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Toxicity and genotoxicity assessment in sediments from the Matanza-Riachuelo river basin (Argentina) under the influence of heavy metals and organic contaminants

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ABSTRACT

The aim of this study was to investigate the parameters of chemical extraction associated with the detection of toxicity and genotoxicity in sediment sample extracts. Quantitative analysis of metals and polycyclic aromatic hydrocarbons (PAHs), together with a battery of four bioassays, was performed in order to evaluate the extraction efficiency of inorganic and organic toxicants. The extracts were carried out using two inorganic solvents, two organic solvents and two extraction methodologies, making a total of five extracts. Two toxicity tests, the algal growth inhibition of *Pseudokirchneriella subcapitata* and the root elongation inhibition of *Lactuca sativa*, and two genotoxicity tests, the analysis of revertants of *Salmonella typhimurium* and the analysis of micronuclei and chromosomal aberrations in *Allium cepa*, were performed. According to the chemical analysis, the acidic solution extracted more heavy metal concentrations than distilled water, and dichloromethane extracted more but fewer concentrations of PAH compounds than methanol. Shaker extracts with distilled water were non-toxic to *P. subcapitata*, but were toxic to L. *sativa*. The acidic extracts were more toxic to *P. subcapitata* than to L. *sativa*. The methanolic organic extracts were more toxic to the alga than those obtained with dichloromethane. None of these extracts resulted toxic to L. *sativa*. Mutagenic effects were only detected in the organic dichloromethane extracts in the presence of metabolic activation. All the inorganic and organic extracts were genotoxic to *A. cepa*. This study showed that the implementation of different extraction methods together with a battery of bioassays could be suitable tools for detecting toxicity and genotoxicity in sediment samples.

1. Introduction

Many areas of Latin America have been affected by industrial development and the intensive use of natural resources by agriculture and livestock. These activities release a wide variety of pollutants into the environment that reach surface waters through industrial and domestic effluents, runoff and atmospheric deposition. Both water-soluble and hydrophobic contaminants can be persistent and maintain their physical and chemical characteristics while they are transported and distributed throughout the aquatic environment. These non-degradable pollutants may accumulate in different compartments or undergo transformations resulting in compounds with more or less bioavailability. The use of stream sediments for assessing aquatic pollution in environmental studies is mostly due to the ability of this compartment to concentrate pollutants, acting either as a sink or as a secondary source of contaminants in the water column and aquatic biota (Minissi et al., 1998; White et al., 1998; Vargas et al., 2001; Chen and White, 2004). Most of these chemicals are toxic, genotoxic or carcinogenic, and they become part of complex environmental mixtures which can have adverse health effects on humans and indigenous biota (Ohe et al., 2004; Vargas et al., 2008; Cappi da Costa et al., 2012).

Tools such as biological tests are useful for integrating the effects of all bioavailable contaminants and their interactions in the ecosystems (White, 2002; Chen and White, 2004; Klamer et al., 2005; Magdaleno et al., 2008; Cappi da Costa et al., 2012). These assays evaluate possible synergistic or antagonistic effects of the contaminants, broadening the

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study of the physical and chemical parameters commonly used in evaluating complex mixtures. Toxicity and genotoxicity assessment of sediment can be conducted on whole sediments, interstitial water, sediment elutriates, or sediment extracts. Many extraction techniques have been used to detect the mutagenicity potential of chemical compounds using organic, aqueous and acidic solvents, as well as other methods, such as shaking, sonication, soxhlet and accelerated solvent extraction (Di Giorgio et al., 2011; Cappi da Costa et al., 2012; de Souza Pohren et al., 2012). A selection of the appropriate solvent and extraction method depends on the physical–chemical properties of the sediment and putative contaminants (Chen and White, 2004).

Ecotoxicological test methods on small-scale, based on cellular components, cells, organs, small animals and plants, have the advantage of being highly sensitive, rapid and reproducible and they only require minute amounts of sample material. One of the most common aquatic toxicological tests is the algal growth inhibition test (USEPA, 2002; ISO, 2009). This test utilises the in vivo phytotoxic effects of sample matrixes such as pore water and organic extracts of sediments and water (Källqvist et al., 2008). Algae are used in test batteries for environmental hazard assessment due to their importance as dominant primary producers in most aquatic ecosystems (Blaise et al., 1998; Franklin et al., 2002; Vendrell et al., 2009). In particular, the green microalga *Pseudokirchneriella subcapitata* is one of the most widely used species in toxicity tests due to its sensitivity to different pollutants, its easy maintenance in laboratory cultures, and its relatively short life cycle (Lewis, 1995; USEPA, 2002; Magdaleno et al., 2014). Additionally, many tests on higher plant species have been shown to be highly sensitive to environmental stress (Dutka, 1989; Wang and Freemark, 1995; Bowers et al., 1997; Charles et al., 2011; Abreu et al., 2014). *Lactuca sativa* present several advantages among the plant species recommended by the environmental agencies and organizations for standard toxicity tests (USEPA, 1996; OECD, 2006): the test is simple, quick, reliable, inexpensive, and does not require major equipment.

The *Salmonella*/microsome assay (Ames test) is a widely accepted short-term assay for identifying substances that can cause genetic damage (Mortelmans and Zeiger, 2000). It is used worldwide for detecting the mutagenicity of samples from different environmental matrices, such as water, sediment, soil and atmosphere, as well as pure chemicals (Ducatti and Vargas, 2003; Ohe et al., 2004; White and Claxton, 2004; Magdaleno et al., 2008; Umbuzeiro et al., 2008). On the other hand, aspects ranging from gene mutations to chromosome damage and aneuploidies can be identified by the analysis of eukaryotes. Higher plants present characteristics that can be used in genetic models to assess environmental pollutants, and they are often used in monitoring studies (Leme and Marin-Morales, 2009). Various tests have been performed with a variety of plant species, e.g. *Tradescantia pallida* (Ma, 1981), *Vicia faba* (Kanaya et al., 1994), *Zea mays* (Grant

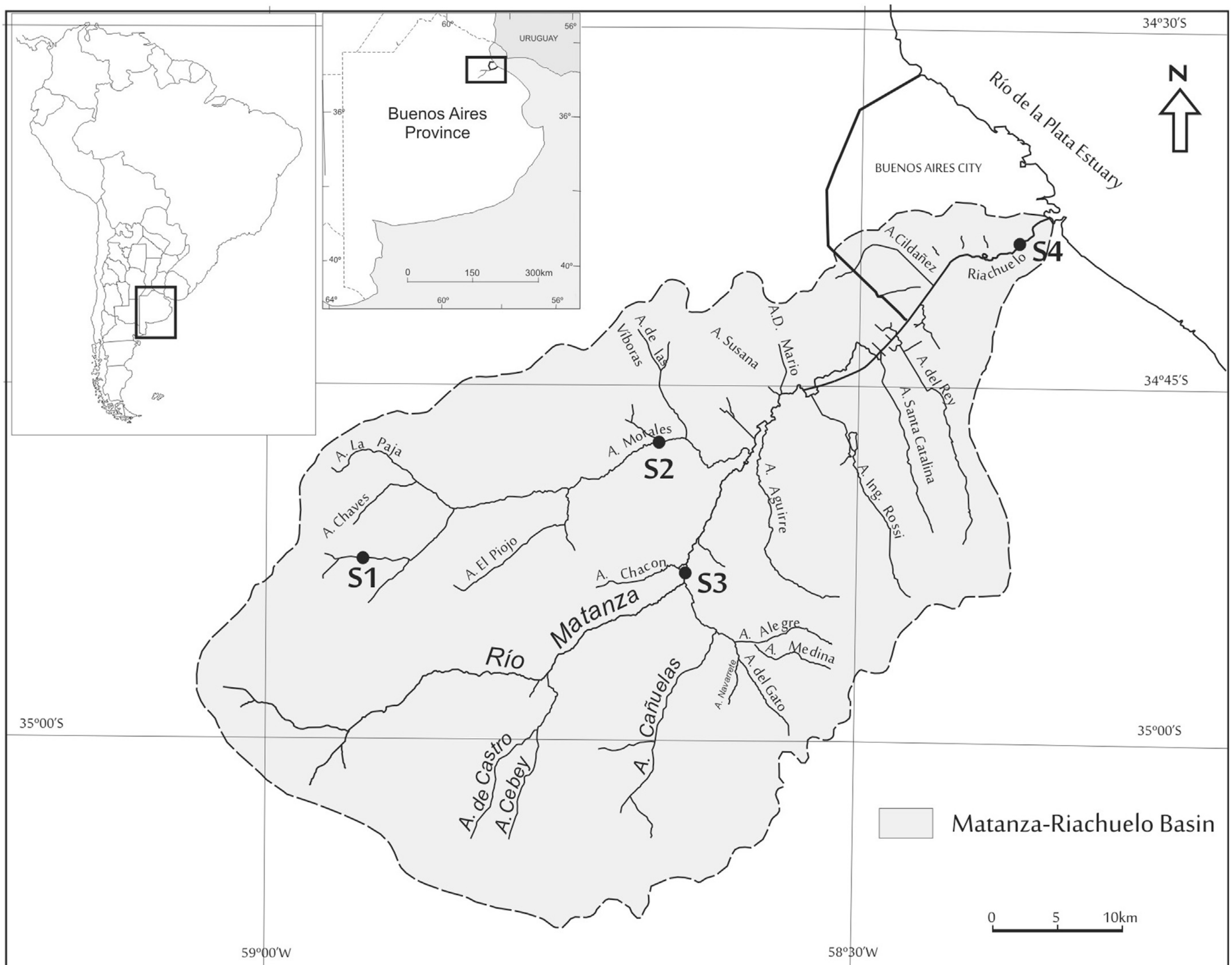

Fig. 1. Location of sampling sites in the Matanza-Riachuelo River (Buenos Aires, Argentina).