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Integral assessment of pollution in the Suquía River (Córdoba, Argentina) as a contribution to lotic ecosystem restoration programs

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ABSTRACT

The Suquía River lower–middle basin (Córdoba, Argentina) is subject to a strong anthropic impact because it receives pollutants from different sources (industries, wastewaters, heavy traffic, agricultural land use, etc.) We have assessed the degree of watershed degradation of Suquía River lower–middle sections through the analysis of different ecosystem compartments (air, water, riparian soil, sediments and biota), in order to provide useful data to be considered in future river restoration programs. Four study sites were selected along the river (La Calera city, Córdoba city, Corazón de María village and Río Primero city) which were sampled during the low- and high-water flow periods. We analyzed: a) chemical and physical characteristics of water, sediments, and riparian soil; b) heavy metal content of water and sediments, and c) semi-volatile organic compounds in air. Besides, pollutant bioindicators such as fish assemblages, lichens (*Usnea amblyoclada*), vascular plants (*Tradescantia pallida*), and microorganisms (fecal coliform and *Escherichia coli*) were used to further assess the status of the river. All analyzed ecological compartments were affected by water pollution, particularly, fish assemblages, sediments and riparian soils by heavy metal and coliform bacteria. Moreover, we detected a possible contribution of sulfur and a high pollutant content in air that merit further research about other air–water exchanges. Accordingly, we strongly suggest that an action to restore or remediate the anthropic effect on the Suquía River be extended to all possible compartments along the river.

1. Introduction

Human activities have greatly altered freshwater ecosystems worldwide. The Suquía River (Córdoba, Argentina), as most water courses running across big cities, receives complex pollutants from different sources. Furthermore, it is particularly vulnerable to pollution due to its scarce and seasonal flow, short length and endorheic basin (Wunderlin et al., 2001; Contardo-Jara et al., 2009). It is well known that watersheds of arid or semiarid regions have scarce capacity of self-purification and drag of pollutants. At the same time, its endorheic condition complicates the output of xenobiotics compounds, contributing to their accumulation in the basin (Gaiero et al., 1997).

Air, water, sediment and soil maintain a close relationship because they are reciprocal sinks and sources of pollutants. Therefore, the pollution of a river basin is not confined to a single compartment or to a nearby source (Swackhamer et al., 2004). The most important mechanisms of pollutant dispersal are volatilization and transport by the atmosphere (Shen et al., 2005; Shoieb et al., 2006; Jahnke et al., 2007a), deposition by rainfall, irrigation for agriculture, and leaching to groundwater (Carpenter et al., 1998; Williamson et al., 2008; Bazargan-Lari et al., 2009).

It is widely accepted that polluted waters affect not only the human population (by agricultural, recreational and drinking water uses; Yau et al., 2009), but also riparian soils, air and biota. From these ecological compartments, more harmful and enduring in time effects have been described (Depledge and Galloway, 2005; Katz et al., 2009).

Nowadays restoration programs for polluted rivers are widespread throughout the world, comprising purification and control of watershed uptakes (Parkyn et al., 2003; Craig et al., 2008; White and Stromberg, 2009). If restoration programs were applied to Suquía River, the scarce information available about the magnitude of the system alteration and its resilience capability would pose severe limitations.

The main problems that the Suquía River basin is coping are anthropogenic activities, sewages, agricultural and industrial effluents from point and nonpoint pollution sources (Wunderlin et al., 2001; Hued and Bistoni, 2005; Nimptsch et al., 2005). In recent years numerous

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studies have demonstrated the effects of the watershed degradation on local aquatic biota (Bistoni et al., 1999; Cazenave et al., 2005; Hued and Bistoni, 2005). On the other hand, previous studies have demonstrated the adverse impact of air pollutants on a lichen and a vascular plant species (Carreras et al., 2006; 2009). These toxic effects were associated to the primary air pollution in Córdoba city driven by the traffic, the poor control on emissions and the little use of catalytic converters which produce a great amount of toxic gases and particulate (Olcese and Toselli, 2002). Despite these evidence, no studies have been conducted in order to combine comprehensive information from different compartments (air, water, sediments, soil and biota). These facts generate uncertainty at the moment to plan restoration actions.

Our main goal was to assess the degree of watershed degradation of Suquía River lower–middle sections through the analysis of different ecosystem compartments (air, water, riparian soil, sediments and biota), in order to provide useful data to be considered in future river restoration programs. We carried out a systematized study with an integral approach and applied specific methodologies to characterize each ecological compartment. Air organic pollutants as well as microbial and chemical characteristics of riparian soils are reported for the first time.

2. Materials and methods

2.1. Study area

The Suquía River is located in a semi-arid region of Córdoba province (Argentina) and drains into the depression of the Mar Chiquita Lake. The watershed covers approximately 7.700 km^2, of which almost 900 km^2 corresponds to the Córdoba city drainage area. The mean annual rainfall is in the range of 700 to 900 mm, with a dry season (from May to November) and a wet season (from October to April) with most of the rainfall occurring in January and February. The Suquía River begins at the San Roque Dam and flows mainly from west to east for about 200 km until Mar Chiquita Lake. Thirty kilometers away from the dam, it enters Córdoba city flowing through a cement channel for approximately 6 km, and then alternating with open banks for about 40 km. The hydrological system of this river comprises three drainage areas: a) the high basin, in a mountainous area with headwaters and streams of torrential character, which flow into the San Roque Dam; b) the middle basin with drainage areas belonging to the eastern slope of the Sierras Chicas and their foothills, together with Córdoba city drainage area; and c) the lower basin, from Cordoba city to Mar Chiquita Lake, in a level area, where the river exhibits typical meanders and a shallow and scarce flow.

The San Roque Dam is an artificial lake where fishing, swimming, boating and sailing are practiced. These recreational activities have promoted the urbanization of the lake shorelines and surroundings. This dam is the main drinking water source for Córdoba city (1.29 million inhabitants). In the last 20 years, the city's population has almost doubled and growing industrialization has increased the risk of having toxic effluents discharged into the river. Downtown, La Cañada brook contributes to the river flow, and near the eastern edge of the city the Suquía River is affected by the city's sewage discharge from the Municipal Waste Water Treatment Plant (WWTP) (Pesce and Wunderlin, 2000; Wunderlin et al., 2001) (Fig. 1).

The flow regime of rivers that form Suquía River drainage network is exclusively pluvial origin, with a marked seasonality of the flow due to the irregular distribution of rainfall throughout the year (Pasquini et al., 2011). Though there is not a systematic study, the river flow can be estimated from the water released by the San Roque Dam. The Suquía River has shown a high flow period, from December to April, with an estimated flow greater than 15 $m^3 s^{-1}$; whereas during the dry season, from May to November, its estimated flow is 2.7 $m^3 s^{-1}$ (Vázquez et al., 1979).

With the exception of Suquía River basin headwaters (mean altitude of 1000 m.a.s.l. and dominated by high metamorphic rocks), the drainage basin is covered by Tertiary and Modern sediments. Sediment erosion and the ubiquitous presence of marble quarries, confer a clear alkaline character to its waters. According to Gaiero et al. (1997) in the middle–low basin sediments are introduced into the mainstream by bank erosion.

2.2. Study sites

Four study sites were selected in the lower–middle basin of the Suquía River (Fig. 1):

a) Site 1 (31° 21′ 45″ S and 64° 20′ 99″ W, 488 m.a.s.l.): Located in La Calera city, 18.4 km downstream San Roque Dam and 18 km upstream of Córdoba city west border. In this site the river carries contaminants coming from the eutrophic San Roque Dam as well as sewage discharges and urban run-off from villages further upstream (Amé et al., 2003).
b) Site 2 (31° 23′ 82″ S and 64° 14′62 ″ W, 393 m.a.s.l.): Positioned in Córdoba city, 27.8 km downstream Site 1. At this point the river runs through a cement channel that replaces the natural river

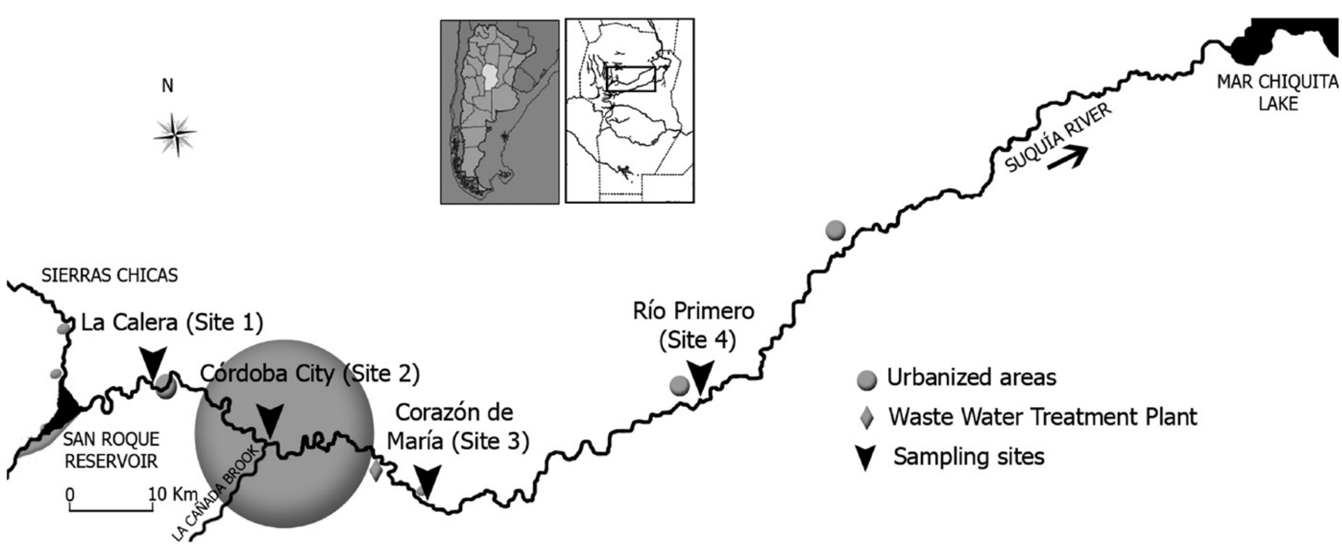

Fig. 1. Study sites in the Suquía River lower–middle basin.