a 10% minimum target for the market share of biofuels by 2020, the member states are free to decide their preferred “mix” of renewable to take account of their different potentials of bioenergy policy. The national action plans shall also set out “adequate measures to be taken to achieve these targets, including national policies to develop existing biomass resources and mobilise new biomass resources for different uses”. This will influence the degree of agricultural intensification, and certain limits on the type and size of biomass production for energy purposes should be imposed.

In view of the Policy Review of the Strategy for Water Scarcity and Droughts, the European Commission has launched several studies (such as GAP analysis, water use in agriculture) which have been integrated in a Blueprint to safeguard European waters published in 2012 [6].

Finally, the EU Strategy for the Danube Region (EUSDR) is the macro-regional development strategy and action plan for the regions and countries located in the catchment area of the Danube River. It targets the sustainable development of the Danube macro-region as well as the protection of its natural areas, landscapes and cultural heritage. The measures related to the Danube Strategy will largely follow the ICPDR’s Danube River Basin Management Plan of 2009. The Danube Strategy emphasises the importance of intersectoral collaboration. An active process of cooperation between authorities responsible for agriculture and environment is to be supported to ensure that measures against agricultural pollution are put in place: manure storage facilities, buffer strips, fertiliser and pesticide application limits, for example.

2 Nutrient Pollution in the DRB

Nutrient pollution is mainly caused by emissions from the agglomeration, industrial and agricultural sectors. Furthermore, for agglomerations, the P emissions via household detergents play a significant role. For nutrient pollution, point and diffuse source discharges are to be distinguished. Point source discharges are caused by single activities and are locally confined, whereas diffuse source discharges are caused by widespread activities like agriculture with multiple pathways (erosion, tile drainage, etc.). Agriculture is the major source of diffuse inputs, including fertilisers as well as effluent from huge pig farms and agro-industrial units. Therefore, it is assumed in order to reduce diffuse sources of pollution due to the use of fertilisers that by 2015, the MS will implement the action plans and codes of Good Agricultural Practice on fertilisation under the Nitrates Directive, and the non-MS will apply the ICPDR recommendations on the Best Agricultural Practices (BAP).

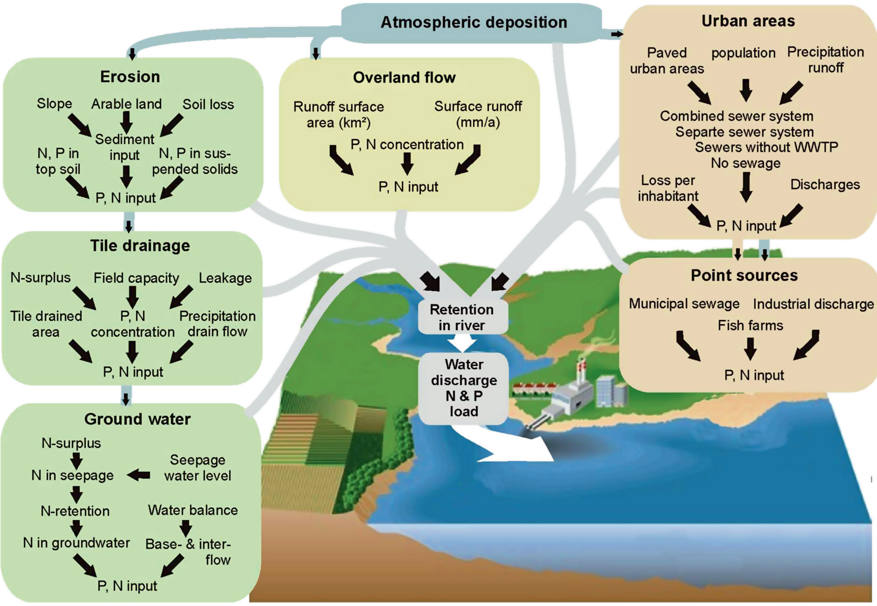


Fig. 2 MONERIS model nutrients inputs into the river systems

Information on the major sources of phosphorus and nitrogen to surface water is important in the assessment of current programmes of measures and future initiatives on abating nutrient pollution. Understanding the transformation and losses of nutrients in the river systems and knowledge about the relative contributions of phosphorus and nitrogen in terms of the total load, the chemical form and input form (continuous vs. climate dependent) are essential in making best choices regarding how to manage nutrient reduction efforts in the basin. Information on source contributions of nutrient loadings has been broken out on the level of an analytical unit, through the application of MONERIS (http://www.icpdr.org/main/activities-projects/moneris-modelling-nutrient-emissions-river-systems) (Fig. 2), which allows regionally differentiated quantification of nutrient emissions into a river system.

N and P emissions cause eutrophication in many DRBD surface waters and contribute to eutrophication in the Black Sea North Western shelf. For the period 1988–2005, the Danube, as one of the major rivers discharging into the Black Sea, was estimated to introduce on average about 35,000 tonnes of P and 400,000 tonnes of inorganic N into the Black Sea each year (Fig. 3).

The present level of the total nutrient load in the Danube River system is considerable higher than in the 1960s, but lower than in the late 1980s. The decrease from the 1990s to the present situation is due to the political as well as economic changes in the middle and lower DRB resulting in (1) the closure of nutrient discharging industries, (2) a significant decrease of the application of mineral fertilisers and (3) the closure of large animal farms (agricultural point sources).

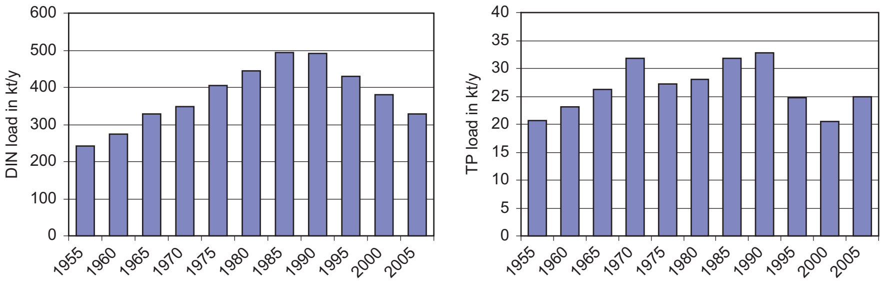


Fig. 3 Long-term discharges of dissolved inorganic nitrogen (DIN) and total phosphorus (TP) (1955–2005)

Furthermore, the application of economic mechanisms in water management (e.g. the *polluter pays principle* also applied in the middle and downstream DRB countries) and the improvement of wastewater treatment (especially in upstream countries) contributed to this decrease.

Whereas point emissions from waste water treatment plants and industrial sources are directly discharged into the rivers, diffuse emissions into surface waters come from different pathways, represented by separate flow components. The direct and diffuse components must be separated, since the underlying processes and the nutrient concentrations are different. The model facilitates the calculations of emissions into surface waters, calculations of nutrient retention in surface waters, and allows a comparison between the calculated and the observed loads.

The N_{tot} and P_{tot} total generated load emissions (point and diffuse) for reference year 2006 emitted from agglomerations $\geq$2,000 PE) were 168.0 kt/a and 28.6 kt/a, respectively.

2.1 Identification of Point Nutrient Sources

Nutrient pollution from point sources is mainly caused by emissions from insufficiently treated or untreated wastewater into surface waters (from agglomerations, industry and agriculture). It should be mentioned that the operation of secondary and tertiary treatment levels at wastewater treatment plants (WWTPs) is of particular importance for the respective elimination/reduction of nitrates/phosphates.

Nutrient emissions and the eventual impact from point sources can be measured and expressed in terms of inorganic nitrogen, total nitrogen (N_{tot}), ammonia (NH_4), nitrate (NO_3), nitrite (NO_2) or total phosphorus (P_{tot}) and phosphates (PO_4).

The emission of phosphates via household detergents is significant in the DRB, and it is included in the agglomerations contribution to total emissions. P emissions due to laundry and dishwasher detergents in the DRB are estimated at 9,190 t/a. This is 15.7% of the total P emissions.

The use of mineral fertilisers significantly contributes to nutrient pollution in the DRB, and it is included in the agglomerations contribution to total emissions. The two most important plant nutrients applied as mineral fertilisers are N and P.

2.2 *Diffuse Sources of Nutrients*

Diffuse pollution was highlighted as a major impact on the Danube River systems in the DBA in 2005, as well in the SWMI paper in 2008. Since then, work has continued in the basin to develop measures to address diffuse pollution through a number of routes such as regulation, economic support and catchment management initiatives. The DRBMP published in 2009 set clear and ambitious targets for environmental improvement through the reduction of diffuse pollution in the DRBD. Figures 4 and 5 show the MONERIS results describing that altogether

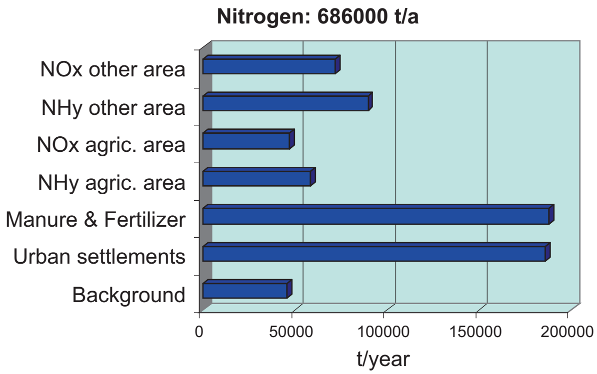


Fig. 4 Sources of nitrogen emissions in the DRBD

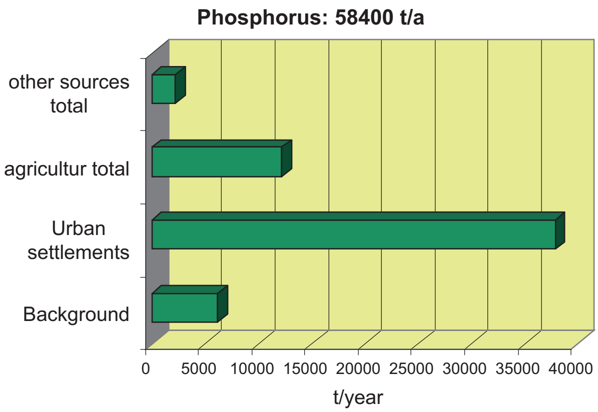
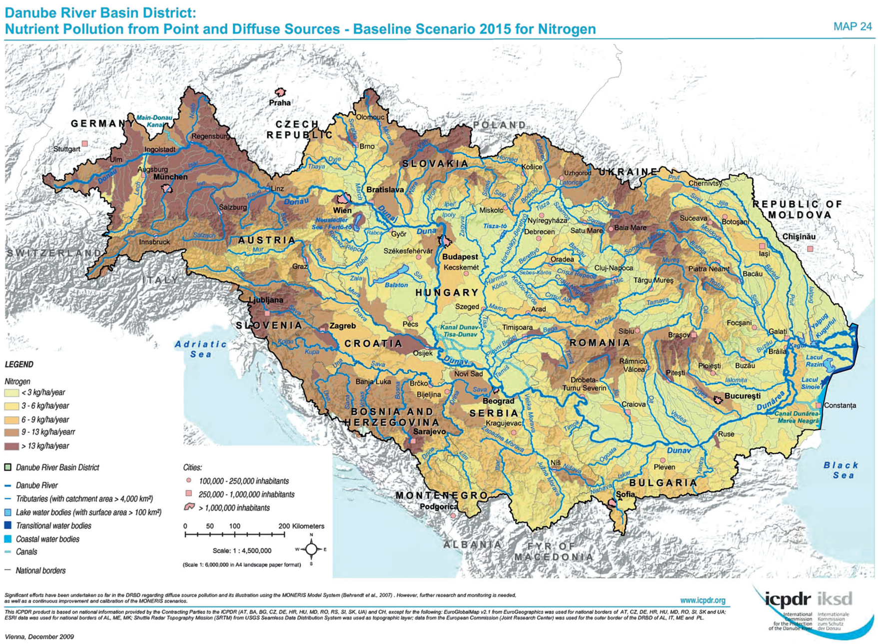


Fig. 5 Sources of phosphorus emissions in the DRBD

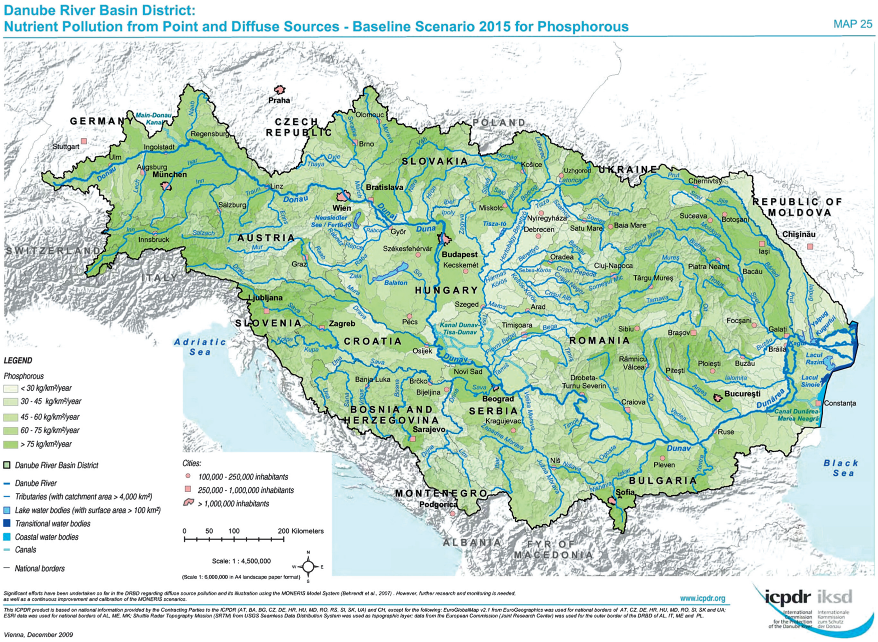
686 kt of N and 58 kt of P in total are annually emitted into the DRB. Values for atmospheric deposition – ammonia nitrogen and nitrogen oxides (NHy and NOx) – are also indicated.

The background conditions presented in MONERIS (7% for N; 9% for P) represent the pre-industrial situation with very limited airborne emissions of reactive N and erosion of soils not yet saturated with P. Consequently, these values are small in comparison with the current emissions in the DRB.

The main contributors for both N and P emissions are agglomerations not served by sewerage collection and wastewater treatment. For N pollution, the input from agriculture (fertilisers, manure, NO_x and NH_y) is the most important (43% of total emissions). For P, emissions from agriculture (area under cultivation, erosion, intensity of production, specific crops and livestock densities) are the second largest source after input from urban settlements. The share of agricultural emissions differs significantly between countries in the DRB (Map 1 and Map 2).



Map 1 Nutrient pollution: Baseline scenario 2015 for nitrogen [2]



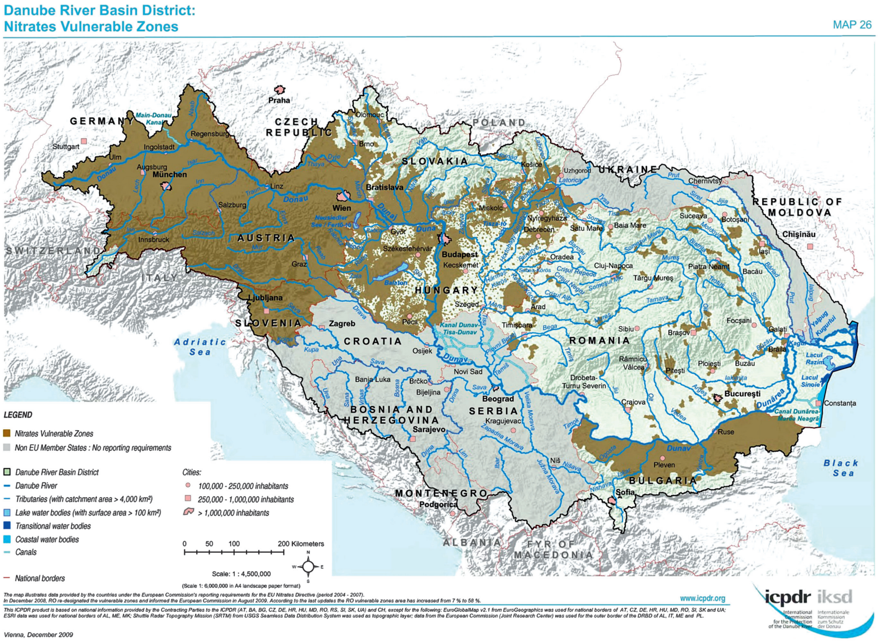
Map 2 Nutrient pollution: baseline scenario 2015 for phosphorus [2]

3 Actions to Manage Nutrients in the DRB

3.1 Implementation of Nutrient Management Legislation

The nutrients management regulatory framework will play an important role in ensuring that visions and the management objectives for nutrient management to meet the WFD objectives are an important consideration in decisions about land use planning and natural resource management. The EU directives have been adopted at the national level, and a number of other regulatory and planning controls are in place to manage point and diffuse sources of nutrients and prevent land degradation.

The EU Nitrate Directive was issued in 1991 [4]. The objectives are to reduce water pollution caused or induced by nitrates from agricultural sources and to prevent such pollution. Member states are required to identify Nitrate Vulnerable Zones (NVZs) on the basis of the results of monitoring requirements. Action Programmes with mandatory measures concerning agricultural practices must be implemented in these areas, and monitoring of water quality according to specific requirements is performed. The action programmes include the maximum amounts of animal manure that can be applied to land every year, which is equivalent to 210 kg N per ha for the first NAPs and 170 kg N per ha for the next ones. Also Codes of Good Agricultural Practice (CGAP) must be elaborated and are



Map 3 Nutrient vulnerable zones in the DRBD [2]

mandatory in the NVZs and voluntary outside the NVZs. To ensure that actions are successfully carried out, an implementation framework has been developed, and responsibilities as well as agreed time frames have been incorporated into specific actions. Different Danube countries have taken different approaches regarding the designation of NVZs (Map 3). The territorial approach was accepted by Austria, Germany and Slovenia, while in Czech Republic, Hungary, Romania and Slovakia and Bulgaria, Nutrient Vulnerable Zones were identified.

3.2 Implementing Authorities, Funding Opportunities and Monitoring of Implementation

The guiding principle and recommendation organising the implementation of the RDPs are established in the relevant set of rural development regulations.

The implementation procedures cover several aspects including the designation of the implementing bodies, definition of their responsibilities and tasks and vertical coordination required to translate in concrete actions on-the-ground the national and regional level rules. At the MS level, the institutional set-up for implementation procedures is based on three bodies, which every MS has to designate according to Article 74 of the RD Regulation, namely:

1. The Managing Authority
2. The Paying Agency
3. The Certifying Body

There are conditions and specific rules for financing expenditure under the common agricultural policy (CAP). Two funds were created: the European Agricultural Guarantee Fund (EAGF) and the European Agricultural Fund for Rural Development (EAFRD) as stipulated by the Council Regulation (EC) No 1290/2005 of 21 June 2005 on the financing of the common agricultural policy. The most predominant approach used to the implementation of Leader projects (http://ec.europa.eu/agriculture/rur/leaderplus/index_en.htm) was “measure by measure”. It is essential to encourage appropriate stakeholders to steer projects and also to identify financing means.

Monitoring and evaluation, acceptance by farmers and controllability of the measures are important factors in the implementation of nutrient management policies. Measures need to be reviewed nationally, through jointly organised mechanisms (such as interministerial committees operational in a number of the Danube countries) to ensure the coordination of resources. The evaluation is based on reliable information and evidence base to link nutrient inputs (cause) with the water quality information (effect) and the most cost effective methods of reducing nutrient pollution. The effectiveness of the measures is closely linked with the mechanism of control, and the review of the measures provides evidence that the management of nutrient pollution is effective. To determine the nutrient reductions, the effectiveness of the measures, the transformations in the river systems, the responses of the systems and the lag times, both pre- and post-implementation monitoring must be designed. In addition the anticipation of the nutrient reduction and its trends can be assessed based on monitoring data.

The quantification of achievable nutrient load reductions and implementation costs is useful when assessing the fulfilment of the WFD objectives. The concept of ecosystem services is often used by the Danube countries to provide a better understanding of the costs and benefits of various initiatives.

According to the calculation of scenarios (MONERIS results), a comparison between the 2006 and anticipated reduction by 2015 shows a reduction of both N and P pollution in the Danube River Basin. In 2006, the N emissions to surface waters were 686 kt/a, whereas the calculated values to achieve the management objective by 2015 will be 602 kt/a, which is a reduction of 12% (84 kt/a) (Fig. 6). For phosphorus, (Fig. 7), P emissions to surface waters were in 2006 of 58 kt/a, whereas the calculated values to achieve the management objective by 2015 will be 46 kt/a, which is a reduction of 21% (12 kt/a). This evaluation documented the conclusion that the management objective by 2015 related to reduction of nutrient load to the level of 1960s will be only partially achieved for nitrogen and phosphorus.

For each of the RBMP cycle, a basin-wide integrated assessment will be conducted every 6 years to assess the progress and document the lessons learned through the implementation process. With the determination of what pollution

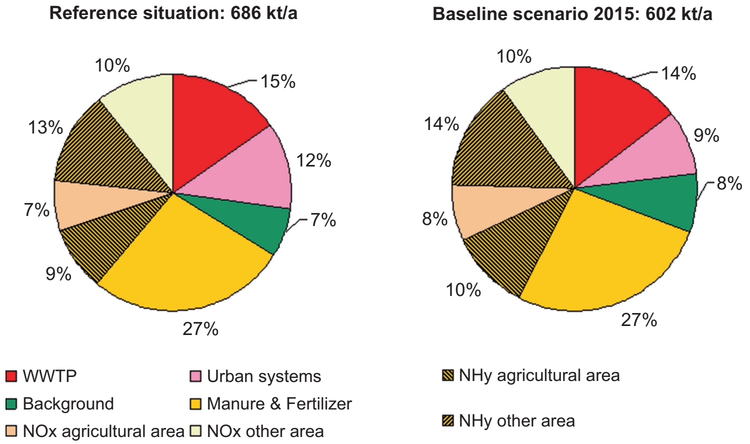


Fig. 6 Sources of nitrogen emissions in the DRB in 2006 and 2015

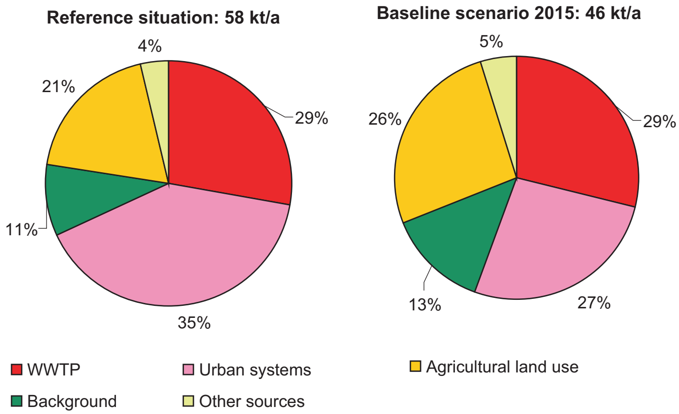


Fig. 7 Sources of phosphorus emissions in the DRB in 2006 and 2015

reductions are achievable, quantitative reduction targets can be established and future progress evaluated in relation to achieving respective WFD targets.

4 Conclusions

Nutrient removal is required to avoid eutrophication in many DRB surface waters and the Black Sea North Western Shelf, in particular taking into account the character of the receiving coastal waters as a sensitive area under the UWWTD.

The nutrient loads discharged from the DRB are an important factor responsible for the deterioration and eutrophication of parts of the Black Sea ecosystem.

The DRBM Plan highlighted that the nitrogen load to the Black Sea will reach a level that is below the present state but still far above (40%) that of the 1960s, and therefore, the management objectives and the WFD environmental objectives on the basin-wide scale will not be achieved by 2015. For phosphorous, the respective management objective and the WFD environmental objectives on the basin-wide scale will not be achieved by 2015, as the level will be still 15% above the level in the 1960s. This requires that further actions are taken beyond 2015. The implementation of the Nitrates Directive in EU Member States, an improved application of the concept of BAT in non-EU Member States, and the reductions in nutrient pollution achieved in wasterwater treatment plants with nitrogen and phosphorus removal for agglomerations >10,000 PE will reduce nutrient pollution considerably.

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