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Anthropogenic changes in the fluxes to estuaries: Wastewater discharges compared with river loads in small rias

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ABSTRACT

The modification of chemical inputs into estuaries/rias by wastewater discharges is poorly documented. Concentrations and fluxes of nutrient salts, organic matter and trace metals in rivers and wastewaters to the mesotrophic Rias of Ortigueira (38 km^2) and Viveiro (27 km^2), located on the western Cantabrian coast (Bay of Biscay), were evaluated to assess changes in the land-sea fluxes. Water was sampled monthly during a year in the Mera (6.0 $m^3\ s^{-1}$) and Landro (9.4 $m^3\ s^{-1}$) rivers flowing into the Rias of Ortigueira and Viveiro, respectively. The urban effluents of Ortigueira (1800 inhabitants; treated sewage) and the Viveiro (7100 inhabitants; municipal treated sewage and untreated industrial wastewaters) were also monitored. Concentrations of chemical compounds and their fluxes were quite similar and close to pristine conditions in both rivers. Nitrate (98% of DIN), the limiting nutrient of ria primary production, was controlled by river flow while phosphate by wastewater discharge. Sewage discharges should not disturb the Ria of Ortigueira. Wastewaters fluxes of phosphate, POC, PON, dissolved Cu and particulate Cd, Cu and Zn into the Ria of Viveiro exceeded those of the Landro River, mainly during summer. Also, untreated wastewater effluents from fish food processing in such small fishing ports can be a source of contamination. The Rias of Ortigueira and Vivieiro are a reference point to evaluate fluvial pristine conditions and wastewater discharges on small estuary-ria receptor systems.

1. Introduction

Rivers represent the main pathway of weathered materials into the ocean through the estuaries. Since the beginning of the 20th century the industrial revolution has resulted in a "*drastic release*" of nutrients, organic matter and metals into the natural environment (Gaillardet et al., 2003). It is estimated that human influence has more than doubled the annual discharge of materials into the ocean by rivers (Salomons and Förstner, 1984). Smith et al. (2005) demonstrated how human activities altered the global biogeochemical cycles, particularly, the coastal fluxes of C, N and P. Estuarine chemistry has changed during the Anthropocene (Meybeck and Vörösmarty, 2005), in particular urbanized estuaries receiving wastewater discharged. In addition to the natural source of nutrients related to rock weathering and the leaching of organic soils (Viers et al., 2007) anthropogenic inputs from dispersed sources (e.g. fertilizers) or point sources (e.g. wastewater facilities) have altered the land-sea fluxes.

In confined ecosystems, wastewater treatment plants may release higher quantities of nutrients and metals than dispersed or other point sources, altering the natural biogeochemical cycles with pernicious effects in the receiving coastal ecosystems (Carey and Migliaccio, 2009). Whereas nutrients input is a key factor for the functioning of estuarine and coastal ecosystems (de Jonge et al., 2002), excess of nutrients, namely resulting from wastewater effluents, can lead to increase of algal biomass, reduction of dissolved

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oxygen and ultimately to harmful algal blooms and fish mortality (Carey and Migliaccio, 2009). Metals in estuaries and rias often occur at moderate concentrations (Kennish, 1997; Prego and Cobelo-García, 2003), mainly due to contaminated streams as shown to occur in the Ria of Ferrol (Cobelo-García et al., 2004). Elevated metal concentrations may affect resident and migratory organisms (da Silva Oliveira et al., 2007), as well as reduce the functioning of the ecosystem. The treatment of municipal and industrial wastewater may be a key measure to reduce the metal impact (Santos-Echeandía, 2009). Comparison of metals inputs from natural processes and wastewater have only rarely been made. Paul and Meyer (2001) pointed out that the Archers treatment plant (West Paris, France) increased the Seine River flow by up to 40% in summer periods, and wastewater effluents comprise 69% of the Platte River (Denver, USA) annual flow (Dennehy et al., 1998). Recently, several borderline hypoxic situations (Lanoux et al., 2013) and cases of metal contamination on urban wastewater inputs (Deycard et al., 2014) have been reported from the parts of the fluvial Gironde Estuary. To the best of our knowledge, no comparative data is available for estuaries despite the increase of wastewater treatment plants (WWTPs) in the last decades.

The aim of this study is to assess the relevance of wastewater effluents relative to river loads into an estuary. This comparison was made for nutrients, organic matter and metals in the Rias of Ortigueira and Viveiro, representative of the Northern Galician Rias. Concentrations and fluxes in river inputs and wastewaters effluents were considered.

2. Survey area

Northern Galician Rias are located in the southwestern coast of the Bay of Biscay. Rias are funnel-like incised valleys where the lower part of the river has been flooded. Only the inner part can be considered as an estuary from both hydrographic and their resulting sedimentological considerations (Evans and Prego, 2003). Northern Galician Rias include the Rias of Ortigueira and Viveiro (Fig. 1), these have surface area respectively 38–27 km^2 and are 30–35 m depth at their open mouths which are exposed to the North swell. In the innermost parts they receive the main freshwater input from the Mera River (Ria of Ortigueira) and the Landro River (Ria of Viveiro), which have drainage basins of 127 and 270 km^2, respectively. The annual average flow of 6.0 $m^3\ s^{-1}$ of the Mera River and 9.4 $m^3\ s^{-1}$ of the Landro River, during the period of 1975–2013 (data from of 'Augas-de-Galicia' Co.), defines them as small rivers according to the Meybeck et al. (1996) classification.

The climate of northern Galicia is wet and temperate, Cfb Köppen type (i.e. Marine Climate; Hess, 2014), with an annual average temperature of 13.1 °C and an average annual precipitation of 1370 mm. Depending on the climate the fluvial regime shows seasonality with higher flows in December–February and lower flows from July to September.

The Mera River flows through a basin composed of metamorphic, mafic and ultramafic rocks while that of the Landro River contains metamorphic and granitic alkaline rocks. The drainage basins are covered by eucalyptus and pine forests and scrublands with only a small proportion of cultivated areas in the floodplains. The soil permeability of the river basins is low (Río-Barja and Rodríguez-Lestegás, 1992). Both rivers have very shallow estuaries containing extensive marshlands and beach barriers in their inner parts.

The population density is low (≈70 inhab km^2) and is mostly concentrated near the river mouths. The town of Ortigueira had 1800 inhabitants (2008 INE database) and its municipal sewage (≈3 × 10^5 $m^3\ yr^{-1}$) is discharged to the inner ria after physico-chemical and biological treatment, including U.V. disinfection in the wastewater treatment plant (WWTP). In 2008 the town of Viveiro had 7100 inhabitants (2008 INE database) and its wastewater (≈1.7 × 10^6 $m^3\ yr^{-1}$) is discharged into the middle ria

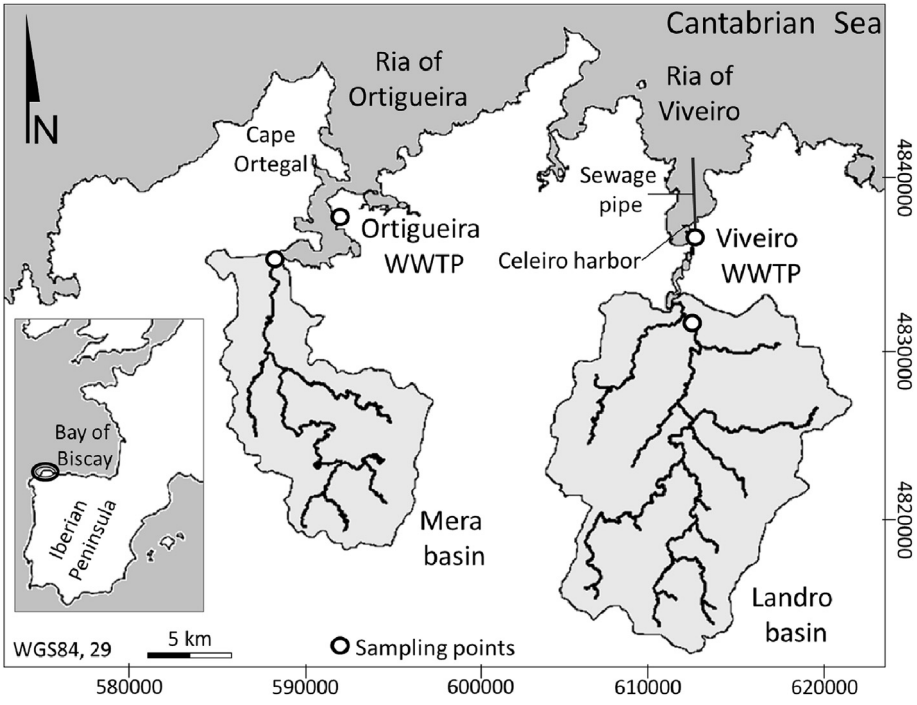

Fig. 1. Geographic setting of the fluvial basins and wastewater treatment plants (WWTPs) of the Western Cantabrian coast (Bay of Biscay) from Sitga (http://mapas.xunta.es/portada) and Sigpac (http://sigpac.mapa.es/fega/visor/). The Mera River and the Ortigueira WWTP flowing into the Ria of Ortigueira; the Landro River and the Viviero WWTP (together with an untreated flux from the Celeiro) flowing into the Ria of Viveiro.