Modelling of Water Flow and Water Transport as the Basis for Predicting the Distribution of Diffuse Solute Input into the Groundwater.

Johann FANK, Gerhard ROCK

January, 29th 2007
Content

- **Introduction**
- **Groundwater flow and transport modelling**
  - Transient groundwater flow modelling
  - Transient groundwater transport modelling (tracer)
- **Concepts for coupling unsaturated and saturated transport modelling**
  - Sequential coupling of unsaturated and saturated zone model
  - Particle tracking of nitrate concentration in the groundwater flow model
  - Water and solute balancing
- **Conclusions**

**Prediction of solute distribution in groundwater**

- **Prediction of solutes distribution from point sources**
  - transport modelling based on groundwater flow models and the concept of hydrodynamic dispersion.
  - Shallow aquifers:
    - 2D groundwater flow model
    - flow parameters as a mean value over the aquifers depth
    - Transport modelling assumes a full mixing of the solute in the aquifer
- **Prediction of the impact from diffuse sources**
  - the location of the source equals the area of prediction
  - entry of solute mass acts on different locations all over the prediction area in a high variability in time
Agricultural test area and research station Wagna

Latitude 46.7 ° N  
Longitude 344.5 ° W  
Altitude 266.7 m a.s.l.  
Extent 300 x 200 m

36 Test fields (20 x 50 m)  
K – conventional farming  
B - organic farming

2 lysimeters  
K_MONO  
B_MONO

Groundwater  
Flow Direction N – S  
Overburden 3.5 – 5.0 m  
Thickness 3.5 – 5.0 m  
Hydr. Cond. $3.3 \times 10^{-3}$ m/s  
Flow velocity ~ 1 – 2 m/d

Calibration of a transient groundwater flow model
Calibration of a transient groundwater flow model

Hydraulic Conductivity
- 0-0.3 m: agricultural land
- 0.3-1.5 m: Observation Points
- 1.5-3.0 m: groundwater table elevation in m a.s.l.


GW [m a.s.l.]
wb30  wb12  wb02  Tracing Experiment

Tracer injection

max. Br C [mg/l]
- > 50 mg/l
- > 19 mg/l
- > 1 mg/l
- <= 1 mg/l

agricultural land fields
groundwater table elevation [m a.s.l.]
Calibration of a transient Bromide transport model

- Using experimental dispersivity parameters model calibration at the central flow line is well done, concentrations at measuring points beside is over-estimated
- Numerical transport modelling is extremely sensitive to unobserved transient groundwater flow processes
Modelling solute distribution from diffuse sources

Data Base

- Regional scaled transient 2D groundwater flow model for the western part of the Leibnitzer Feld calibrated on a daily basis (1993 – 2003)
- SIMWASER & STOTRASIM calculated groundwater recharge and nitrate input into the groundwater for the test field as presented by H. KUPFERSBERGER on a daily basis (1987 – 2003)

Goal: Estimation of Nitrate concentration distribution in space and time for the test area

Sequential coupling of unsaturated and saturated zone model

Non reactive transient 2D FE groundwater transport model

- Based on the 2D flow model
- Dispersivity was set to 5 m, 0.5 m respectively
- Results of unsaturated zone modelling have been used as an upper boundary condition for
  - Water flow
  - Nitrate concentration

Nitrate concentration at the inflow boundary has been estimated using a solute balance model based on the mixing equation

- Groundwater flow balance at the inflow boundary
- Groundwater recharge at the test field (unsaturated modelling)
- Nitrate concentration of seepage water (unsaturated modelling)
- Measured nitrate concentration in groundwater at the test area
Sequential coupling of unsaturated and saturated zone model

- Due to numerical oscillation, problems arose in modeling nitrate distribution in space and time
  - Model configuration
    - Density of FE-net
    - Timesteps for calculation
  - Boundary conditions
    - Concentration boundary condition at the groundwater inflow part
    - Mass boundary condition at the groundwater level

- Where nitrate concentration has been calculated, an overestimation at or after periods of groundwater recharge is visible

FEFLOW – Modelling results

- NO3 Wagna
- FEFLOW

- Nitrat [mg/l]
- GW-NB [mm]
- GW - NO3 Wagna

© JOANNEUM RESEARCH Forschungsgesellschaft mbH
Particle tracking of nitrate concentration in the flow model

- To obviate numerical problems with transport modelling
- Nitrate concentration from unsaturated zone modelling and from groundwater inflow boundary will be transferred to particles
- This particles are used as time and space distributed input to the groundwater flow model.
- Using particle tracking method the flow path will be followed through the entire groundwater in the model area. At any certain time step nitrate distribution may be visualized. Modelling results are consistent with the well calibrated flow model.
- Up to now this method is not workable on regional scale due to an extreme demand on computer capacity (CPU, memory, hard disk, run time).

Water and solute balancing

\[ C_{QT} = \frac{Q_{NB} \cdot C_{NB} + Q_Z \cdot C_{QZ}}{Q_T} \]

- \( C_{QT} \) Nitrate concentration [mg/l] in the groundwater below the investigated test field
- \( Q_{NB} \) Groundwater recharge [l/s] from infiltrating precipitation (result of SIMWASER modelling) at the investigated test field
- \( C_{NB} \) Nitrate concentration [mg/l] of seepage water at groundwater level (result of STOTRASIM modelling) for the investigated test field
- \( Q_Z \) Groundwater inflow [l/s] into the investigated test field (groundwater flow balance from the transient groundwater flow model)
- \( C_{QZ} \) Nitrate concentration [mg/l] in groundwater at the inflow boundary of every test field in the research area Wagna (calculation result from the upstream test field)
- \( Q_T \) Total Water balance [l/s] in the investigated test field (\( Q_{NB} + Q_Z \))
Time series of nitrate concentration along a flow line

Nitrate distribution [mg/l] in the test fields (mean value 1995)
Conclusions

- The prediction of the distribution of nitrate from diffuse sources in shallow aquifers is an unresolved problem.
- Numerical transport modelling is extremely sensitive to un-observed transient groundwater flow processes.
- Coupling of unsaturated transport and nitrate transport in the saturated zone has to be discussed further.
- Water and solute balancing gave significant results on the distribution of nitrate in groundwater in space and time (yearly mean values for the test fields).
  - A simple mixing equation couple
    - Unsaturated zone modelling
    - Groundwater flow modelling
    - Measurements of nitrate concentration at the inflow boundary
  - The equation (after transformation) may be used to estimate nitrate leaching to groundwater, if amount of fertilizer is unknown.