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An Environmental Consequence for Dublin Bay of a Shift From Hydro-Carbon to Other Energy Production Methods

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An environmental consequence for Dublin Bay of a shift from hydro-carbon to other energy production methods

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Short Abstract

The Liffey Estuary and Dublin Bay, Ireland are of a great recreational and conservational value. Until recently, the Electricity Supply Board (ESB) plant at Poolbeg, Dublin, abstracted dilution water from the estuary for cooling purposes and subsequently discharged this water back to the estuary at temperatures that were sometimes *7-9°C* above ambient values. Prior to its discharge to the estuary, the ESB cooling water was mixed with the sewage effluent from Ringsend Treatment Works, creating a warmer and less-saline pollutant plume that remained buoyant on the water surface, adversely effecting water quality. The ESB plant has since closed as part of a competitive energy market agreement.

This paper examines the impact of this closure on water quality in the Liffey Estuary and Dublin Bay using a three-dimensional hydro-environmental model. Three discharge scenarios corresponding to the periods before and after the cessation of thermal discharges are compared.. The results showed considerably lower E.coli concentrations in the Estuary and inner Bay in comparison to the time when the thermal discharges and extraction of dilution water ceased, although the effect on E.coli concentrations of removing the cooling water was small.

Keywords: E.coli, heated discharges, thermal generation plant, three-dimensional model

Introduction

The Electricity Supply Board (ESB) is a national body with responsibility for energy supply in Ireland. The ESB generating facility at Poolbeg, Dublin (Figure 1) was the largest gas and oil power plant in Ireland with an installed capacity of 1020 *MW*. The plant abstracted 2.1 million cubic metres a day of once-through seawater to cool the heat exchanger and discharged the heated water into the Liffey Estuary at a temperature that could have been be up to 7-9 *°C* above ambient values. The heated discharges negatively impacts on the estuarine fish species, some of which are of international conservation importance and are listed in the EU Habitats Directive (92/43/EEC).

Before being discharged the cooling water from this plant was mixed with the sewage effluent from Ringsend Treatment Works creating a warmer and less-saline pollutant plume that remained buoyant on the water surface. The resulting stratification could profoundly affect the assimilation of polluting discharges by preventing the mixing between the warm upper levels and the cooler water beneath . This has been a source of concern for local authorities as it affects the compliance of waters of Dublin Bay to the Bathing Water Directive (2006/7/EC) at beaches of high recreational and national importance (e.g. Dollymount, Sandymount and Merrion Strand).

The ESB has recently closed down the plant at Poolbeg as part of a competition agreement with the Irish Energy Regulators

to facilitate the introduction of additional energy providers to the Irish market The agreement has been particularly useful for expanding the operation of greener energy providers (e.g. Airticity).
The decision to close Poolbeg is expected to reduce the stress on the aquatic environment and was welcomed by environmentalists .
Although the cessation of thermal discharges is expected to help improve the aquatic life in the estuary, stratification will still exist due to the wastewater discharges from the Ringsend sewage treatment works (STW).

The current study investigates the effect of closing down the ESB generation plant at Poolbeg on the water quality of the Liffey Estuary and Dublin Bay. Using a three-dimensional hydro-environmental model, this paper examines and compares the distributions of E.coli in the estuary and bay for a number of discharge scenarios corresponding to the periods before and after cessation of thermal discharges

Methods
The study uses the three-dimensional flexible mesh finite volume, hydro-environmental model MIKE3 (DHI, 2011). MIKE3 solves the Navier-Stokes equations taking into account the effect of temperature and salinity on density-driven flows and incorporates a transport module which was used to simulate the advection, dispersion, and decay of *Escherichia coli* (E.coli) discharged from Ringsend Sewage Treatment Plant. The two-step modelling procedure involved (i) development of a calibrated hydrodynamic and water quality model of Dublin Bay using a complete set of velocity (speed and direction) and water quality data (temperature, salinity, and E.coli), and (ii) use of the calibrated model to simulate discharge scenarios corresponding to the periods before and after the cessation of the ESB thermal discharges.

An unstructured triangular grid of 42056 elements and 22962 nodes was constructed for the model area. The average element length size ranged from *1.2km* at the open sea boundary to *20m* in the vicinity of the ESB discharge outfall. The vertical mesh of the model consisted of 6 layers. The model was subsequently used to simulate the flow in the Liffey Estuary and Dublin Bay of a mean neap tide using open-sea tidal elevations as boundary conditions. The model was run until its hydrodynamic variables demonstrated a quasi-steady state (normally after three tidal cycles). The hydrodynamic variables (velocity magnitude and direction) were first calibrated by adjusting the bottom friction coefficient (roughness height) which was subsequently varied to achieve a match between simulated and measured water velocities (at eight locations in the Bay). The vertical profiles of temperature and salinity were fitted to measurements by adjusting the horizontal and vertical turbulence models.
The sensitivity of the E.coli model to dispersion and decay coefficients was also tested. The hydro-environmental model was then used to simulate hydrodynamic and water quality scenarios to study and compare the effect of three discharge scenarios (Table 1) on the distribution of E.Coli in the Liffey Estuary and inner Dublin Bay:

(i) Scenario A: combined discharges of the ESB power plant and Ringsend STW;
(ii) Scenario B: Cessation of ESB thermal discharges but continued extraction of estuary water to dilute wastewater discharges from Ringsend STW;

(iii) Scenario C: Direct discharges of sewage from Ringsend STW into the Liffey Estuary without prior dilution.

Results

Model calibration

Measurements of current speed and direction at eight stations in the bay (points H1 - H8 in Figure 1) were used for model calibration and verification. The best match between measured velocity and direction was obtained with a roughness height value of 0.1m.

In addition, an adequate match between measured (at points T1 and T2 in Figure 1) and simulated vertical profiles of temperature was achieved.

The E.coli model transport was adjusted by varying the diffusion coefficient and the decay rate (T_{90}) for which a value of 18 hours was used. The value is comparable to those used in a previous study of Dublin Bay (Bedri et al, 2011) and similar marine environments (Falconer and Chen, 1996; Chapra, 1997). A reasonable match was obtained between the measured and simulated E.coli at Point WQ (Figure 1).

Discharge Scenarios

During the ebb stage of the tidal cycle (Figures 2a, 2b, and 2c), the tide pushes the sewage effluent plume eastwards out of Dublin Harbour and into the Bay, draining water out of the Tolka Estuary and South Bull Lagoon (also identified in Figure 1). Once in the bay, the plume flows eastwards and is then deflected northwards, first towards Dollymount Strand and then further eastwards towards Howth Head. During the flood tide, the incoming water pushes the plume back into the harbour and up the Liffey and Tolka estuaries, while in the inner bay and in the vicinity of the harbour mouth, the flood tide sweeps the discharge plume northwards towards Dollymount Strand (Figures 2d, 2e, and 2f).

Figures (2a, 2b) and (2d, 2e) show very little difference in the distribution of E.coli between Scenarios A and B particularly in the inner Bay. In the estuary, the concentrations of E.coli are slightly higher in Scenario A than B. This perhaps can be explained by the fact that salinity has a greater effect on density and hence on flow fields and transported waste than temperature and therefore, the absence of a temperature gradient in the estuary in Scenario B would result in an insignificant reduction to the water density.

Scenario C resulted in considerably lower E.coli concentrations in the Estuary and inner Bay in comparison to Scenarios A and B (Figures 2c and 2f). This is due to the low flow value ($3.6m^3/s$) of the Ringsend sewage discharge (Table 1) which results in faster dispersion through the water column (8-10m depth in the vicinity of the outfall) and greater dissipation by the tidal currents in comparison to the discharges of Scenarios A and B.

In terms of the water quality at the recreational areas, it can be noticed that the high water stage (Scenarios A and B) gives higher counts of E.coli at Dollymount Strand than does the low water stage. This is because at high water levels, there is a direct hydraulic connection with the estuary over the North Wall (Figure 1) which is inundated at flood stage. The E.coli concentration exceeded 500 cfu/100 ml in the vicinity of Dollymount Strand at the time of high water which is the upper limit for good and sufficient quality (based on the 95 and 90-percentile values respectively). Figure 2 shows that the water quality at Sandymount and Merrion Strand is less impaired than Dollymount Strand because of the South wall which extends a long distance eastwards into the bay, separating the waters of the beaches on the south side of the bay from the flow exiting the estuary. Hence the south wall prevents the E.coli plume from flowing directly southwards to the beaches of Sandymount and Merrion Strand except when the wind is from the North East.

Although the cessation of ESB discharges showed no significant improvement in the bathing water quality of Scenario B compared to Scenario A, the elimination of heated discharges is expected to have a positive impact on the aquatic life in the Liffey Estuary, an aspect which is beyond the scope of the current study.

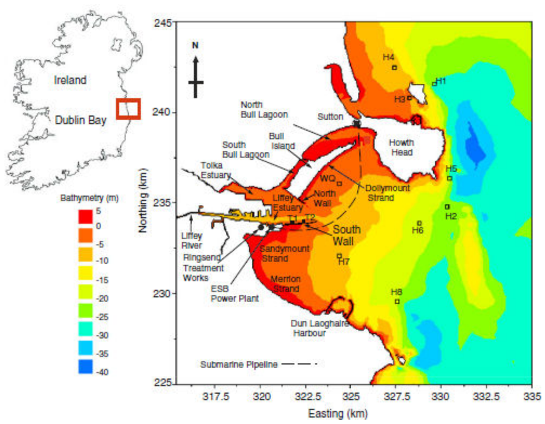

Fig. 1. Study area: Liffey Estuary and Dublin Bay.

Boundary conditions	Scenario		
	A	B	C
Ambient water *Temperature(^oC)* *Salinity (PSU)*	 16 34	 16 34	 16 34
Liffey River *Flow (m^3/s)* *Temperature(^oC)* *Salinity(PSU)*	 12.42 16 15	 12.42 16 15	 12.42 16 15
Discharge outfall *Flow (m^3/s)* *Temperature(^oC)* *Salinity(PSU)*	 27.2 21 30	 27.2 16 30	 3.6 16 6

Table. 1. Discharge Scenarios

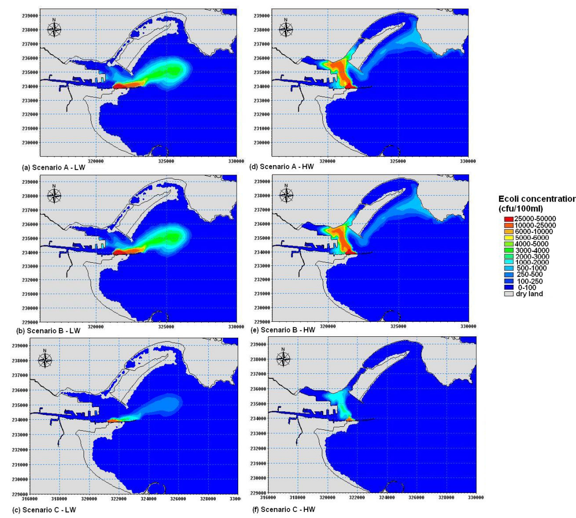

Fig. 2. E.coli distributions in the estuary and Bay (LW= time of low water, HW= time of high water).

Discussion and Conclusions

This paper presents a three-dimensional hydro-environmental model of the Liffey Estuary and Dublin Bay to study the environmental consequence of closing down the ESB Power Plant at Poolbeg. 'Before' and 'after' scenarios were compared to assess the change of water quality status as a result of the expected reduced stratification after the shut down of the plant. Results demonstrated a higher count of E.coli in the inner bay at high water stages of the tide compared to lower stages. The results also showed very little difference in the distribution of E.coli between Scenarios A and B particularly in the inner bay while in the estuary, the concentrations of E.coli are slightly higher in Scenario A than B. Scenario C resulted in considerably lower E.coli concentrations in the estuary and inner bay in comparison to Scenarios A and B.

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