CFD techniques for mixing and dispersion of desalination and other marine discharges

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Background and motivation

CFD: a tool for dispersion modelling

Preliminary results

Planned work
Motivation

Desal / IWPP discharge plumes

→ Benthic thermal-saline impact

Dispersion prediction is vital for:

- EIA
- Engineering studies (outfall design, recirculation)
Dispersion modelling approaches

- Far-field dispersion
- Model coupling
- Near-field dilution (mixing zone)
Coupled studies are common

HR Wallingford framework:


Validated against newly available mid-/far-field data:

Benefits:

- Methods generally work well for smaller discharges:
  - Simple exchanges of mass & momentum
- Relatively quick to implement

Drawbacks

- Plume interactions / neighbouring facilities:
  - 2-way exchange of pollutant concentrations is challenging

Potential solution: CFD

- Computing power increases
- Adaptive meshing techniques
- Seamless coverage of the entire domain
- History – near-field

- Fluidity:
  - Open-source, developed by Imperial
  - Navier-Stokes on 3D unstructured meshes
  - Discretisation: Finite element & control volume
  - Mesh adaptivity

- Key differentiator – multi-scale:
  3D CFD model
  + efficient coastal flow modelling system

- Used to simulate ocean and tidal flows
Long-term goals:

- Extend Fluidity’s multi-scale capabilities
  ➔ a fully integrated CFD hydrodynamic & pollutant dispersion model

First stage:

- Explore near-field abilities
  - Horizontal buoyant jet
  - Angled dense jet

- Compared predictions with
  - published laboratory data, or
  - validated integral models.

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<table>
<thead>
<tr>
<th>Parameter</th>
<th>Horizontal buoyant jet</th>
<th>Angled dense jet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inlet diameter (mm)</td>
<td>9.4</td>
<td>3.3</td>
</tr>
<tr>
<td>Densimetric Froude number, F</td>
<td>10.7</td>
<td>21.3</td>
</tr>
<tr>
<td>Reynolds number</td>
<td>6000</td>
<td>2500</td>
</tr>
<tr>
<td>References for comparison</td>
<td>CorJet integral model</td>
<td>Experimental data</td>
</tr>
<tr>
<td>Parameters for comparison</td>
<td>• Centreline trajectory</td>
<td>• Centreline terminal rise height</td>
</tr>
<tr>
<td></td>
<td>• Mean axial velocity decay</td>
<td>• Bottom impact distance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Minimum impact dilution</td>
</tr>
</tbody>
</table>

Parameters for comparison:

- Centreline trajectory
- Mean axial velocity decay
Numerical methods

- Unstructured tetrahedral elements
- Turbulence:
  - k-ε
  - V-LES
- Adaptive time-stepping and meshing
Horizontal buoyant jet
Horizontal buoyant jet

Centreline trajectory

Centreline velocity decay
Angled dense jet

Salinity (g/L)
42.4
10
1.5
Angled dense jet

Terminal rise height
Impact distance
Impact dilution

<table>
<thead>
<tr>
<th>Study</th>
<th>$k_1 = z_t/dF$</th>
<th>$k_2 = x_t/dF$</th>
<th>$k_3 = S_t/F$</th>
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</thead>
<tbody>
<tr>
<td>Zeitoun et al. (1972)</td>
<td>-</td>
<td>3.19</td>
<td>1.12</td>
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<tr>
<td>Roberts et al. (1997)</td>
<td>-</td>
<td>2.4</td>
<td>1.6 +/- 0.12</td>
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<tr>
<td>Nemlioglu &amp; Roberts (2006)</td>
<td>-</td>
<td>3.25</td>
<td>1.7</td>
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<td>Cipollina et al. (2005)</td>
<td>1.77</td>
<td>2.25</td>
<td>-</td>
</tr>
<tr>
<td>Kikkert et al. (2007)</td>
<td>1.6</td>
<td>2.72</td>
<td>1.81</td>
</tr>
<tr>
<td>Papakonstantis et al. (2011a and 2011b)</td>
<td>1.68</td>
<td>2.75</td>
<td>1.68 +/- 0.1</td>
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</tbody>
</table>
HR Wallingford uses a validated coupled modelling procedure involving
- Hydrodynamic models
- Near-field models

Future will involve more CFD

Preliminary work with Imperial College is encouraging:
- Buoyant jet compares well (trajectories and dilutions)
- Dense case requires mesh refinement

Next steps of PhD:
- Adapt mesh to far-field
- Range of ambient currents
- Multiport diffusers