INTEGRATED RIVER-BASIN MODELLING AS A TOOL for WATER MANAGEMENT in the SCOPE of the WFD

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Models & the implementation of the WFD

WFD:
- What are the effects of driving forces and pressures?
- What is the impact?
- What is the risk of not achieving the good status?
Some utilisations of the PEGASE model in the scope of the implementation of the WFD
realized by / in collaboration with > 8 Water Agencies

- Ministry of Environment, Région wallonne, Belgium
- Flanders Environment Agency, Belgium
- Rhin-Meuse Water Agency, France
- Artois-Picardie Water Agency, France
- Loire-Bretagne Water Agency, France
- Adour-Garonne Water Agency, France
- Water Administration, Luxemburg
- Saarland & Rhine-Palatine Environment Agencies, Germany
- several local Water Authorities
Some utilisations of the PEGASE model in the scope of the implementation of the WFD
The PEGASE model

PEGASE = Planification Et Gestion de l’ASsainissement des Eaux

**Inputs**
- Basins
- Land use
- Hydrographic network
- Hydro-meteo
- Driving forces /
  Pressures

**Outputs / results**
- Pollutant loads to the river network
- River flow & veloc.
  Water temperature
- Biomasses
  Ecosystem activity
- Water quality
  Fluxes

**PEGASE model**
Input data: geo- & hydrological referential

- DTM, land use, river network
- Selection of rivers that are included explicitly in the model
LE BASSIN LOIRE-BRETAGNE

Délimitation des principaux bassins hydrographiques
Input data: point discharges

- Domestic loads (population) + industrial discharges
- Connections to sewer systems and purification plants

Source: Agence de l'Eau Rhin-Meuse
**Diffuse loads** : calculation of:

- Diffuse loads from soils: statistical functions (emission factors) depending on soil type and land use (forest, meadow, culture)
- Direct loads from rearing (bovine, porcine, ... populations)

Source: Agence de l’Eau Rhin-Meuse
Diffuse loads

Source: AERM
PEGASE : calculations

• Calculation of the loads and discharges to the river network

• Calculation of the hydrological / hydraulic variables

• Calculation of ecosystem and water quality variables:
The processes that are included are:
  . Physico-chemical processes
  . Primary production: phytoplankton, phyto-benthos
  . Grazing: zooplankton
  . Organic matter degradation by bacteria
     (planctonic, biofilm, benthic)
  . Nitrification, denitrification
  . Oxygen productions and consumptions
  . Nutrient cycling processes
PEGASE : results

Non-stationnary (dynamic) simulation of:

- Flows, depths, velocities, ... in the river network \((\Delta x \sim 300 \text{ m})\)
- Ecosystem and water quality variables (daily / hourly):
  - Biomasses
  - Concentrations (BOD, COD, DOC, POC, N, P, D.Oxygen, ...)
  - Fluxes
- Quality indexes \((Seq-Eau)\) : scale 1 - 100
  5 levels
  
  good  |  very good

- Results: profiles (in space), evolutions (in time), maps, tables

The results can be calculated for each of the surface water bodies
PEGASE: utilisation in the scope of the WFD

THE SUCCESSIVE STEPS:

1) IMPLEMENTATION of the model in a basin (district)
   Main characteristic of PEGASE: input = 'classical' data

2) VALIDATION of the model: simulation of past/present situations
   Main characteristic of PEGASE:
   very few or NO calibration needed (all processes are already calibrated)
   calibration needed only for emission functions of diffuse loads

3) PRESSURE / IMPACT ANALYSIS (Art. 5 analysis)
   Assessment of the impacts of domestic, industrial, diffuse loads

4) SIMULATION OF SCENARIO’S (2015 scenario’s)
   Assessment of the RISK of failing to meet the GOOD STATUS

5) SIMULATION OF ADDITIONAL MEASURES
   => support for the public participation / consultation

6) SUPPORT for the DESIGN of the MONITORING NETWORKS
<table>
<thead>
<tr>
<th>PEGASE River Model</th>
<th>Sélection des rivières</th>
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<tbody>
<tr>
<td>Région Wallonne</td>
<td></td>
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</tbody>
</table>

PEGASE : Région wallonne
VALIDATION : SIMULATION OF PAST / PRESENT SITUATIONS
PEGASE : Région wallonne

VALIDATION : SIMULATION OF PAST / PRESENT SITUATIONS

REGION WALLONNE
CONCENTRATIONS DANS LE RESEAU HYDROGRAPHIQUE

AZOTE (G/M3)

RW TEST Pegase non Stationnaire : (calcul bilans)

LA MEUSE
ANNEE : 1996

Qua RW003293  ENGIS
Distance source : 575.6km
Biomasse du phytoplancton (Meuse)
REGION WALLONNE

CONCENTRATIONS DANS LE RESEAU HYDROGRAPHIQUE

OXYGENE (G/M3)

RW TEST Pegase non Stationnaire : (calcul bilans)

LA MEUSE

Date Simulation : 16 Juillet 1996
Debit confluence : 27.44 m3/s
MEUSE Liege & Vise – Year 2002:
Comparison
OBSERVED vs CALCULATED values
of Dissolved Oxygen concentrations
(mg O2 / l)
MEUSE Liege – Year 2002:
Comparison
OBSERVED vs CALCULATED values
SEQ-EAU INDEXES
Histogramme de fréquence par classes (10) en PO4 - bassin Meuse

PEGASE : Région wallonne
VALIDATION : SIMULATION OF PAST / PRESENT SITUATIONS
MEUSE basin in Wallonia : PO4 concentrations - Year 2002
PEGASE : Région wallonne
VALIDATION : SIMULATION OF PAST / PRESENT SITUATIONS
MEUSE basin in Wallonia : PHOSPHORUS quality index - Year 2002

Histogramme de fréquence par classes (10) en MP - bassin Meuse

Valeurs calculées aux stations de mesure
Valeurs mesurées aux stations de mesure

CALCULATED
OBSERVED

% de fréquence

classes d'indice

Valeurs calculées aux stations de mesure
Valeurs mesurées aux stations de mesure
MEUSE basin in Wallonia: cumulative distribution of PO4 concentrations (calculated + observed) - Year 2002
PEGASE : utilisation in the scope of the WFD
VALIDATION : SIMULATION OF PAST / PRESENT SITUATIONS

REGION WALLONNE - PEGASE
INDICES SEQUEAU - MATIERES PHOSPHOREES
RW2 Situation actuelle - Annee 2002

Limit of the good status

Source : DGRNE
PEGASE : utilisation in the scope of the WFD
VALIDATION : SIMULATION OF PAST / PRESENT SITUATIONS

<table>
<thead>
<tr>
<th>PEGASE</th>
<th>Résultat de la simulation</th>
</tr>
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<tbody>
<tr>
<td>Agence de l'Eau Adour-Garonne</td>
<td>Altération NITR</td>
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Simulation non stationnaire 2002
Bassin de la Dordogne
**PEGASE : utilisation in the scope of the WFD**

**ANALYSIS OF PRESSURE / IMPACT RELATIONS**

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**REGION WALLONNE - PEGASE**

**COMPARAISON DES INDICES SEQUEAU - MATIERES PHOSPHOREES**

- RW2 Situation actuelle - Année 2002
- RW2 Rejets urbains a zero - Année 2002

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**Impact of domestic load on Phos quality index**

Source: DGRNE
PEGASE: utilisation in the scope of the WFD

SIMULATION OF 2015 SCENARIO'S / ASSESSMENT OF THE RISK

Present situation (2002)

Predicted situation for 2015: Q.Index is < 60

=> AT RISK

Limit of the good status

Nitrate quality index
PEGASE: utilisation in the scope of the WFD

SIMULATION OF 2015 SCENARIO’S / ASSESSMENT OF THE RISK

Present situation (2002)

Predicated situation for 2015: Q.Index is > 60

=> NOT AT RISK

Source: DGRNE
PEGASE
For international basins / districts :

The MOSEL-SAAR Basin

Agence de l’eau Rhin-Meuse Land Rhenanie-Palatinat Land Saar Luxemburg Wallonia
PEGASE for international basins / districts:
The MOSEL-SAAR Basin
PEGASE for international basins / districts:
The MOSEL-SAAR Basin
PEGASE for international basins / districts: The MOSEL-SAAR Basin

Matieres azotees (Nh4/NO2/NO3/Nkj - gN/m3) Stikstoffhaltigen
mos02 Test Pegase NST sur Moselle (BV Complet)

Date simulation: 2 aout 2002
Debit confluence: 2.31 m3/s

la Nied

Graph showing concentrations of various nitrogen forms over a distance of 100 km.
PEGASE for international basins / districts:
The SCHELDT Basin (F + W + VL + BR)

20,020 km²
858 rivers
Total length: 8,702 km
PEGASE for international basins / districts:
The SCHELDT Basin (F + W + VL + BR)
PEGASE for international basins / districts:

The MEUSE Basin
(F + W + VL + ..... ?)
PEGASE in the cooperation POLAND – FRANCE: The UPPER VISTULA basin
In the scope of the PIRENE programme:

new developments:

1) Modelling of the micro-pollutant concentrations

- Domestic discharges: Eq-InHab μP
- Industrial discharges: inventory of discharges
- Direct discharge by the bovines / porcines
- Diffuse load from the soil: emission factors

- Calculation of concentrations in the water column:
  - in the dissolved phase (water)
  - in the particulate phase (solid particles)
- Calculation of sedimentation processes
- Calculation of adsorption / désorption processes water ⇔ solid particles

Tests have been made for: Cd, Cu, Zn, Pb
Cr, Ni, As, Hg
Concentration of μPollutants in the SAMBRE river – Year 2002
PEGASE: recent developments

2) Modelling of biological quality (biological indexes)

Step 1: assessment of the hydromorphological quality (ULg-Arlon)

QUAL-PHY quality indexes (AERM)
PEGASE : recent developments

2) Modelling of **biological quality** (biological indexes)

Step 2 : statistical sub-models (*multiple linear regressions*)

**DIATOM INDEX :**

\[
IPS = F (\text{Moox, Maz, Nit, MPhos, QPhys_fond})
\]

test W : $R^2 > 0.80$

**MACRO-INVERTEBRATES INDEX :**

\[
IBGN = F (\text{Moox, Maz, Nit, MPHOS, phys_fond})
\]

test W : $R^2 > 0.92$
PEGASE: recent developments

2) Modelling of biological quality (biological indexes)
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PEGASE: recent developments

2) Modelling of biological quality (biological indexes)
 IPS calculé

2015
2008
2000
1992

Full integrated modelling in the perspective of the WFD

• + Explicit (deterministic) modelling of SOILS
• + Explicit (deterministic) modelling of GROUNDWATER
• + Detailed (deterministic) modelling of the RIVER NETWORK (incl. full hydrodynamic modelling)
PIRENE programme:

Full integrated modelling:
SOILS + GROUNDWATER + SURFACE WATERS

- SOIL sub-model (3-D) (Epic-Grid)
- GROUNDWATER sub-model (3-D)
- SURFACE WATERS sub-model

Deep percolation
Runoff + hypodermic flux

Multiprocessors SP2 SGI ... or Monoprocessor

Processors: 1, 2, 3, 4

Module Superviseur
Module SOILS
Module Eaux Surface
Module Eaux Souterraines

Communication MPI
Synchronisation

(FUSAGx)

(GEOMAC-ULg + HG – FPMs)

(HYD + CEME-ULg)
PIRENE programme:

Results of the soil sub-model (FUSAGx):

Nitrate concentrations / bottom of the Non Saturated Zone
Averaged value – Period 1998 - 2000

Conc. NO₃ (mg/l)
- Nodata
- < 10
- 11 - 25
- 26 - 40
- 41 - 50
- > 50
PIRENE programme: Results of the integrated model:
Daily fluxes of nitrates from the SOILS and GROUNDWATER to the SURFACE WATERS

Basin of the SEMOIS at Membre (1.318 km²)
Daily fluxes of nitrates (kg N / day) to the river network
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