



MIKE 21/3
Particle Analysis Module
Short Description



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MIKE 21/3 PA

Introduction

MIKE 21/3 PA is a software package for the simulation of transport and fate of dissolved and suspended substances discharged or accidentally spilled in lakes, estuaries, coastal areas or at the open sea.

The transport of substances can be simulated in two or three dimensions.

The substance simulated may be a pollutant of any kind, conservative or non-conservative, e.g. suspended sediment particles, inorganic phosphorus, nitrogen, bacteria and chemicals.

The pollutant is considered as particles being advected with the surrounding water body and dispersed as a result of random processes. To each particle a corresponding mass is attached. This mass can change during the simulation as a result of decay or deposition.

The basic - Lagrangian type - approach involves no other discretizations than those associated with the description of the topography of the model area and the wind, current and water level fields.

This concept has several advantages, including e.g.

- finite differencing phenomena associated with numerical dispersion are eliminated
- computer requirements are drastically reduced as compared to e.g. models of the Eulerian type.

MIKE 21/3 PA assumes that current velocities and water levels can be prescribed in time and space in a computational grid covering the model area. This information can be provided e.g. by means of a preceding hydrodynamic model simulation.

Application Areas

MIKE 21/3 PA can be applied to the study of engineering applications, including e.g.

- sedimentation problems
- planning and design of outfalls
- risk analyses. Accidental spillage of hazardous substances
- environmental impact assessment
- monitoring of outfalls
- monitoring of dredging works

MIKE 21/3 PA can be running in three modes:

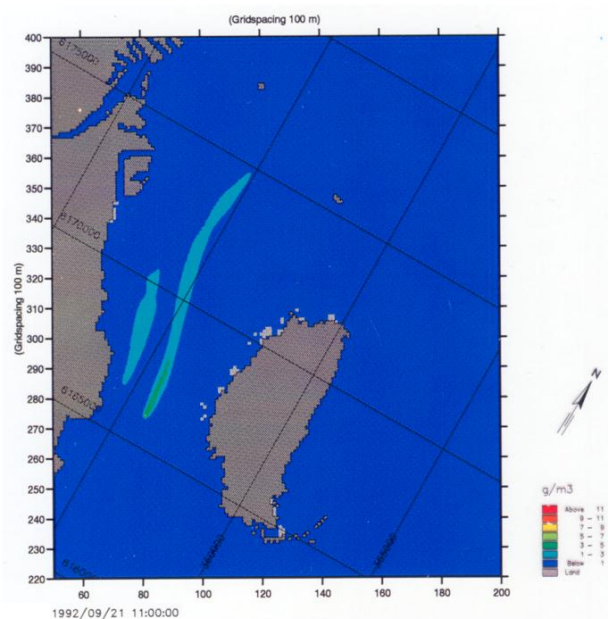
- 'cold start'
- 'hot start'
- 'data base'

The difference between 'cold start' and 'hot start' is basically that the cold start mode provides a simulation starting from 'scratch' while in the 'hot start' mode, the simulation is a continuation of a previous one.

The 'database' mode is a special device developed for on-line monitoring of pollution sources. This mode is operated on the basis of a library of flow fields in combination with an online registration of the current velocity in one or more stations in the area of interest. On the basis of correlation procedure, library flow fields are then selected from single point measurements.

MIKE 21/3 PA includes formulations for the effects of:

- decaying
- light attenuation
- exceeding concentrations
- line discharge calculations
- nested grid output facilities
- cohesive/non-cohesive sediment
- constant/time varying sources



Spreading of dredged spoils – Øresund Link, Denmark-Sweden. Suspended sediment concentrations g/m^3 in a plume (1992/09/21 11:00)

Basic Equations

The overall transport of particles during a time interval Δt , results from an advective component (current) and a dispersive component, which accounts for the non-resolved flow processes.

The advective component is determined on the basis of the Lagrangian principle. An interpolation scheme in both time and space is employed to generate the velocity vector at off-grid points. In the time domain a simple linear interpolation has been adopted. In the space domain a bilinear type interpolation is employed.

The particle transport equation at the i^{th} timestep can be expressed as:

$$\bar{x}_{i+1} = \bar{x}_i + \bar{v} \cdot \Delta t + \underline{\underline{D}} \cdot \bar{v} + \bar{\gamma}$$

where

$$\bar{v} = \begin{pmatrix} u_x \\ u_y \\ -V_{sett} \end{pmatrix}, |\bar{U}| = \sqrt{u_x^2 + u_y^2}$$

$$\underline{\underline{D}} = \frac{1}{|\bar{U}|} \begin{pmatrix} \Delta D_L & -\Delta D_T & 0 \\ \Delta D_L & \Delta D_T & 0 \\ 0 & 0 & 0 \end{pmatrix}$$

$$\bar{\gamma} = \begin{pmatrix} \Delta D_0 \\ \Delta D_0 \\ \Delta D_{0w} \end{pmatrix}$$

The dispersive displacements are given as:

ΔD_L longitudinal dispersion caused by turbulence

ΔD_T transversal dispersion

ΔD_0 neutral dispersion

ΔD_{0w} dispersion caused by wind acting on the surface

where

$$\Delta D_L = \sqrt{6 \cdot D_L \cdot \Delta t} \cdot \left([RND_1]_0^1 - \frac{1}{2} \right) \cdot 2$$

$$\Delta D_T = \sqrt{6 \cdot D_T \cdot \Delta t} \cdot \left([RND_2]_0^1 - \frac{1}{2} \right) \cdot 2$$

$$\Delta D_0 = \sqrt{6 \cdot D_0 \cdot \Delta t} \cdot \left([RND_3]_0^1 - \frac{1}{2} \right) \cdot 2$$

$$\Delta D_{0w} = \sqrt{6 \cdot D_0 + D_V \cdot \Delta t} \cdot \left([RND_4]_0^1 - \frac{1}{2} \right) \cdot 2$$

The hydrodynamic flow field is considered to be a function of the depth according to the Nikuradse logarithmic law:

$$\frac{|\bar{U}_{HD}(x, y)|}{U_f} = 8.6 \cdot 2.45 \cdot \ln \left(\frac{h}{k/30} \right)$$

The flow field includes wind effects by

$$\bar{U}(x, y, z) = \bar{U}_{HD}(x, y, z) - \frac{1}{h_w} \int_0^{h_w} \bar{U}_w(z) dz + U_w(z)$$

where the velocity distribution due to wind shear stresses in the free surface is considered to be given by

$$U_w(z) = C_w \cdot W \cdot \exp(-k_0 \cdot z), \quad k_0 = 3/h_w$$

Symbol List

\bar{x}_i	Particle coordinates in three dimensions at time step i (m)
Δt	Time step (sec)
u_x, u_y	Horizontal current velocities (m/s)
V_{sett}	Settling velocity (m/s)
D_L	Longitudinal dispersion coefficient (m^2/s)
D_T	Transversal dispersion coefficient (m^2/s)
D_0	Neutral dispersion coefficient (m^2/s)
D_w	Dispersion due to wind (m^2/s)
[RND]	A uniform distributed random number [0;1]
U_f	Friction velocity (m/s)
k	Bottom roughness (m)
$\bar{U}_{HD}(x, y)$	Depth integrated current velocity field (m/s)
h_w	Depth of wind influence (m)
h	Water depth (m)
C_w	Wind friction coefficient (-)
W	Wind speed (m/s)
x, y, z	Particle coordinates (m)



Solution Technique

The spreading of material is calculated by dividing the spill into discrete parcels, also termed particles.

The movements of particles are given as a sum of an advective and a dispersive displacement. The advective component is determined by the hydrodynamic flow field and the dispersive component as a result of random processes (e.g. turbulence in the water).

The dispersive component is divided into three categories of dispersion termed as the neutral ΔD_n , transversal ΔD_T , and longitudinal ΔD_L dispersion.

The longitudinal and transversal dispersion refers to the turbulence in the water. The neutral dispersion refers to spreading induced by gravity effects. A uniformly distributed random variable is generated and multiplied by a dispersion coefficient and propagates in all directions. Due to the central limit theorem, the sum of a large random sample tends towards a normal distribution independent of the distribution of each random variable. The result is therefore a Gaussian representation of the dispersion.

Input

The basic input data to MIKE 21/3 PA consists of

- hydrodynamic data including bathymetry
- bed friction coefficients
- source data
- wind data
- material specifications
- simulation period
- dispersion coefficients
- velocity profile specifications
- exceeding concentration specification
- specification of light attenuation
- line discharge specifications
- decay coefficients

The source data can be specified both as constant and time varying and the model can run with up to 64 simultaneous source specifications.

Output

Three types of output can be obtained from MIKE 21/3 PA:

- 2D-maps containing the instantaneous output data which consists of:
 - particle concentration
 - light attenuation
 - erosion/deposition/net sedimentation
- 2D-maps containing the averaged or accumulated output data which consists of:
 - particle concentration
 - light attenuation
 - erosion/deposition/net sedimentation
 - exceeding concentration
- Time series of both instantaneous and accumulated line discharge rates.

The 2D output maps can be specified in up to six different output areas covering different areas with different items selected and including a nested grid option.

Graphical User interface

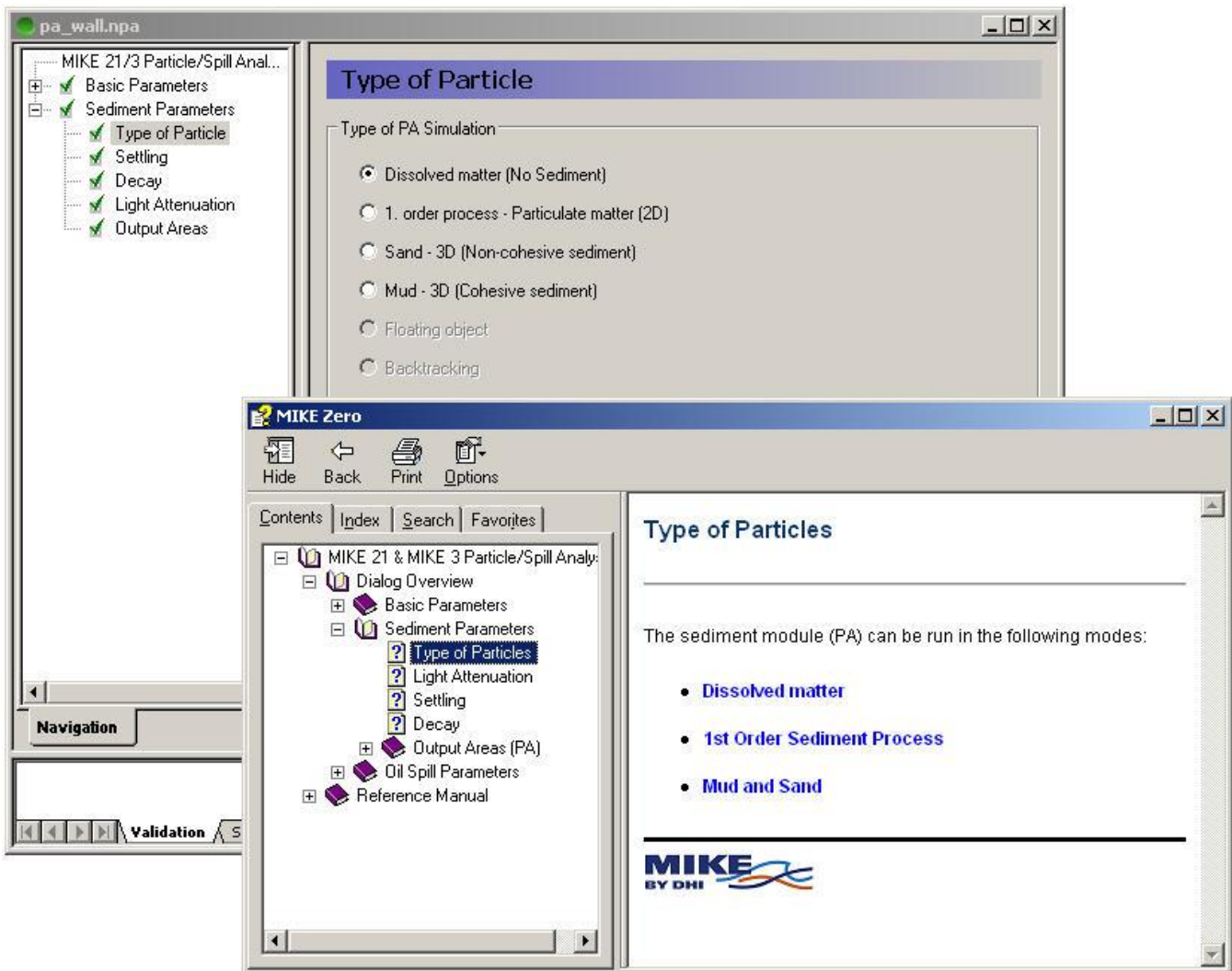
MIKE 21/3 PA is operated through a fully Windows integrated Graphical User Interface and is compiled as a true 32-bit application. Support is provided at each stage by an Online Help System.

Hardware and Operating System Requirements

The MIKE 21/3 PA Module supports Microsoft Windows XP Professional Edition (32 and 64 bit), Microsoft Windows Vista Business (32 and 64 bit) and Microsoft Windows 7 Enterprise (32 and 64 bit). Microsoft Internet Explorer 6.0 (or higher) is required for network license management as well as for accessing the Online Help.

The recommended minimum hardware requirements for executing MIKE 21/3 PA are listed below:

Processor:	3 GHz PC (or higher)
Memory (RAM):	4 GB (or higher)
Hard disk:	160 GB (or higher)
Monitor:	SVGA, resolution 1024x768
Graphic card:	32 MB RAM (or higher), 32 bit true colour
Media:	CD-ROM/DVD drive, 20 x speed (or higher)



Graphical User Interface of the MIKE 21/3 Particle Analysis Module, including an example of the Online Help system

Support

News about new features, applications, papers, updates, patches, etc. are available here:

www.mikebydhi.com/Download/DocumentsAndTools.aspx

For further information on the MIKE 21/3 Particle Analysis software, please contact your local DHI office or the Software Support Centre:

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