I-036 - WATER QUALITY IN UNSTEADY ESTUARINE TIDAL FLOW: NITROGEN MODELING AND FIELD EXPERIENCES INTO THE INTAKE CHANNEL OF CERVIA SALINE IN ADRIATIC SEA

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ABSTRACT

Aim of the present work is to describe and to model water quality into a short estuarine channel strongly conditioned by tidal oscillations. These typical transition water volumes are frequently subjected to discharge of effluent from urban drainage system or from wastewater treatment plant and are very important in sanitary conditioning of marine coastal areas.

Field experiences are carried out during three days into the intake channel of the Etrurian Saline at Cervia (RA) and made possible a complete hourly parametric description of water quality during four tidal cycles. Concentration of biomass, ammonia, salinity, nitrate and orthophosphate are analyzed as a temporary step of two hours in surface and bottom samples caught at 200 m from the sea outfall. In the same time it has been measured water temperature, pH and sea level in outfall.

Calculations developed in measured tidal flow conditions present a good agreement with results of field experiences.

KEYWORDS: sea water quality, tidal flow, nitrogen, estuarine channel, wastewater, hourly measurements, nitrogen sediment release, aeration rate.

INTRODUCTION

Quality of seawater in coastal small deep areas is strongly conditioned by existing wastewater discharging systems. South padan adriatic region frequently presents wastewater outfalls into channels that provide to discharge into sea according with unsteady tidal flow. So near coastal bathing seaside can present water quality strongly variable during the day. Turbulent mixing and oxidation capabilities are function of channel morphology and tidal conditions. Ammonia input and balance of freshwater in transition water volumes can modify ammonia-nitrate equilibrium and thermocline assessment in output discharge.

The present survey follows other experimental works developed on Candinano Channel at Ravenna (1) and on Harbour Channel of Rimini (5) based on comparison between model results with analysis of water quality sampled at different distance from sea outfall but temporarily limited to a few sample for day.

In the present paper are discussed and compared with calculations the results of analysis carried out continuously, as a temporary step of two hours, in surface and bottom samples from a fixed point at 200 m from the sea outfall. All parameters have been registered during four tidal cycles, the same behaviour for values of salinity, oxygen, ammonia and nitrate in surface and bottom water reveals conditions of complete mixing for volumes at sampling section. Analysis to control characteristics of sea-water input has been executed with a step of six hours.

FLOW DESCRIPTION

In case of channel not exceeding length of 2-3 kilometers, minimal variations of water level surveyed versus spatial distance made impossible to describe unsteady tidal flow calculating velocity by classic resistance in outfall. The existing low resistance to flow make not applicable also all others calculations of velocity based on energy slope,
roughness coefficient and hydraulic radius. So we have utilized a simplified scheme of calculations for hydraulic flow dividing the channel into fifteen independent cells not connected one-another. At each section flowrate has been calculated in function of water surface enclosed between each section and internal head of the channel. With the hypotheses of negligible flow resistance and cyclical simplification of tidal behaviour in outfall, flowrate at each section can be computed from continuity equation utilizing the simplified scheme:

\[
dy \cdot b_i \cdot L_i = u_i \cdot dt \cdot b_i \cdot L_i
\]

with; \(y\) = water level at outfall; \(u_i\) = water velocity at section; \(b_i\) = width of section; \(L_i\) = distance of section from head channel. Water level \(y\) has been measured every two hours and interpreted for step calculation by a double harmonic function. The channel studied is 2.25 Km long, presents variable width from 9 to 6 m and depth ranging between 2 to 1.5 m. Bed slope is near to zero and section form is rectangular for all cells.

**MASS BALANCE AND CINETICS**

Low depth maintains cells in complete mixed status for most part of time, this happens for most section of the channel excepting two final cells near internal head of the channel where period of complete mixing is less than 12 hours. Temperature and concentration values of salinity, oxygen and nitrogen forms were constant along vertical profile (see graphs) and showed very low variations in flow direction so for nutrient and salinity balance it has been utilized a completely mixed scheme in one-dimensional flow instead of a classic advection diffusion equation. Some incoming water flow are present in internal section, model can introduce nutrient loadings from internal cells. In present case of study simulation considers external nutrient loading coming from input wastewater and internal release coming from bottom sediment. It has been considered input oxygen from surface aeration and from photosynthesis. All parameters measured has been calculated as concentration applying mass balance. Calculation grid provides 15 reaction cells 150 metres long resolved in a finite scheme difference. The balance of nitrogen and oxygen is so schematized for a cell:

![Schematic diagram of mass balance and cinetics](image)

Cinetics are described according with Monod and Michaelis-Menten equations assuming half-saturation constants as calibration parameters. For example the following equations reports ammonia nitrification rate \(v_N\) for cell as function of temperature \(T\), N-NH4 concentration, and oxygen concentration O2 in the cell

\[
v_{Ni} = v_{Nmax} \cdot \left[1 + \left(\frac{NH4}{N-NH4} + kN\right)\right] O2 \left(\frac{O2}{kO2} + kO2\right)
\]

with \(v_{Nmax}\) = maximum nitrification rate \((s^{-1})\); \(T\) = water temperature \(^{\circ}\)C; \(kN, kO2\) = half-saturation constants for ammonium and dissolved oxygen \((mg/l)\)
Growth rate for phytoplankton biomass $p_i$ is described in function of Nitrate-Nitrogen concentration according with Michaelis Menten, in function of solar irradiance (Steele equation) and related to Reynolds Number as relation reported in reference (6). For temperature dependence it has been utilized the following equation that is provided of a maximum:

$$p_i = p_{\text{max}} \cdot \sin\left[\frac{\pi}{2} \cdot \left(\frac{T_i - T_0}{T_m - T_0}\right) \cdot \exp\left(k_s \cdot \left(\frac{T_i - T_m}{T_m}\right)\right)\right]$$

where: $k_s$ = characteristic coefficient for each algal species ($\text{s}^{-1}$) ; $p_{\text{max}}$ = max growth rate ($\text{s}^{-1}$) ; $T_m$ = max growth rate temperature ($\degree\text{C}$) ; $T_0$ = min growth rate temperature ($\degree\text{C}$)

FIELD MEASUREMENTS AND ANALYSIS

Water quality data for transition water volumes and particularly in tidal channel flow are rare and often limited to scarce daily samples. So we have carried out a work of analysis and measurements continuously during a period of two days (2.8.01 h.14.00 - 4.8.01 h.14.00). It has been chosen the intake channel of Cervia Saline as indicator of a tidal flow strongly conditioned in water quality from the Adriatic sea. So from a fixed point at 200 m from the sea outfall, every two hours in surface and bottom, have been measured directly temperature, oxygen, pH, and conducibility and are taken samples for detection in laboratory of Nitrate Nitrogen, Nitrite Nitrogen, Ammonia Nitrogen, Phosphate and Chlorophyll.

RESULTS

Following graphs present results of simulation compared with results of analysis showing a good agreement between values calculated and simulated. Calculation experiences reveal as very important in calibration a good description for channel section and tidal rise. Aeration rate due to photosynthesis and ammonia sediments release rate from bottom of the channel are very sensitive calibration parameters.

![SALINITY](image)

Fig. 1: Salinity measured and calculated at measurement section.
Table 1: Main cinetic parameters used in simulation

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<thead>
<tr>
<th>mark</th>
<th>name</th>
<th>value - unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_{\text{max}}$</td>
<td>max algal growth rate</td>
<td>2.1 ($d^{-1}$)</td>
</tr>
<tr>
<td>$V_{\text{Nmax}}$</td>
<td>max nitrification velocity</td>
<td>0.15 ($d^{-1}$)</td>
</tr>
<tr>
<td>$k_N$</td>
<td>half-saturation nitrification constant</td>
<td>0.05 (mg/L)</td>
</tr>
<tr>
<td>$r_N$</td>
<td>ammonia sediment release rate</td>
<td>0.14 (g/mq/d)</td>
</tr>
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**Fig. 2: Ammonia-Nitrogen measured and calculated at measurement section.**

Calculation presents good stability for all parameters, but accuracy in describing oxygen balance makes easier other calibration phases and increase general stability for the entire system. Denitrification process has been considered in balance equation of nitrogen inversely related to oxygen concentration. Maintainment of aerobic conditions along water column in all sections the channel made these phenomena not very considerable. Simulation works with 60 seconds time step and it has been executed for 345600 (four day) seconds.
Fig. 3: Dissolved oxygen measured and calculated at measurement section.

Fig. 4: Nitrate-Nitrogen measured and calculated at measurement section.
Simulation is realized by 60 seconds time step and it has been executed for 345600 seconds (four day). Are possible, in numerical stability condition, longer time execution, oxygen, salinity, ammonia parameters reveal the overcoming of initial transitory phase approximately after a time of one day.

CONCLUSIONS

The present paper describes and models nitrogen into an estuarine channel strongly conditioned by tidal oscillations and releases from bottom sediments.

Field experiences produced results as a temporary step of two hours, in surface and bottom of the channel, this made possible a complete parametric description of channel water quality during four tidal cycles.

Calculations, developed in different tidal flow conditions, show a good agreement with results of field experiences for salinity nitrate-nitrogen ammonia-nitrogen and dissolved oxygen.

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