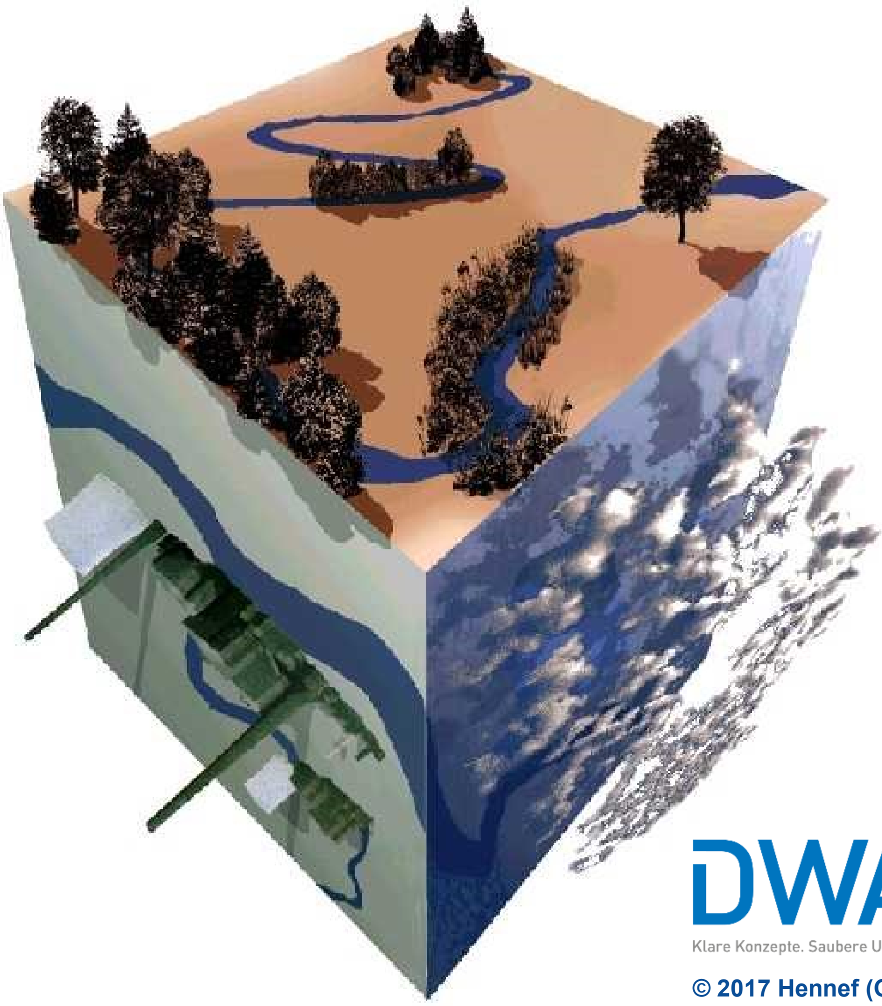
DWA – Water Quality Model *FGSM*



Klare Konzepte. Saubere Umwelt.

German Association for Water, Wastewater and Waste

Handout

DWA Water Quality Model

1 Features

The DWA Water Quality Model is a comprehensive and powerful tool for the dynamic simulation of quantitative and qualitative conditions and processes in rivers and streams. A rapidly evolving body of law and regulation, particularly on the European level, necessitates monitoring of surface waters within the broad objective of achieving and maintaining good ecological status. The importance of an integrated approach to water resources planning and development is emphasised. As frequent monitoring of surface waters with sufficient density is not practical, simulation monitoring has become a vital tool of water resources and water management.
A highly significant step in this direction was the issue of the Water Framework Directive of the European Commission in December 2000. This directive requires the development of river basin management plans including programs of measures to achieve prescribed water quality objectives within a defined time span.

The main objective in developing the DWA Water Quality Model was to create a generally available tool for water quality management adjusted predominantly to the practical day-by-day activities in public agencies, private companies and research institutions. The model, available in a new version in 2015, has found remarkable acceptance in water resources practice. Applications range from large rivers to small brooks. Special attention is focused on small watercourses, because they are highly sensitive to changes in morphological, physical and chemical environmental conditions. Table 1 shows fields of application in water quality simulation.

Table 1: Water quality simulation, fields of application

Fields of application	**Comments**
Data analysis	Interpretation of measurement data with respect to • Extreme values • Reasons for periodic and random variations • Longitudinal differentiations • Reconstructions of missing data in space and time Generation of continuous graphs of various parameters in space and time reflecting measurement data • Longitudinal profiles • Time series Analysis of data requirements • Design and control of monitoring networks • Selection and composition of sets of measurement data • Required density of measurements in space and time
Systems analysis	• Analysis of sources, sinks and transformation processes relevant for water quality • Determination of relevant parameters in physical, chemical and biological processes
Comprehensive presentation of quality information and simulation results	In connection with geographic information systems • Presentation of water quality in space and time • Presentation of relevant influences • Presentation of cause-effect relations
Management planning Investigation of the environmental behaviour of priority substances Environmental impact assessment	• Comparison of results for different planning scenarios • Cost effectiveness under studies in context of effluent requirements • Determining potential effectiveness of proposed measures with respect to water quality objectives or uses • Design and evaluation of alternatives in morphological remediation of rivers • Estimation of fate of priority substances in river systems • Development of measures for attaining the aquatic milieu and habitat conditions required to achieve the ecological objectives
Development of rules for systems regulation, operational optimisation and management	• E.g. discharge regulations in case of accidental pollution • Design of minimum flow in case of water abstractions • Design and optimisation of combined sewer systems and effluent allocation
Development and operation of alarm systems	Predicting the progress downstream of pollutants following accidental discharges, in combination with monitoring systems

Despite its high complexity, the handling of the model is not difficult to learn, since several supporting tools and routines facilitate the implementation, data acquisition and application. The user receives a detailed handbook with the model. Moreover, the DWA offers training courses and a hotline. Experiences with practical application of the model are presented and discussed in user conferences. They may provide the basis for further improvements and extensions of the model.

The model is strictly modular in structure. It consists of the following six parts:

- Data input
- Data processing and administration
- Module for flow simulation
- Modules for quality simulation
- Solution of the transport equation
- Presentation of results

The general availability and required flexibility in application could only be achieved by following certain specifications concerning the model as a whole and in its parts as shown in Table 2.

Table 2: Specifications for development of DWA Water Quality Model

Simulation of river systems including diversions, water transfer systems, interaction with groundwater etc.
Simulation of static and highly dynamic processes (accidental pollution)
Integrated flow simulation
Low numerical dispersion in solutions of transport equation
Adjustment to list of simulation parameters according to requirements in Table 1
Modular structure of the model
Selection of quality module combinations according to the actual problem
Reduction of data acquisition effort by providing supporting tools (internal database, standard profiles etc.)
Facile handling of model, detailed model documentation, training and support of users
Long-term fitting of model to trends and changes in water management practice and legal and administrative frame conditions

The model contains 20 separate modules as shown in Table 3: a flow simulation model which allows the computing of both static and highly dynamic flows for monotonous or branched river systems; and 19 modules which comprise the physical, chemical and biological processes relevant to water quality. Calculations involving the latter 19 can only be performed in conjunction with the flow simulation module.
The flow simulation is based on the St-Venant-Equations, the simulation of the quality constituents on the transport equation. The algorithm for the solution of the transport equation is nearly free of numerical dispersion and thus particularly suitable in cases of accidental pollution.

Table 3: Modules of DWA Water Quality Model

No.	Name
0	Flow
1	Radiation
2	Water temperature
3	Conservative substances, tracer
4	BOD / COD
5	Phosphorous
6	Nitrogen compounds
7	Silicate
8	Diatoms
9	Green algae
10	Zooplankton I
11	Zooplankton II
12	Benthic flora and fauna, exchange with the sediment
13	Suspended solids
14	Oxygen balance
15	pH-value
16	Heavy metals
17	Organic substances
18	Iron
19	Hygiene (e.coli)

The modules are highly interrelated. For each simulation problem a suitable combination has to be composed. To avoid mistakes due to incorrect selection of modules a number of combinations for common applications are predefined. These are tabulated and can be selected individually. To provide flexibility, a large number of options have been introduced which assure proper adjustment of the model to the actual problem structure. The users may also select or switch of certain functions according to their relevance in the actual case.

The simulation of status quo scenarios delivers, as verified through actual measurements, an enormous gain in knowledge. Results available for freely selectable time intervals and river locations which cannot be obtained in any monitoring programme due to the high labour requirement. Consequently, the time and effort required for measuring campaigns can be held to a minimum (saving potential).
Moreover, results for periods of time which are not usually represented in measuring campaigns (e.g. night time), are available.

A core tasks of water quality simulation is to provide impact analysis for planning purposes. Based on a real system the given status is modified according to a variety of planning alternatives. The results of the model calculations serve as a basis for assessing the planning variants.

2 Interfaces with other water management models

The DWA Water Quality Model was designed to ensure facile connection to other models used in water management. Data transfer takes place transparently via ACII data interfaces. So, it is possible – and also tested in practice – to interface the DWA Water Quality Model with model tools which calculate the effects of precipitation in catchments (precipitation runoff models, sewer network models), for example. Precisely such precipitation induced model calculations often represent the loading conditions which emerge as worst-case scenarios for quality management in flowing waters. Figure 1 shows an example of coupling precipitation runoff simulation and sewer network simulation with the DWA Water Quality Model for the water management-relevant parameter ammonium.

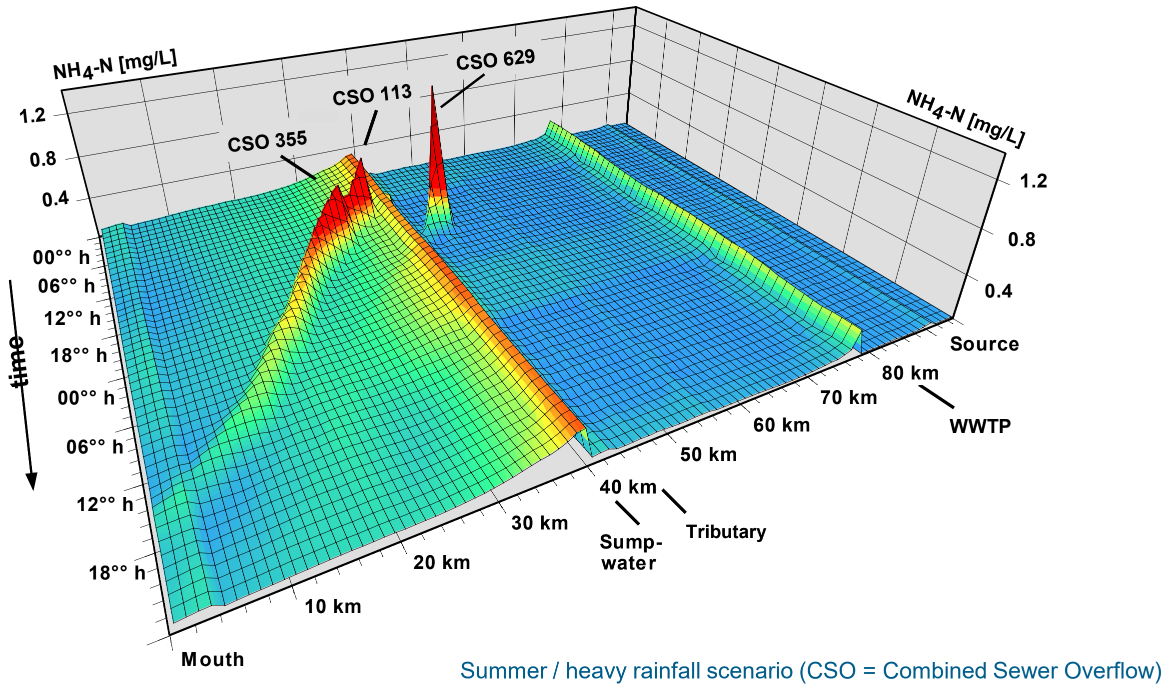


Figure 1: Ammonium concentration during heavy precipitation in the middle reaches of a river (model coupling: NASIM, LWA-FLUT and DWA Water Quality Model; CSO = combined sewer overflow, GKW = collective wastewater treatment plant)

3 Use of the model for teaching purposes / public relations

To further its establishment, it is essential that young specialists are provided with the opportunity to get to know and use the DWA Water Quality Model during their studies.

Experience proves that instruments used in the course of studies successfully, are preferred for use in professional life.

Within the scope of regular lectures the DWA Water Quality model was / is introduced to students at the following universities:

- Duisburg-Essen University
- RWTH Aachen University
- Trier University
- Braunschweig University

4 Model application up to present

Until now more than 70 licences to use the model have been sold to authorities, engineering offices, associations, universities, municipalities and industrial plants. The licence revenues are used to further develop the model. Several user conferences have shown the model being applied to address various water management issues. The DWA Water Quality Model is also used in several R&D projects. Some fields of application can be mentioned as examples in which water management-relevant planning processes have been supported through use of the DWA Water Quality Model:

- Water quality simulation as an instrument for analysing the impact of point discharges in flowing water systems (tested on the Werse river)
- Management planning according to the European Water Framework Directive (tested on the Niers river)
- Modelling of planned measures influencing the oxygen balance (tested on the Havel river)
- Modelling of heat load induced by cooling water and sump water discharges (tested on the Erft river)

5 Model sustainability

In the course of the reinforced immission-orientated approach to water management, various fields of application open up for using the DWA Water Quality Model. A number of key topics covered by Water Framework Directive provisions can be addressed through water quality modelling are in essence:

- Condition analysis, deficit analysis
- Planning of measures and assessment
- Water monitoring
- Public relations

The model supports condition analysis by presenting current load status and general conditions of the ecology in flowing water bodies related to different loading, climate and runoff scenarios. The deficits relative to the target status serve as a basis for planning of measures. In reflects to the Water Framework Directive the simulation of the water status delivers in particular the bases for assessing the sensitivity of flowing waters with respect to loads (significance of loads).

Water quality modelling can also be used for measure planning. Classical fields of application are verification of fulfilment Water Framework Directive objectives or guarantee of relevant water uses via a combination of selected measures. Selection of optimal alternatives based on a transparent rating system is necessary. Essential criteria are:

- Estimation of effects of measures
- Feasibility of measures
- Fulfilment of Water Framework Directive requirements
- Cost optimisation, comparison of costs, cost recovery
- Implementation concept (prioritisation, time frame, virtual states)
- Acceptance of measures

In accordance with the demand for cost efficiency set down in the Water Framework Directive, the simulation results also deliver the basis for the comparison of effects of different planning alternatives in the scope of cost effectiveness studies. Due to the integrated modelling of quantity and quality and the application of hydraulic methods for runoff simulation, the DWA Water Quality Model is also an effective tool for investigating the effects of design variations in restoration projects.

Last but not least, should also be noted that it is possible to estimate the behaviour of chemicals (e.g. organic micropollutants) in flowing waters.

6 Chances on international market

Favourable market opportunities arise for the present English-speaking, exportable version of the DWA Water Quality Model. Moreover, the international distribution of the model supports the representation of know-how present in the Federal Republic of Germany. This expert knowledge is documented in a field-tested, scientifically sound tool and it is put into service of both the European and non-European water management. Other model developers, in the United States for example, operate worldwide, though, the quality models mostly do not have the same performance features (e.g. radiation module) as the DWA Water Quality Model has. Based on the acceptance of the model during model acquisition at the federal level, prospects for successful international distribution of the DWA Water Quality Modell appear excellent.

7 Professional supervision

The DWA working group GB-1.4 “Modellrechnung in der Wassergütewirtschaft” (model calculation in water management) is responsible for professional supervision. Members of the working group are:

Dr. rer. nat. Ekkehard Christoffels, Erftverband, Bergheim (spokesman)
Dipl.-Systemwiss. Sven Ernesti, TriniDat, Düsseldorf
Dipl. Biol. Ulrich Kaul, Bayerisches Landesamt für Umwelt, Augsburg
Dipl.-Ing. Volker Kirchesch, German Federal Institute of Hydrology, Koblenz
Dr. Klaus Peter Lange, Ecosystem Saxonia, Dresden
Dr. Mike Müller IGB Leipzig Ingenieurbüro für Grundwasser GmbH, Leipzig
Dr. Steffen Müller, formerly Bayer. Landesamt für Wasserwirtschaft, Munich
Prof. Dr. Andrè Niemann, University of Duisburg-Essen
Dipl. Biol. Andreas Petruk, Lippeverband, Essen
Dipl.-Ing. Markus Rosellen, Erftverband, Bergheim
Dr. Stefan Schwarzer Ingenieurbüro, Leipzig

8 Conditions (plus value added tax)

1) DWA Water Quality Model (English version)

• Program incl. User Manual	free
• 2.5-day introductory course	by arrangement
• User conferences (invitation will be sent automatically)	free
• Hotline	by arrangement

9 Application of the DWA Water Quality Model (in brief)

European research project “Application of integrative modelling and monitoring approaches for river basin management evaluation (M3)“
Tudor (Luxemburg), Delfland (Niederlande), Erftverband (Bergheim)

Federal Ministry of Education and Research R&D project in the scope of the support initiative ‘river basin management’
Title: Stoff- und Datenmanagement in Flusseinzugsgebieten für Schwermetalle am Beispiel der Erft (Substance and data management for heavy metals in river catchments using the example of the Erft)
RWTH-Aachen / Erftverband, Bergheim

Model-supported optimisation of the investment of financial resources for improving the oxygen balance in the Neckar
University of Stuttgart
Department for Water Engineering by order of the Federal State Baden-Wuerttemberg

Water quality simulation in consideration of diffuse nutrient input hydrographs
Work report April 2002 ISBN 3-935669-85-2
DWA working group GB 5.6 „Diffuse Quellen“ (diffuse sources)

Water quality simulation as a practical tool for management planning of local river basins with the example of the Werse

Final report March 2002, by order of the Federal State North Rhine-Westphalia
North Rhine-Westphalia State Environment Agency / Staatliches Umweltamt Münster (environmental agency)/ Research Institute for Water and Waste Management at RWTH Aachen (FiW) / Erftverband aqua tec

Applicability of the DWA model for the North Rhine-Westphalia state government and determination of the influence of combined sewer overflow on the Werre
University of Paderborn branch Höxter, by order of the Federal State North Rhine-Westphalia

Application of the DWA Water Quality Model for developing management plans according to the European Water Framework Directive on the example of the Niers
AEW Plan / Niersverband / Staatliches Umweltamt Krefeld (municipal office of environment), by order of the Federal State North Rhine-Westphalia

Expert opinion concerning management of the Weiße Elster
Assessment of the influence on the water quality of measures minimising erosion within the scope of the Expo project 'Jahne'
Ecosystem Saxonia GmbH, Dresden

General management planning of the Glems river near Stuttgart
Ingenieurgesellschaft (engineering society) Prof. Dr. Sieker GmbH, Dahlwitz-Hoppegarten

Combined influence of wastewater treatment plants and combined sewer overflows with the example of the submountainous mountain stream Gersprenz near Brensbach
Darmstadt Regional Council

Investigation of the ecological potential of the Untere Wupper
Effects of combined sewer discharges on the example of the Dhünn
Wupperverband, Wuppertal

Scenarios concerning the influence of modified hydrological and morphological conditions on oxygen balance and phytoplankton development in the lower reaches of the Spree
Leibniz-Institute of Freshwater Ecology and Inland Fisheries, Berlin

Simulation of the federal waterway Neckar
Landesanstalt für Umweltschutz Baden-Württemberg

Simulation of the influence of wastewater treatment plant discharges with the example of the Altmühl
Investigation of the effects of structural measures with the example of the Roter Main
Investigations on problems of eutrophication of the Main
Bayerisches Landesamt für Wasserwirtschaft, München

Thermal load plan Lippe
Lippeverband, Essen

Investigation on the effects of combined sewer discharges at the Hasseler Mühlenbach
Lippeverband, Essen

Study of effects of future development of sump water discharges on the Erft
Erftverband, Bergheim

Influence of wastewater treatment plant discharges on water quality of small low mountain range rivers – description of status conditions and simulation of water management-relevant measures
Landesamt für Wasserwirtschaft Rheinland-Pfalz (State Office for Water Management Rhineland-Palatinate)

Modelling of the Mittlere Ruhr – Study on application of DWA Water Quality Model
Ruhrverband, Essen

Expertise for assessing water management and water ecological effects of different variants of water use by power plants
WASY GmbH, Berlin

10 Publications Directory

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6. Workshop zur großskaligen Modellierung in der Hydrologie, Schwerpunkt "Flussgebietsmanagement", Umweltforschungszentrum Leipzig-Halle, Magdeburg, ISBN 3-89958-031-1

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