THE APPLICATION OF MOHID TO ASSESS THE POTENTIAL EFFECT OF SEWAGE DISCHARGE SYSTEM AT BAHÍA BLANCA ESTUARY (ARGENTINA)

J.O. PIERINI, F. CAMPUZANO, J. MARCOVECCHIO AND G.M.E. PERILLO

1 INTRODUCTION

The Bahía Blanca urban wastewater treatment plant (UWWTP) discharges the wastewater from the city into the Bahía Blanca Estuary through a tidal channel located 4 km south from the closest city, Ingeniero White, and 1.7 km south from the mouth of the Napostá Creek. There are four UWWTPs discharging in the Bahía Blanca Estuary, with the highest flow from the Bahía Blanca UWWTP at 65000 $m^3\ d^{-1}$, corresponding to 77% of the total (Heffner et al. 2003). Wastewater is an important source of freshwater in the Bahía Blanca estuary comprising 23.3% of the overall freshwater, with contributions of a similar magnitude as the freshwater inputs from the Napostá Grande Creek, 86400 $m^3\ d^{-1}$ (Carrica 1998) and the Sauce Chico creek, 164000 $m^3\ d^{-1}$.

Sewerage systems in Bahía Blanca city are designed with overflow structures that discharge into local waterways when the capacity of the system is exceeded. Overflows occur when the hydraulic capacity of the system is exceeded due to heavy rains. During dry periods, overflow can also take place due to blockages or pump failures. Aguas Bonaerenses Sociedad Anónima (ABSA) manages the main network. The aim of this research was to analyze the potential risks of sewage in the estuary and the installation of a new UWWTP on the coast in the inner Bahía Blanca estuary near bathing waters, i.e. the Maldonado Municipal pool.

2 STUDY APPROACH

The problems associated with wastewater discharges in estuarine and riverine areas are of growing engineering interest, since the increase of pollutant loads in the last decades may lead to serious environmental impacts. In order to quantify river and estuary pollution problems it is necessary to predict the concentration distribution of the pollutant loads in the area under study under different conditions. Numerical models constitute a powerful tool for the study of diffusion and dispersion of pollutants. Model simulations reproduced two different sewage discharges (West and East UWWTPs) in the inner part of Bahía Blanca estuary (Figure 1). The actual UWWTP discharges into a tidal channel, located 5 km away from Puerto Ingeniero White (Latitude: 38°48'34.51" S Longitude: 62°13'19.70" W) in the vicinity of the Napostá River mouth (Figure 1). Official data made available by ABSA estimate an UWWTP discharge of 0.575 $m^3\ s^{-1}$ on average, although on the other hand Piccolo and Perillo (1990) estimated a discharge of 10 $m^3\ s^{-1}$ and sometimes higher than this value. Maldonado Channel is a waterway mainly used when the Napostá River reaches flows over 30 $m^3\ s^{-1}$, preventing floodings by deviation of part of the water. This channel is used during torrential rains, maximum flow under average conditions is 3.6 $m^3\ s^{-1}$.

Samples were collected from five sites along the principal channel of the Bahía Blanca Estuary. Pollutants were characterized in the sewage of Bahía Blanca to determine its physical, chemical, toxicological and microbiological character (MBB 2004). The analyses included: organic and inorganic nutrients, microbial faecal indicators and toxicants. Although the project was not a study of the stormwater impacts, we looked for the pollutants common to both to distinguish the impacts of the overflow during rain events. During the ECOMANAGE Project we simulated the potential impact of sewage discharges and the installation of a new primary treatment plant in the inner estuary. But for the new location of a Treatment Plant there are no data or knowledge of the environmental impact. The next stage of the ECOMANAGE project will be to determine the environmental water-quality of Bahía Blanca estuary in relation to the pollutants found in the untreated sewage. We found that the most cost-effective approach was to test samples for faecal coliform contamination during the event at all locations and times. Faecal coliform (thermo-tolerant coliform) tests were completed in 2003 to identify areas of greatest contamination. The more expensive and time-consuming analyses were then used as confirmation tests for the presence of human faecal contamination.

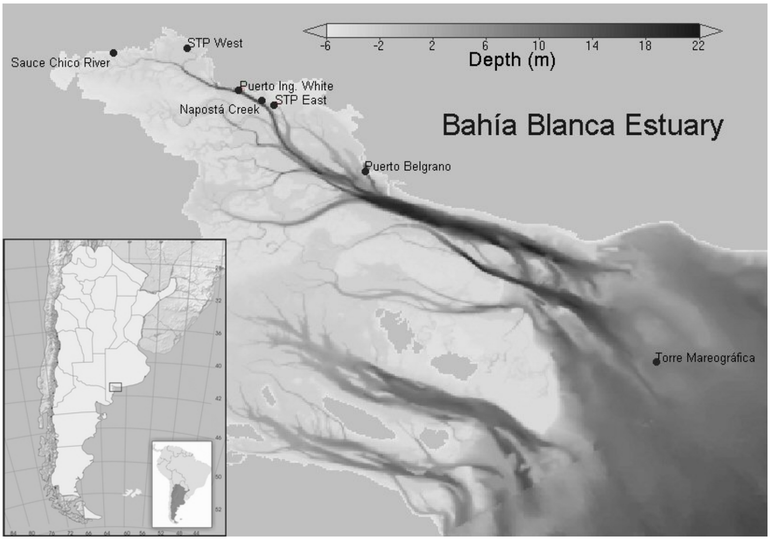

FIGURE 1: *Location of the Sewage Treatment Plant (West and East STP), water discharge and tidal gauges within Bahía Blanca estuary.*

Knowing the environmental water-quality in the recipïent, we were able to compare environmental impact caused by the two treatment plants. Human faecal contamination in the waterway was used to assess the public health hazard and potential risk assessment based on pathogenic indicators (*Escherichia coli*). The *Escherichia coli* abundance was then used in the risk assessment model to determine potential human public health risks over the inner part of estuary. Risk assessment requires knowledge of the extent of human exposure, such as recreational waters (Maldonado pools). While we observed children as well as complete families swimming within the study area, a quantitative assessment of the use (exposure to hazard) of the waterway was beyond the scope of this study.

This study took into account the two treatment plants focusing on the potential impacts and hazards over the inner part of Bahía Blanca estuary as well as the feasibility of using a hydrodynamic model to interpret the pathogenic contamination due to sewage inputs.

3 MATERIAL AND METHODS

3.1 Study Area

The selected area (Figure 1) is located in the southwest of Buenos Aires Province (Argentina). This area is a hydrographic basin of 19000 km^2. It is a mesotidal estuary characterized by a complex tidal channel network separated by islands, wide low marshes and tidal flats. Furthermore, the tidal flats are covered by dense nets of minor tidal channels and creeks. All major channels open to the inner continental shelf form ebb deltas, some of which are largely modified by present day dynamic conditions. The study is concentrated on a sector of the main channel (Figure 1) located in the northern part of the estuary. This channel is approximately 70 km long and 3 km wide in its lower reaches. The average depth of the channel is 10 m and the circulation is dominated by a quasi stationary tidal wave (Perillo et al. 2004). Mean tidal range varies from 2 m at an offshore Oceanographic Tower to 3.5 m at Puerto Ingeniero White (Figure 1). Prevalent winds for the area are mainly from the Northwest and North. These continental winds are strong and flow approximately parallel to the axis of the channel, thus affecting the circulation and vertical mixing in the estuary. The main pathogenic inputs were two sewage treatment plants, located in the northern part of the estuary, equipped with activated sludge treatments (Figure 1). Treated wastewater was monthly sampled at the five sampling stations of the outfall near Napostá Creek. These sites were selected based on their levels of bacterial contamination or hydrodynamic circulation. Water samples were stored at 4 ^{o}C during shipment and analysed within 36 h.

3.2 Hydrodynamic Model

The MOHID hydrodynamic model (Coelho et al. 2002, Santos et al. 2002) was used to force a model covering the study site (from the coordinates (-61.41W, -39.38S) to the inner estuary). In order to study the different hydrodynamic processes involved in Bahía Blanca it was needed to adopt different spatial scales. As a result, the model of Bahía Blanca consists of a set of three nested grids: (1) Level Argentina: covers the Atlantic coast of South America (-70W -40W, -60S -20S) with a resolution of 0.06^{o}; (2) Level Rincón: a secondary model covering the area known as El Rincón with 0.02^{o} resolution (-62.6W -60.5W, -42.8S -38.68S); (3) Level Bahía Blanca: a third submodel covering the main area of interest, the Bahía Blanca with 0.005^{o} resolution (covering from the coordinates (-61.41W, -39.38S) to the inner estuary. The main interest in developing different resolutions has been to study different process in more detail according to the available data and to optimize the runtime of the model. Bathymetric data used for composing the different model domains come mainly from two sources: (i) from CGPBB (Consorcio de Gestión del Puerto de Bahía Blanca) with a waterline obtained from evaluation of 6 sets of Landsat 5 and Landsat 7 data resulting in a high density bathymetry (50 m x 50 m) for the Level Bahía Blanca (Pierini 2007); and, (ii) from the GEBCO digital atlas, a one minute global bathymetric grid database (IOC, IHO and BODC, 2003) for the other areas (Figure 2). The Argentina model was forced with tidal components provided by the generic tidal FES95.2 model (Le Provost et al. 1998). In order to simulate water level at the boundaries a network of ”imaginary” tidal gauges fringing the model boundary on the primary model. The model automagically performs triangulations between the different ”imaginary” tidal gauges to impose the tide on every cell of the boundary. This model then provides boundary conditions consecutively to the nested submodels. In this study, wind and wave conditions were not considered.

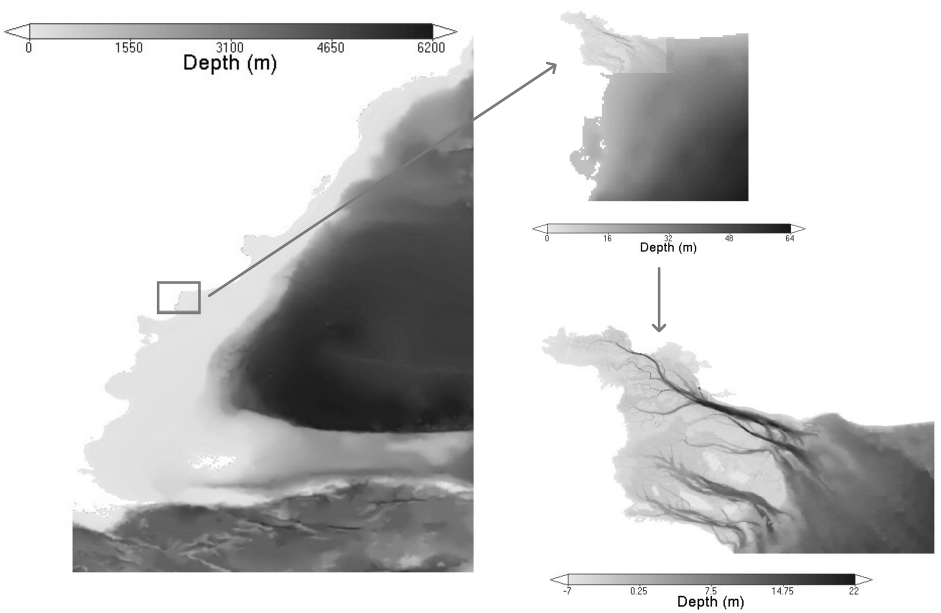

FIGURE 2: *Nested models used for Bahía Blanca Model. On the left is the primary model (Argentina model), on the right above is the secondary model (El Rincon model) and lower right is the tertiary model (Bahía Blanca model).*

3.3 Lagrangian model

The model application couples two different transport models; while the hydrodynamics and environment properties as temperature, salinity and solar radiation are calculated by a eulerian approach, the discharges and evolution are lagrangian oriented. Particle properties are affected by their environment.

4 RESULTS

The variation of *E. coli* concentration from day 0 (starting date of the outbreak) to day 90 (when the simulation was stopped) is reported in Figure 3 for all sample sites. An increase of the contamination was observed during the first days corresponding to the dispersion in the estuary. After 90 days concentrations were well established and were only dependent on the tide and decay rate. The effect of the semidiurnal tide was well modelled. The maximal concentration was observed every 12 h at high tide. The *E. coli* water concentration was highly variable, depending on the tide. In this simulation, the maximal water concentration at 17-7-2003 was equivalent to 10^5 CFU/100 ml (St 4, Figure 3 and 4), after 90 days, the spatial distribution was observed in the other samples sites. The model indicated minimal and maximal concentration of *E. coli* for the five sites. For example, at St 3, all the *E. coli* results obtained by analysis were in accordance with the model, as no sample was found to be contaminated by more than 4560 CFU/100 ml except at the discharge station (Table 1). All the results obtained fitted the values calculated with the model.

TABLE 1: Escherichia coli *observed and modelled with MOHID.*

	***E. Coli* concentration (CFU/100 ml)**					
	17 – Jun – 2003		**30 – Jul – 2003**		**10 – Sept - 2003**	
St	**Obs**	**Mod**	**Obs**	**Mod**	**Obs**	**Mod**
1	2300	2200	4400	4560	1000	1500
2	400	320	1700	1780	1400	1510
3	1700	1700	2100	2212	3600	3655
4	100000	100000	180000	184000	240000	243000
5	2500	2500	2300	2300	2000	1922

5 DISCUSSION AND CONCLUSION

For the integration of the wastewater issue in the coastal management in Bahía Blanca estuary, and more widely in all sensitive coastal ecosystems a systemic methodology based on modelling and simulations can allow the investigation of several different technical solutions which are evaluated using environmental and health criteria. Coastal management for sustainable development requires the investigation of alternative strategies which should optimize: resource preservation, water quality, technical aspects and human uses. Once the urban wastewater has been discharged it is diluted by the estuarine water. The resulting mixture flows towards the main channel of the estuary, a further dilution gradually occurring as a result of mixing with the estuarine water.

The modelling approach embedded in an ecosystem approach is designed to provide to the public a physical and environmental understanding of the processes, as well as to help decision makers to analyze the public demands and to evaluate the environmental investments. The narrow application of a modelling system and production of the results is not sufficient because of the complexity of the situations and the nature of the challenges. The use of optimizing models for systems analysis as linear programming could be used to evaluate and validate some technical solution. This form of numerical approach will only work if everyone involved in the process understands the benefits and limitations of its application and agrees with its uses.

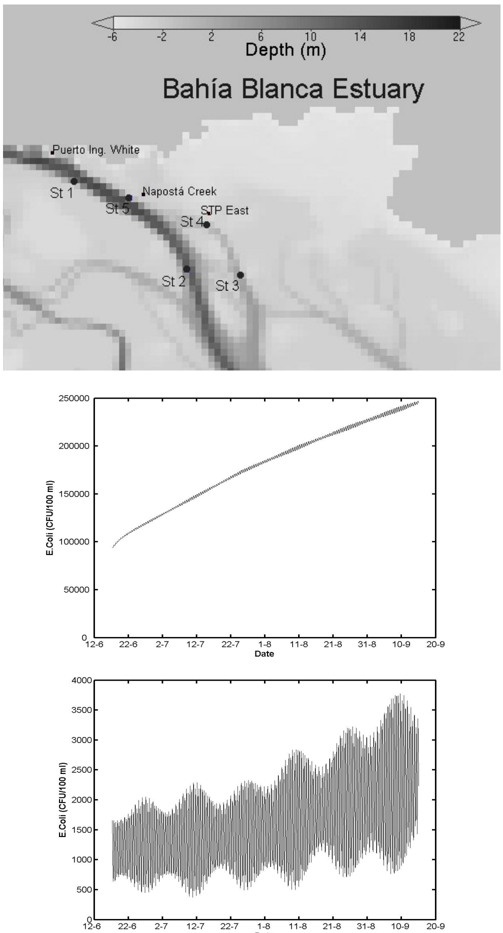

FIGURE 3: *Location of the* E. coli *samples near STP East and temporary evolution in St 4 and St 3.*

Mathematical models were previously shown to be efficient to evaluate sewage impact on bacterial contamination (Kashefipour et al. 2002, Pierini 2007). The use of mathematical modelling could help to interpret the large *Escherichia coli* variations observed along the estuary, principally from the new sewage discharge in the inner part of estuary, near Maldonado

Municipal pool. Moreover, this location requires the construction of a very efficient, sensitive and expensive tertiary process in the treatment plant. In case of malfunctioning - 10^5 CFU/100 ml - the effluent could generate a large polluted area. Consequently, the outflow must be (re)located to an always submerged point, several meters below the low tide level where the currents are continuous as in the main channel.

The model was capable of predicting complex two dimensional flow features and provided a rational tool for environmental decision making. The Estuarine impact assessment using a two-dimensional circulation and transport model has been implemented. The MOHID model described herein is expected to be a useful tool in the efforts to reduce the pollution in the Bahía Blanca estuary. Several projects may have strategic options which are not amenable to simple comparative analysis. In these cases, analytical techniques must help the decision-maker by showing the implications of the various options with the necessary multi-disciplinary perspective, rather than presenting a prescription for action. This recognizes that such complex investment decisions are inherently political. The strategy is then based on the decision maker's capacity to understand the environmental challenge and the human uses and also, to accept the results of the modelling approach which might deeply modify the initial project.

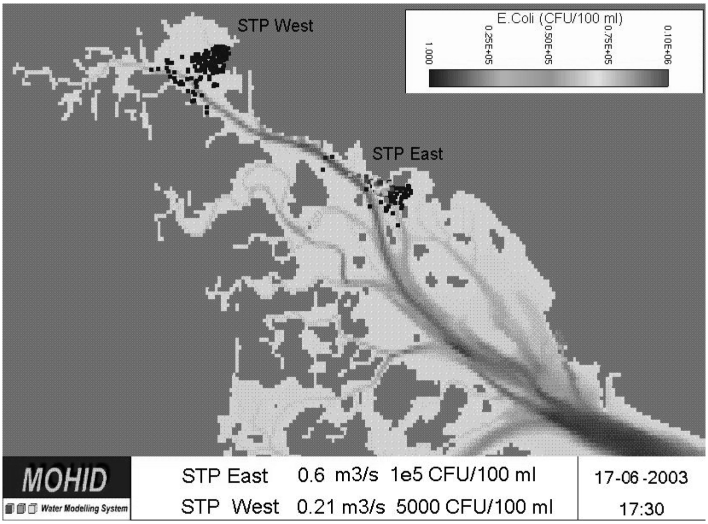

FIGURE 4: *Spatial distribution of* E. coli *with STP West and East discharges in Bahía Blanca Estuary.*

REFERENCES

Canteras JC, Juanes JA, Perez L, Koev KN (1995) Modeling the coliforms inactivation rates in the Cantabrian Sea (Bay of Biscay) from in situ and laboratory determinations of T90. Water Science and Technology 32: 37-44

Carrica JC (1998) Hidrogeología de la cuenca del Arroyo Napostá Grande, Provincia de Buenos Aires. PhD Thesis. Universidad Nacional del Sur. Bahía Blanca. Argentina. pp: 215 and annexes.

Coelho HS, Neves RJ, White M, Leitao PC, Santos AJ (2002) A model for ocean circulation on the Iberian coast. Journal of Marine Systems 32: 153-179

Heffner M, Bodnariuk P, López F, Vaschetti G (2003) Aportes de agua a la Ría de Bahía Blanca. Informes Medioambientales. Comité Tecnico Ejecutivo de la municipalidad de Bahía Blanca. (in Spanish)

IOC, IHO, BODC (2003) Centenary Edition of the GEBCO Digital Atlas. Published on CD-ROM on behalf of the Intergovernmental Oceanographic Commission and the International Hydrographic Organization as part of the General Bathymetric Chart of the Oceans; British Oceanographic Data Centre, Liverpool.

Kashefipour SM, Falconer RA (2002) Longitudinal dispersion coefficients in natural channels. Water Research 36: 1596-1608

Le Provost C, Lyard F, Molines JM, Genco ML, Rabilloud F (1998) A hydrodynamic ocean tide model improved by assimilating a satellite altimeter-derived data set. Journal of Geophysical Research 103: 5513-5529

Municipalidad de Bahía Blanca (2004) Estudio Bacteriológicos realizados en aguas y sedimentos del Estuario de Bahía Blanca. Informe Final. pp:11 (in Spanish)

Perillo GM, Piccolo MC, Arango JM, Sequeira ME (1987) Hidrografía y circulación del estuario de Bahía Blanca (Argentina) en condiciones de baja descarga. 2 Congreso Latinoamericano sobre Ciencias del Mar, II, pp.95-104 (in Spanish)

Perillo GME, Piccolo MC, Palma ED, Pérez DE, Pierini JO (2004) Oceanografía Física. En: Piccolo MC, Hoffmeyer MS (eds) Ecosistema del Estuario de Bahía Blanca, pp.61-67 (in Spanish)

Piccolo MC, GME Perillo (1990) Physical Characteristics of the Bahía Blanca Estuary (Argentine). Estuarine, Coastal and Shelf Science 31: 303-317

Pierini JO (2007) Circulación y transporte en zonas costeras del estuario de Bahía Blanca. PhD Thesis, Universidad de Buenos Aires, pp: 225 (in Spanish)

Santos A, Martins H, Coelho H, Leitao PC, Neves R (2002) A circulation model for the European ocean margin. Applied Mathematical Modelling 26: 563-582