Study of the autodepuration potential of a tidal ecosystem affected by urban sewage

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Abstract

This paper shows the results obtained in various studies undertaken in the years 1999 to 2001 in the Faculty of Marine and Environmental Sciences of University of Cadiz, in Spain. This work was carried out in the sensible ecosystem of the estuary of Iro River. This estuary is directly affected by an important urban sewage. Although the waste is treated in a treatment plant before the discharge, a high level of contamination by nutrients and pathogens are measured in the aquatic ecosystem. The aim of this work was to determine the natural dilution and depuration process of the aquatic system.

1 Introduction

The Iro River is strongly affected by the tides at its mouth, in Sancti Petri Channel. The River is located to the east and south of the Bay of Cadiz, in the municipal jurisdiction of Chiclana de la Frontera (population ~ 60,000). The estuary crosses Chiclana and in the limit of the town, an important contamination source provided by the effluent from an urban wastewater treatment is localized.

Iro River estuary is quite interesting to study from a social and ecological point of view because of some peculiarities:

- As the river crosses Chiclana, it receives water from agricultural sources as well as the urban wastewater discharge.
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- The river provides water to several fish farms.
- There are important residential and tourist zones in the area, with leisure and water sport facilities.
- Iro River and surrounding area are located into the Natural Park Bay of Cadiz, and therefore are subject to specific statutory regulations.
- The river is subject to strong tidal effects, such that water flow depends more on tidal movements than on the supply of fluvial freshwater.

Due to these reasons, the Council of Chiclana de la Frontera has carried out different studies with the University of Cadiz, in order to determine the status of the water quality of the River and the processes of dilution and autodepuration in it. In this paper initial results of physical-chemical and microbiological characterization are presented.

2 Materials and methods

2.1 Sample stations

Ten sample stations were selected in order to characterize the dilution process in the Iro River.

Figure 1: Iro River – Location of the sample stations
Figure 1 shows the morphology of Iro River and the location of sampling stations. Station RI-1 is located at the head of the estuary in the middle of the town of Chiclana. Station RI-2 is located in the mixing area of the discharges and the receiving waters. Stations RI-3, 4, 5, 6, 7, 8 and 9 are located along the estuary to the mouth, and RI-10 is located in the mixing area of the waters of the Iro River and Sancti Petri Channel.

2.2 Sample collection, handling and storage

The study was restricted to the moments of high tide with the sample collection taken in the middle of the flow using a zodiac boat. From each station, a punctual sample was taken at 0.5 m from the top with the aim to keep out the effect of ultraviolet radiation to the microbiological population. PH, salinity and temperature determinations were realised at the moment of the collection. Samples for physical-chemical analysis were stored in a PPT container of 2 litre capacity, and samples for microbiological analysis were stored in a borosilicate-sterilized bottle of 1 litre capacity. All the samples were conserved at 4°C until the analysis in the laboratory.

2.3 Physical-chemical analysis

A limited number of physical-chemical parameters (pH, temperature, salinity), dissolved organic carbon (DOC) levels, and nutrients (nitrite, nitrate, ammonium and phosphate) were evaluated according with standardised and documented seawater procedures (Grasshoff et al., 1983; APHA-AWWA-WPCF, 1988; Rodier, 1992).

2.4 Microbiological analysis

Analysis of Faecal streptococci (FS) and Faecal coliform (FC) were realised by membrane filtration procedure and incubation in specific medium according with standardised procedures (APHA-AWWA-WPCF, 1988). In order to avoid an excessive concentration of salts in the membrane, a maximum volume sample of 20 ml. was allowed in the filtration.

3 Results and discussions

The quality of seawater and subsequent effect of the wastewaters in the environment was evaluated by analysing the parameters mentioned above in the ten sampling stations selected along the Iro River. Table 1 summarised the means of results obtained in the sample stations.

3.1 Spatial variability

Plots of the spatial variability of the variables along the estuary are showed in Figure 2 (physical-chemical variables) and Figure 3 (microbiological variables). In the mixing area (IR-2), a decrease in the values of salinity is correlated with a great increment in the concentration of several parameters that presents high concentrations in typical urban sewages (ammonium, phosphate, DOC, faecal
Table 1: Analytical results of the variables

<table>
<thead>
<tr>
<th>Station</th>
<th>Distance (km)</th>
<th>pH</th>
<th>T (°C)</th>
<th>Salinity</th>
<th>NH₄⁺ (mmol L⁻¹)</th>
<th>NO₃⁻ (mmol L⁻¹)</th>
<th>NO₂⁻ (mmol L⁻¹)</th>
<th>PO₄³⁻ (mmol L⁻¹)</th>
<th>DOC (mg L⁻¹)</th>
<th>AB (UFC mL⁻¹)</th>
<th>FS (UFC 100 mL⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RI 1</td>
<td>0</td>
<td>8.23</td>
<td>18.8</td>
<td>35</td>
<td>49.17</td>
<td>47.8</td>
<td>0.75</td>
<td>2.837</td>
<td>6.24</td>
<td>5.71</td>
<td>8.943</td>
</tr>
<tr>
<td>RI 2</td>
<td>500</td>
<td>8.13</td>
<td>18.5</td>
<td>32.2</td>
<td>225.93</td>
<td>65.69</td>
<td>0.67</td>
<td>8.943</td>
<td>6.24</td>
<td>5.71</td>
<td>8.943</td>
</tr>
<tr>
<td>RI 3</td>
<td>1000</td>
<td>8.23</td>
<td>18.9</td>
<td>33.4</td>
<td>105.74</td>
<td>55.81</td>
<td>0.66</td>
<td>8.943</td>
<td>6.24</td>
<td>5.71</td>
<td>8.943</td>
</tr>
<tr>
<td>RI 4</td>
<td>1500</td>
<td>8.25</td>
<td>18.8</td>
<td>34.2</td>
<td>55.72</td>
<td>50.27</td>
<td>0.6</td>
<td>8.943</td>
<td>6.24</td>
<td>5.71</td>
<td>8.943</td>
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<tr>
<td>RI 5</td>
<td>2000</td>
<td>8.26</td>
<td>18.7</td>
<td>34.8</td>
<td>43.12</td>
<td>43.12</td>
<td>0.6</td>
<td>8.943</td>
<td>6.24</td>
<td>5.71</td>
<td>8.943</td>
</tr>
<tr>
<td>RI 6</td>
<td>2500</td>
<td>8.27</td>
<td>18.7</td>
<td>35.2</td>
<td>40.27</td>
<td>40.27</td>
<td>0.6</td>
<td>8.943</td>
<td>6.24</td>
<td>5.71</td>
<td>8.943</td>
</tr>
<tr>
<td>RI 7</td>
<td>3000</td>
<td>8.28</td>
<td>18.8</td>
<td>35.3</td>
<td>22.83</td>
<td>34.31</td>
<td>0.6</td>
<td>8.943</td>
<td>6.24</td>
<td>5.71</td>
<td>8.943</td>
</tr>
<tr>
<td>RI 8</td>
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<td>8.27</td>
<td>18.7</td>
<td>35.5</td>
<td>18.98</td>
<td>34.31</td>
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<td>8.943</td>
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<td>18.8</td>
<td>35.7</td>
<td>17.59</td>
<td>34.31</td>
<td>0.6</td>
<td>8.943</td>
<td>6.24</td>
<td>5.71</td>
<td>8.943</td>
</tr>
<tr>
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<td>8.28</td>
<td>18.8</td>
<td>35.7</td>
<td>16.09</td>
<td>34.31</td>
<td>0.6</td>
<td>8.943</td>
<td>6.24</td>
<td>5.71</td>
<td>8.943</td>
</tr>
</tbody>
</table>

As stations are located to the mouth of the estuary, there is a gradual decrease in the concentration of parameters produced by dilution process. In IR-10, the water of the IRO River acquires the mean values of the global system.

The difference of concentrations of the variables in IR-2 and IR-9 (just before the mixing with Sancti Petri channel) showed a dilution factor of 92, 45, 34, 83, 41, 99 and 98 percentage for ammonium, nitrate, nitrite, phosphate, DOC, FC and FS respectability. With regard to the dilution process, there are two groups of parameters:
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- **Group I** – ammonium, phosphate, FC and FS – of about 85-99 percentage of dilution.
- **Group II** – nitrate, nitrite, DOC – of about 40-45 percentage of dilution.

The conclusion is that it is possible that another different process can be occurring in the estuary (i.e. chemical transformation, depredation of pathogens).

### 3.2 Hypothetical dilution curves

**Figure 4: Dilution curve -Ammonium**

**Figure 5: Dilution curve –Phosphate**
Figure 4, 5 and 6 show the hypothetical dilution curve of the most relevant parameters corresponding to Group I. Variations in the curve of the variables respect to dilution curve show that assimilation processes and other removal processes are present in the system. Ammonium and phosphate are elementary nutrients for primary productivity. Also, ammonium is an instable nitrogen specie. In aquatic ecosystems, ammonium is oxide to nitrite and nitrate. With regard to microbiological indicators, predation processes could be present by natural biota (rotifers, etc.).
Figure 7 and 8 show the hypothetical dilution curve of two parameters corresponding to Group II. Similarities between both curves (salinity and nitrate or DOC) show that the parameters corresponding with this group have an evolution along the estuary due dilution process. This is not a final conclusion so it is necessary to carry out more studies about these parameters.

4 Conclusions

The main conclusions of this study are:

(I) The wastewater causes a significant increase in organic matter, nutrients and concentration of micro-organisms of faecal origin,

(II) The river has great capacity for autodepuration, with levels of contaminants falling to normal levels within a very short distance of the sewage outlet.

(III) In the estuary, the degrees of contamination parameters are not only governed by the dilution process. Chemical transformation and depredation of pathogens are succeeding.

5 Bibliography


