DHI E.coli and Enterococci Model

MIKE Lab Template

Scientific Description

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1 Introduction

MIKE ECO Lab is a numerical lab for Ecological Modelling. It is a generic and open tool for customising aquatic ecosystem models to describe for instance water quality and eutrophication. DHI's expertise and know how concerning ecological modelling has been collected in predefined ecosystem descriptions (MIKE ECO Lab templates) to be loaded and used in MIKE ECO Lab. So the MIKE ECO Lab templates describe physical, chemical and biological processes related to environmental problems and water pollution. The following is a description of the DHI *E.coli* and enterococci template.

The DHI *E.coli* and enterococci template is used in investigation of hygienic water quality and based on sources of pollution as an instrument in water quality assessments. The DHI *E.coli* and enterococci modelling can be applied in studies considering:

- bacterial pollution sources such as domestic and industrial sewage and agricultural run-off
- bacterial pollution from sewage outfall, waste water treatment plants, etc.
- cost effective solution improving the hygienic water quality

The aim of using the *E.coli* and enterococci modelling as an instrument in addressing the hygienic water quality is to obtain, most efficiently in relation to economy and technology, the optimal solution with regards to water quality and potential protect human health.

The *E.coli* and enterococci model describes the fate of *E.coli* and enterococci bacteria.

The *E.coli* and enterococci template is integrated with the advection-dispersion module, which describes the physical transport processes at each grid-point covering the area of interest. Other data required are concentrations at model boundaries, flow and concentrations from pollution sources, water temperature and influx of light etc.

2 Applications

The *E.coli* and enterococci template can be applied in a range of environmental investigations worldwide:

- Studies where the effects of alternative bacteria loading situations are compared and/or different waste water treatment strategies are evaluated
- Studies where the aim is to evaluate different potential bacteria outlets and compare
- Studies addressing bathing water quality
- Studies with the aim of evaluating the potential health risk from point sources

3 Mathematical Formulations

The MIKE 21/3 ECO Lab is coupled to the MIKE 21/3 AD module in order to simulate the simultaneous processes of transport, dispersion and biological/biochemical processes.

The *E.coli* and enterococci model results in a system of two differential equations describing the variations for two components:

1. E.coli (1/100 ml)
2. Enterococci (1/100 ml)

Both *E.coli* and enterococci are subject to decay only, and the decay processes describing the variations of the two bacteria components in time and space are dependent on external factors such as the salinity, water temperature, the light influx, and the discharges.

The salinity and water temperature can be results of MIKE 21/3 AD simulations or be user specified values.

The mathematical formulations of the decay processes and transformations for each state variable are described one by one below.

3.1 E.coli (Ecoli)

The concentration of E.coli is dependent on *E.coli* decay only:

$$\frac{dEcoli}{dt} = -E.coli\ decay = -Kcoli \tag{3.1}$$

3.2 E.coli decay (Kcoli)

The decay model adopted for *E.coli* is originally developed in /2/ Jensen 1990, and later adopted in /1/ Erichsen et al. 2006. The E.coli decay consists of decay contributions from dark respectively light condition.

$$\left(Km + KL \cdot I_{avg}\right) * Ecoli \tag{3.2}$$

Where

Km represents decay contribution when dark conditions (d^{-1})

KL represents decay contribution when light conditions and (d^{-1})

I_{avg} is the average light available for the modelled layer addressed (When MIKE21 is applied this will correspond to average light available in the entire water column).

3.3 E.coli decay when dark conditions (Km)

The decay contribution when dark conditions are described as:

$$km = a_T \bullet T - k_{m0} \tag{3.3}$$

Where
T = actual water temperature [°C]
a_T = 0.002425 [h-1•°C^{-1}]
km0 = 0.00826 [h-1]

3.4 E.coli decay when light conditions (KL)

The decay contribution when light conditions are described as:

$$KL = S_m \bullet (b_T \bullet T + KL_0)/(a \bullet S_m - (a-1) \bullet S) \tag{3.4}$$

Where
T = actual water temperature [°C]
S = actual salinity [psu]
Sm = a reference salinity of 34.5 [psu]
a = 1.54 [-]
b_T = 0.133•10-3 [m2•W-1•h-1•°C-1]
KL_0 = 2.124•10-3 [m2•W-1•h-1]

3.5 Enterococci (Ent)

The concentration of enterococci is dependent on decay only:

$$\frac{dEnt}{dt} = -enterococci\ decay = -Kent \tag{3.5}$$

3.6 Enterococci decay (Kent)

While E.coli decay is relatively well documented the documentation for enterococci decay is still not fully matured. However, most literature suggests that enterococci decay is slower than E.coli decay, but still these estimates are uncertain. The literature investigated suggests that the enterococci decay during night is close to zero. Hence, we have adopted the rates reported in Table 3.1, although they are evaluated as conservative.

Table 3.1 Estimation of enterococci decay

	Decay
Dark	0.5 • E.coli dark decay
Light	0.5 • E.coli light decay

Please note: This assumptions are somehow conservative as some decay will happen when dark conditions. In normal conditions this will not be important, but for periods of low light due to e.g. heavy rains, enterococci concentrations might be overestimated.

4 Data Requirements

- Basic Model Parameters
  - Model grid size and extent
  - Time step and length of simulation
  - Type of output required and its frequency

- Bathymetry and Hydrodynamic Input

- Combined Advection-Dispersion Model
  - Dispersion coefficients.

- Initial Conditions
  - Concentration of parameters

- Boundary Conditions
  - Concentration of parameters

- Pollution Sources
  - Discharge magnitudes and concentration of parameters

- Process Rates
  - Size of coefficients governing the process rates. Some of these coefficients can be determined by calibration. Others will be based on literature values or found from actual measurements and laboratory tests

- MIKE ECO Lab Forcings
  - Solar radiation. Hourly data on solar radiatoion for calculation of light dependent decay

5 References

/1/ Erichsen, A.C., Dannisøe, J.G., Jørgensen, C., Mark, O. and Kaas, H. 2006. Implementation and description of different early warning systems for bathing water quality, Danish EPA, Miljøprojekt Nr. 1101 (in Danish).

/2/ Jensen. 1990. Estimation of E.coli decay from light, temperature and salinity. Status note. Isotopcentralen/ATV, (in Danish).