The ATV-DVWK-Water Quality Model

The ATV-DVWK-Water Quality Model is a comprehensive and powerful tool for the dynamical simulation of the quantitative and qualitative conditions and processes in rivers and streams. It was developed by a working group of the ATV-DVWK in cooperation with the Institute for Applied Mathematics and Statistics of the Technical University of Munich, Germany and several other research institutions. The necessity of a water quality simulation model for use in the practice of water quality protection and watershed management was stipulated by several legal and regulatory activities coming into force in the last years, in particular on the European level, which emphasized the importance of an integrated approach to water management planning and development. The latest and most important step in this direction was the issue of the so-called Water Framework Directive of the European Commission in December 2000. This directive requires the development of river basin management plans including programs of measure to achieve prescribed water quality objectives within a defined time span.

The main objective in developing the ATV-DVWK-Water Quality Model was to create a general available tool for the analysis and solution of water quality problems, which could be adjusted predominantly to the practical day by day activities in administrations, private companies or research institutions. The model is available in version 1.x for several years now and has found a remarkable acceptance in water resources practice. It was applied already in a number of cases, ranging from large rivers to small streams and brooks in rural as well as heavily urbanized areas. A reference list can be found at the end of this text. Special attention is focused on the applicability for smaller watercourses, which usually react very sensitive to changes in the morphological and physico-chemical conditions.

The model can be utilized in a large variety of water management problems. An overview is given in Table 1.

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 periodical and random variations • Longitudinal and cross sectional differentiations • Reconstructions of missing data in space and time Generation of continuous parameter runs of periodical graphs of derived from discrete measurements: • 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
System 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 water quality information and simulation results	In connection with GIS-systems: • Presentation of the water quality in space and time • Presentation of relevant influences • Presentation of cost/benefit relations
Cause-effect relations for management planning Investigation of the environmental behavior of priority substances Environmental impact assessment	• Comparison of results for different planning scenarios • Cost/benefit analysis in context with effluent requirements • Assessment of advanced requirements with respect to quality objectives or uses • Design and evaluation of alternatives in the morphological restoration of rivers • Estimation of the fate of priority substances in river systems • Development of measures for achieving the aquatic milieu and habitat conditions required for the ecological objectives
Development of rules for systems regulation, operational optimization and management	• E.g. regulations in case of accident pollution • Design of minimum flow in case of water abstractions • Design and optimization of mixed sewer systems and effluent allocation
Development and operation of alarm systems	Tracing of accidental pollution in river systems in combination with monitoring systems

The suitability of the model for all the applications given in Table 1 could only be achieved by a proper design of its overall concept. The model structure is strictly modular and consists of 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 prerequisite of a general availability of the model and a high flexibility in the application has lead to certain specifications and requirements concerning the model in total and its parts. Some of these specifications are given in Table 2.

Table 2: Specifications for the development of the water quality model of the ATV-DVWK

Simulation of river systems including diversions, water transfer systems, interactions with groundwater etc.
Simulation of static and highly dynamic processes (accidental pollution)
Integrated flow simulation
Low numerical dispersion in the solutions of the transport equation
Modular structure of the model
Adjustment of the set of simulation parameters according to the requirements of Table 1
Selection of quality module combinations according to the actual task
Geo-referenciation of the simulation system including the network of water bodies and all structural and regulatory elements
Reduction of efforts for data acquisition by providing supporting tools (internal database, standard profiles, data requirements confined to the selected module combination etc.)
Easy handling of the model, detailed model documentation, training and support of the users
Long term fitting of the model to the trends and changes in water management practice and in legal and administrative frame conditions.

The input of all spatial data at the screen is based on a digitized topographic map, which is geo-referenced by the user at the beginning, where all data are attributed with their Gauss-Krueger-Coordinates. The geo-reference is used for some processes in the model; additionally it facilitates the connections to a geographic information system.
Despite of its high complexity, the handling of the model offers a user-friendly GUI (Graphical User Interface) and the implementation, the data acquisition and the application is facilitated by several supporting tools and routines. Together with the model the user gets a documentation package comprising a handbook, a user manual and a model description, which includes all implemented mathematical equations. Moreover the ATV-DVWK is offering training courses and a hot-line. In yearly user conferences the experiences derived from practical case studies are presented and discussed. The feed back from the users is an important source of ideas for further improvements and extensions of the model.

The model includes 18 separate modules as shown in Table 3. They comprise the flow simulation and the important physical, chemical and biological processes, which are relevant for the overall water quality in water bodies.

Table 3: Modules of the water quality model

No.	Name
0	Flow
1	Radiation
2	Water Temperature
3	Conservative Substances, Tracer
4	BOD/COD
5	Phosphorous
6	Nitrogene Compounds
7	Silicate
8	Diatoms
9	Green Algae
10	Zooplankton I
11	Zooplankton II
12	Benthic Flora/Fauna (exchange with the sediment)
13	Suspended Solids
14	Oxygen Budget
15	pH
16	Heavy Metals
17	Organic Substances

The flow simulation is based on the St-Venant-Equations, which are solved completely by the method of characteristics. The algorithm for the solution of the transport equation is practically free of any numerical dispersion and therefore in particular suitable for the simulation of highly dynamic processes, such as storm water discharges.

The **radiation** is simulated considering all influences from the upper part of the atmosphere to the water surface and further down to the bottom of the water column, the sediment and back into the water column. The radiation is the basis for the simulation of the temperature in the water body and at the sediment as well as for photosynthesis and photolysis. The **conservative substances** are influenced by transport and dispersion processes only. They are used mainly for the simulation of tracer experiments and therefore for the adjustment of the hydraulic parameters. The **BOD** is calculated in conjunction with the **COD.** Both are closely connected with several other modules, their breakdown is particularly influencing the oxygen contents. In the following three modules the **nutrients** (phosphorous, nitrogen and silicate) are simulated. They are influencing mainly plant growth. The nitrogen cycles play additionally an important role for the oxygen balance. The modules 8 to 12 describe the development of the **flora and fauna** represented by the phytoplankton, the sessile macrophytes and the phytobenthos as well as the primary and secondary consumers and the macrozoobenthos. These modules are highly connected amongst themselves and with several others. Together they form an important central part of the model. The **suspended solids** in the next module are influencing the light distribution in the water body as well as the adsorptive transport as particulate matter, e.g. of heavy metals. The **oxygen balance** is essential for the aerobic aquatic life and therefore one of the key elements of the model. The simulation of the pH-Value is necessary, when the heavy metals were introduced in the model and it is governing the equilibrium of ionized ammonia and unionized ammonia. Heavy metals and organic priority substances are the last modules. The fate of the organics in the water body is described by five processes (such as photolysis), which are activated according to the specific properties of the simulated substance.

The modules are highly interrelated with one-another. For the simulation of a task a suited combination of modules can be selected. Additionally a large number of options are available to provide a proper adjustment of the model to the actual problem structure. In order to improve flexibility the user has furthermore the possibility to select or to switch off certain functions according to their relevance in the actual case.

Members of the Working Group:

Name	address	phone/ fax/ mail
Dipl. Umweltwiss. Dipl.-Ing. Ekkehard Christoffels	Erftverband Pfaffendorfer Weg 42 D 50126 Bergheim	phone: +49 (0) 2271/88-1109 fax: +49 (0) 2271/88-1210 mail: ekkehard.christoffels@erftverband.de
Dipl.-Biol. Ulrich Kaul	Bayerisches Landesamt für Wasserwirtschaft Lazarettstraße 67 D 80636 München	phone: +49 (0) 89/9214-1129 fax: +49 (0) 89/9214-1692 mail: ulrich.kaul@lfw.bayern.de
Dipl.-Ing. Volker Kirchesch	Bundesanstalt für Gewässerkunde Postfach 309 D 56003 Koblenz	phone: +49 (0) 261/1306-5537 fax: +49 (0) 261/1306-5511 mail: kirchesch@bafg.de
Dr. rer. nat. Klaus Peter Lange	Ecosystem Saxonia GmbH Thomas-Müntzer-Str.5 D 01307 Dresden	phone: +49 (0) 351 /21119-0 fax: +49 (0) 351 /2111911 mail: ecodrlange@aol.com
Dr.-Ing. André Niemann	Dr. Dahlem Beratende Ingenieure Bonsiepen 7 D 45136 Essen	phone: +49 (0) 201/ 89 67 115 fax: +49 (0) 201 / 8967 123 mail: a.niemann@drdahlem.de
Dipl.-Biol. Andreas Petruck	Emschergenossenschaft/Lippeverband Kronprinzenstraße 24 D 45128 Essen	phone: +49 (0) 201 /104-2344 fax: +49 (0) 201 /104-2904 mail: apetruck@eglv.de
RD Dr. rer. nat. Steffen Müller	Bayerisches Landesamt für Wasserwirtschaft Lazarettstraße 67 D 80636 München	phone: +49 (0) 89/9214-1161 fax: +49 (0) 89/9214-1435 mail: steffen.mueller@lfw.bayern.de

guests		
Dr. rer. nat. Tanja Bergfeld	Bundesanstalt für Gewässerkunde Postfach 309 56003 Koblenz	Tel: 0261/1306-65520 Fax: 0261/1306-65152 mail: bergfeld@bafg.de
Dipl.-Ing. Markus Rosellen	Erftverband Pfaffendorfer Weg 42 50126 Bergheim	Tel: 02271/88-1319 Fax: 02271/88-1210 e-mail: markus.rosellen@erftverband.de
Prof. Dr. Ch. Wilhelm	Universität Leipzig Institut für Botanik – Pflanzenphysiologie Johannisstr. 21-23 D 04103 Leipzig	phone: +49 (0) 341/9736874 fax: +49 (0) 341/9736899 mail: cwilhelm@rz.uni-leipzig.de

Further information about the ATV-DVWK-Water Quality Model is available at the following address:

ATV-DVWK GB-4.2
Speaker of the Working Group
Ekkehard Christoffels

c/o Erftverband
Paffendorfer Weg 42
D 50 126 Bergheim

phone: +49 (0) 2271/88-1109
fax: +49 (0) 2271/88-1210
mail: ekkehard.christoffels@erftverband.de

References

Model-based optimization of financial resources for the improvement of the oxygen budget in the Neckar, Germany (Modellgestützte Optimierung des Einsatzes finanzieller Mittel zur Verbesserung des Sauerstoffhaushalts im Neckar)
University of Stuttgart
Institut für Wasserbau
im Auftrag des Landes Baden-Württemberg

Water Quality simulation unter particular accounting of daily pattern of nutrient inputs (Gewässergütesimulation unter besonderer Berücksichtigung von Tagesganglinien diffuser Nährstoffeinträge)
Arbeitsbericht April 2002 ISBN 3-935669-85-2
ATV-DVWK-Arbeitsgruppe GB 5.6 „Diffuse Quellen„

Water quality simulation as a practical instrument fort he management of local river basins by the example of the river Wese, Germany (Gewässergütesimulation als praxisnahes Instrument zur Bewirtschaftungsplanung lokaler Flussgebiete am Beispiel der Werse)
Abschlussbericht März 2002, im Auftrag des Landes NW
Landesumweltamt NW / Staatliches Umweltamt Münster / Forschungsinstitut für Wasser- und Abfallwirtschaft FIW an der RWTH Aachen / Erftverband aqua tec

BMBF R&D project in the context of the initative River Basin Management (BMBF-FuE-Vorhaben im Rahmen der Förderinitiative Flussgebietsmanagement)
Substance and data management in river basins of heavy metals at the example of the Erft (Stoff- und Datenmanagement in Flusseinzugsgebieten für Schwermetalle am Beispiel der Erft)
RWTH-Aachen / Erftverband, Bergheim

Usability of the ATV-DVWK Water Quality Model for the state administration of North-Rhine Westfalia and quantification of combined sewage overflows on the river Werre, Germany (Anwendbarkeit des ATV-DVWK-Modells für die Landesverwaltung NW und Ermittlung des Einflusses von Mischwasserentlastungen auf die Werre)
Universität Paderborn Außenstelle Höxter, im Auftrag des Landes NW

Use of the ATV-DVWK water quality model fort he development of plans of measures according to the EU-WFD at the example of the Niers (Einsatz des ATV-DVWK-Gewässergütemodells bei der Erarbeitung von Bewirtschaftungsplänen nach der EU-Wasserrahmenrichtlinie am Beispiel der Niers)
AEW Plan / Niersverband / Staatliches Umweltamt Krefeld, im Auftrag des Landes NW

Study of the management of the Weiße Elster – Evaluation of the effect of measures fort he minimization of erosion on water quality in the context of the EXPO project Jahne (Gutachten zur Bewirtschaftung der Weißen Elster
Bewertung des Einflusses von Maßnahmen zur Erosionsminderung auf die Gewässergüte im Rahmen des Expo-Projekts Jahne)
Ecosystem Saxonia GmbH, Dresden

Plan of measures fort he Glems near Stuttgart, Germany (Generelle Bewirtschaftungsplanung der Glems

bei Stuttgart)
Ingenieurgesellschaft Prof. Dr. Sieker GmbH, Dahlwitz-Hoppegarten

Combined influence of sewage treatment plants and combined sewage overflows at the example of the sub-montainian stream Gersprenz near Brensbach, Germany (Kombinierter Einfluss von Kläranlagen und Mischwasserentlastungen am Beispiel des submontanen Bergbachs Gersprenz bei Brensbach)
Regierungspräsidium Darmstadt

Investigation of the ecological potential of the lower river Wupper, Germany (Untersuchung des ökologischen Potenzials der Unteren Wupper)
Impact of CSO on the river Dhünn, Germany (Auswirkungen von Mischwassereinleitungen am Beispiel der Dhünn)
Wupperverband, Wuppertal

Scenarios of the influence of changes hydrological and morphological conditions on the oxygen content and the development of phytoplankton in the lower reches of the Sree (Szenarien zum Einfluss veränderter hydrologischer und morphologischer Bedingungen auf den Sauerstoffhaushalt und die Phytoplanktonentwicklung im Unterlauf der Spree)
Leibniz-Institut für Gewässerökologie und Binnenfischerei, Berlin

Simulation of the state water way Neckar (Simulation der Bundeswasserstrasse Neckar)
Landesanstalt für Umweltschutz Baden-Württemberg

Simulation of the influence of sewage treatment works effluents at the example of the Altmühl (Simulation des Einflusses aus Kläranlageneinleitungen am Beispiel der Altmühl)
Survey on the effects of morphological measures at the example of the Rote Main (Untersuchung der Auswirkungen von Strukturmaßnahmen am Beispiel des Roten Mains)
Survey on the eutophy problem at the Main (Untersuchungen zur Eutrophierungsproblematik des Mains)
Bayerisches Landesamt für Wasserwirtschaft, München

Dynamic simulation of water temperature of Evaluation of the impact of thermal discharges on the temperature budget of a lowland stream using a dynamic water quality model.
Petruck A., Beckereit, M. and Stemplewski J (2003), in River Basin Management II (ed. C.A. Brebbia), Wessex Institute of Technology, pages 279-287.

Dynamic Simulation of the effects of combined sewage overflow on an urban lowland stream
Petruck A., Sperling F., and Jäger D. (1998), Water Science and Technology

Studies on the effects of future developments of the discharges of mining water on the river Erft, Germany (Studie zu den Auswirkungen der künftigen Entwicklung der Sümpfwassereinleitungen für die Erft)
Erftverband, Bergheim

Impact of the effluent of sewage treatment plants on the water quality of small mountain brooks – Description of the status and simulation of water resources measures (Einfluss von Kläranlagenabläufen auf die Gewässergüte von kleinen Mittelgebirgsbächen - Zustandsbeschreibung und Simulation wasserwirtschaftlicher Maßnahmen)
Landesamt für Wasserwirtschaft Rheinland-Pfalz

Modelling of the middle river Ruhr, Germany – Study for the usability of the ATV-DVWK Water Quality Modell (Modellierung der Mittleren Ruhr - Studie zum Einsatz des ATV-DVWK-Gewässergütemodells)
Ruhrverband, Essen

Survey of the water resources management and water quality effects of different variations of water usage of thermal power plants (Gutachten zur Beurteilung der wasserwirtschaftlichen und gewässerökologischen Auswirkungen unterschiedlicher Varianten der Wassernutzung von Kraftwerken)
WASY GmbH, Berlin