Nitrogen Emissions via Subsurface Flow Paths in the Odra River Basin

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Finished Phase III of the Polish-German-Czech joint research project "Investigations on the quantity of diffuse entries in the rivers of the Odra catchment and the Pomeranian Bay"

After reporting several times (ERWG letter 3, 4, 6, 7, 9) about the progress of the "PAN/DVWK Joint Project", selected final results shall be communicated in the following, which are part of the Final Report Phase III. For the time being this report is obtainable on CD-ROM from the authors, but is planned to be published in a more representative form in 2003.

The extended tasks of Phase III and the participating institutions, especially those associated since late 1998/early 1999, were completely listed in ERWG letter 9. In brief, the main objectives consisted in calculating the nutrient (N, P) emissions and presenting the actual, observed state of nutrient and heavy metal loads from point and diffuse sources for the entire Odra river system. Also some smaller German rivers directly entering the Oder Haff (Zalew Szczecinski) were included. Emission and load data had to be compiled for the period 1993/97 and compared with the period 1983/87 to evaluate the conformance of the actual situation with the targets of the HELCOM Agreement. In addition, scenario calculations had been planned to be performed for estimating the presumable spatial and temporal development of nutrient loads in the Odra river system.

As a main precondition, the digital database had to be completed. This included not only the historical nitrogen surplus for the last 50 years, actual nutrient and heavy metal emissions from sources outside the agricultural area, or data measured within the river system, but also basin-wide hydrological data such as groundwater contour lines and the depth to the groundwater. Furthermore, an attempt had to be undertaken to validate MODEST, the GIS-based modelling approach for computing groundwater-induced N emissions into the surface waters, which had been continually developed during the preceding phases of the project. The methodical work culminated in a comparison between MODEST and the groundwater component of the conceptual MONERIS model.

Because of the limited space, results will be selected exclusively from the compartment of subsurface nitrogen transport: root zone – subsoil – unsaturated zone – aquifer – surface water, whose analysis started with Phase I in 1996. A more detailed paper concerning the subsurface transport has been accepted for publication in the Polish Journal of Water and Land Development.

Nitrogen emissions via groundwater (MODEST)

As the key tool to calculate the spatial and temporal behaviour of groundwater-induced N emissions into the surface waters, a modelling approach has been developed and applied within the Odra joint project by the German and Polish groups from ZALF, IMUZ, and ARW. This approach called MODEST (**Mo**delling **D**iffuse Nitrogen **E**ntries via **S**ubsurface **T**rails) provides the required spatially distributed cause-effect analysis within the boundaries of coupled small river catchments (Dannowski et al. 2002a). It makes an identification of problematic agricultural areas possible, as well as a scenario-based appraisal of the ground and river water

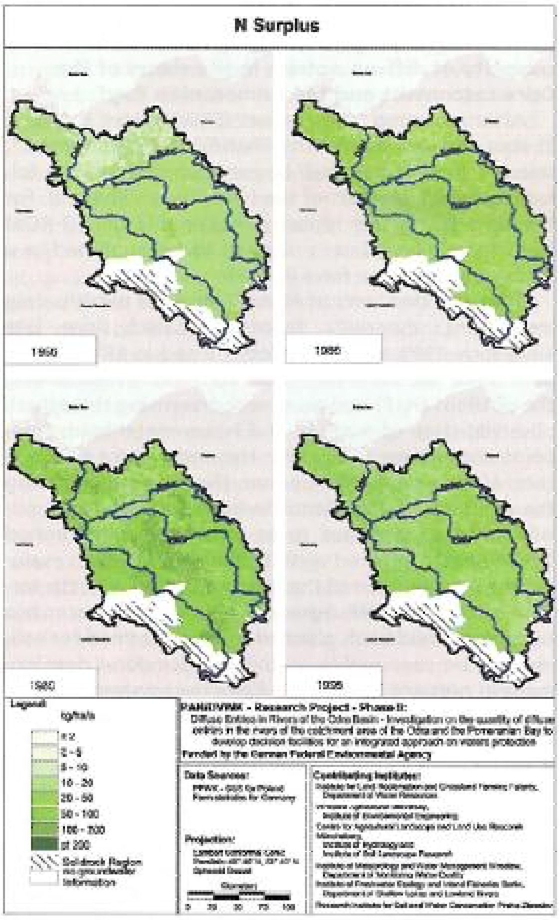

Fig. 9: Spatial N surplus distribution – snapshots of its historical development

quality in their future evolution. The distributed analysis has been restricted to that part of the unconsolidated rock region within the Odra river basin with existing complete information of the groundwater conditions (106,781 km²).

The nitrogen surplus from agricultural activity and atmospheric input has been collected in dependence on space and time with an increment of 5 years to serve as general input information for the region under study. This elaborate preparation was mastered by the ARW group for the Polish part on the basis of statistical data. For Germany data from Bach et al. (1998) were available. The resulting grid-based distributions (presented in Fig. 9 for four selected situations) have been incorporated into the MODEST calculations on groundwater-borne N transport.

Subsequent to the validation (discharge, concentration) and calibration (denitrification parameter) not documented here, MODEST was then used to calculate the fate of nitrogen in form of dissolved nitrates along the subsurface path (Dannowski et al. 2002b), comprehending the improved spatial and temporal database in its full extent. This was retrospectively executed for the historical development including the present state, as well as prospectively starting with the year 2000 for three scenarios.

The maximum N load attained the river system via groundwater around the year 1990, as a result of the increased N surplus 10 years before (Fig. 9, 11). In the reference year (1995, Fig. 10), in contrast to the actual N surplus of about 320,000 t, merely 24,482 t N have been presumably received by the surface waters via groundwater. The difference is due to both a remarkable transport delay and denitrification. The calculated and observed N load is emitted, according to the MODEST results, from only 30 % of the evaluated area.

Scenario calculations 2000/2020

Scenarios were defined taking the predicted use of nitrogen and decreasing agricultural land into consideration according to the official strategies for agricultural development elaborated by the Polish Ministry of Agriculture in 1999. It means that in the Odra basin about 20 % of the land may be withdrawn from agricultural use. All predictions show the use of nitrogen to be increasing, because of very low application nowadays. On the other hand, implementation of the best agricultural practice and increasing of the yield allowed one to assume that increasing of the resulting nitrogen surplus will not be very high. As the analysis has shown, it is not possible to give an exact estimation of the changes of agriculture. Therefore, for scenario calculations was as-

Fig. 10: Specific N load to be received via groundwater by the Odra river system in 1995 (MODEST)

sumed in a simplified manner, that the final (2020) surplus at agricultural land will be increased by 30 % for scenario 1, and decreased by 30 % for scenario 2 in comparison to scenario 0 ("Business as usual").

As to be expected, this variation of N surplus at the agricultural area is not equally reflected in the change of the specific N surplus. The resulting amount of specific N load variation as related to the overall evaluated area of the Odra basin is but ± 5 kg/ha/a resp. 15.6 % up to the year 2020. This is due to the portion of agricultural area in the entire evaluated catchment area as well as the specific N deposition supposed to be stagnant in all the scenarios at the level of 16.3 kg/ha/a.

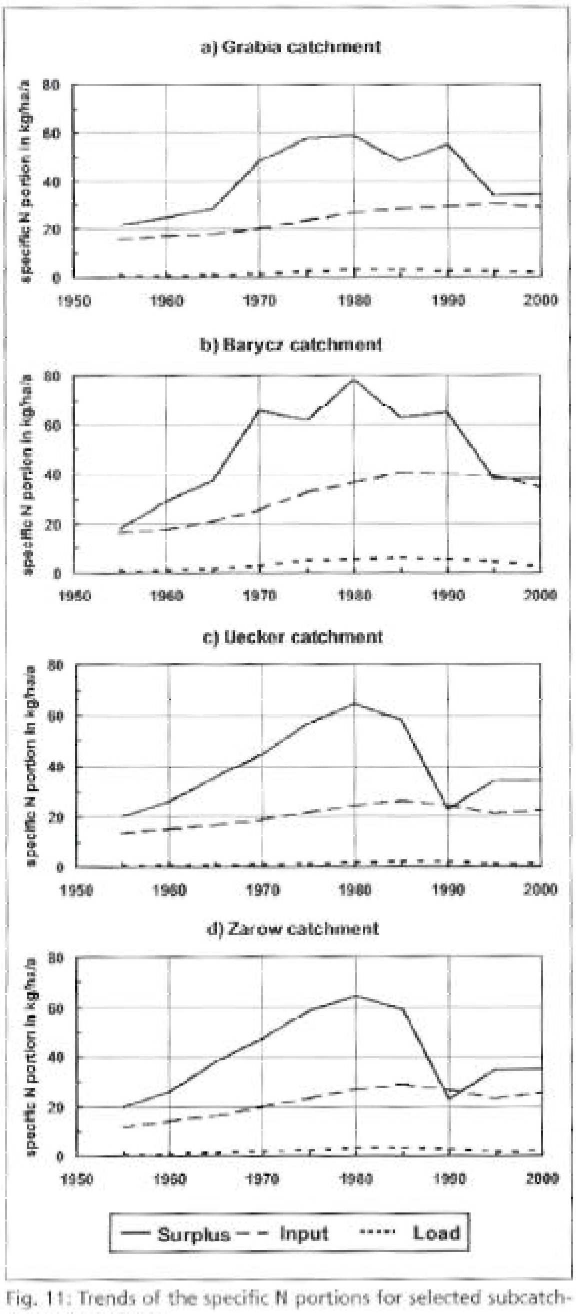

Fig. 11: Trends of the specific N portions for selected subcatchments (MODEST)

The damping and delaying effect of the subsurface N transport/denitrification is evident. Whereas in scenario 0 the specific N surplus does not change beyond the year 2000, the calculated specific N load will continue to decrease throughout the prospective period as a result of the sustained transport process characteristics. Interestingly no substantial time lag is occurring in scenarios 1 and 2 between starting of the changes and showing an effect in the calculated N loads. This may be explained by the very global scenario assumptions, which are quite in contrast to the spatially differentiated historical N surplus development. Consequently, the assumed unified trend of the specific N surplus may display a unifying effect in the scenario results.

Finishing Phase III of the joint project, the following can be stated:

- Close international co-operation resulted in an effective model- and GIS-based methodology for quantifying the dominating processes of subsurface nitrogen transport in large river basins under maximum utilisation of the available large sets of digital data.
- The emission-oriented distributed MODEST approach proved suitable for providing the cause-effect analysis of the subsurface nitrogen transport as required for constituting measures of the complex river basin management. It makes detailed local differentiation possible in analysing the impact of nitrogen on the quality of ground and surface waters at the regional scale, taking the varying intensity of agricultural land use into consideration, as well as climatic, topographic, geo-hydrological, and soil conditions.
- There is an option to upgrade the approach towards a GIS-based Decision Support System to be applied by authorities responsible for land use policies or basin-wide water management in complex river basins.

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