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The occurrence and distribution of a group of organic micropollutants in Mexico City's water sources

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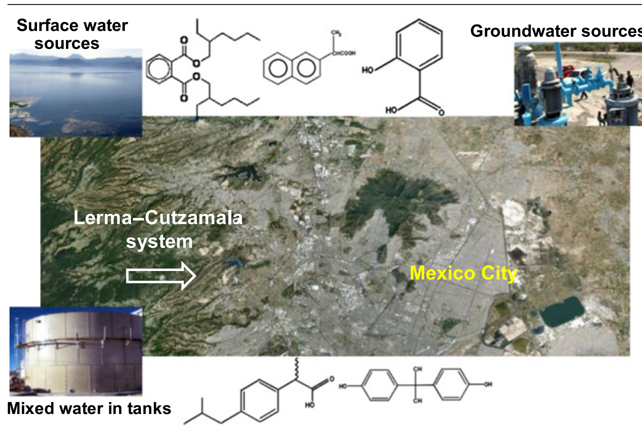
HIGHLIGHTS

- Organic micropollutants were detected in drinking water sources from Mexico City.
- Higher concentrations were found in surface water than in groundwater.
- Concentrations detected in both water sources were lower than the reported elsewhere.
- The study enhances the state of art of micropollutants occurrence in water sources.

GRAPHICAL ABSTRACT



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ABSTRACT

The occurrence and distribution of a group of 17 organic micropollutants in surface and groundwater sources from Mexico City was determined. Water samples were taken from 7 wells, 4 dams and 15 tanks where surface and groundwater are mixed and stored before distribution. Results evidenced the occurrence of seven of the target compounds in groundwater: salicylic acid, diclofenac, di-2-ethylhexylphthalate (DEHP), butylbenzylphthalate (BBP), triclosan, bisphenol A (BPA) and 4-nonylphenol (4-NP). In surface water, 11 target pollutants were detected: same found in groundwater as well as naproxen, ibuprofen, ketoprofen and gemfibrozil. In groundwater, concentration ranges of salicylic acid, 4–NP and DEHP, the most frequently found compounds, were 1–464, 1–47 and 19–232 ng/L, respectively; while in surface water, these ranges were 29–309, 89–655 and 75–2282 ng/L, respectively. Eleven target compounds were detected in mixed water. Concentrations in mixed water were higher than those determined in groundwater but lower than the detected in surface water. Different to that found in ground and surface water, the pesticide 2,4-D was found in mixed water, indicating that some pollutants can reach areas where they are not originally present in the local water sources. Concentration of the organic micropollutants found in this study showed similar to lower to those reported in water sources from developed countries. This study provides information that enriches the state of the art on the occurrence of organic micropollutants in water sources worldwide, notably in megacities of developing countries.

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1. Introduction

There are huge challenges in supplying high quality water to people living in megacities. One example of this can be found in Mexico City, where 21.4 million people live in a metropolitan zone of 8000 km^2. The requirements of water for the city are estimated at 70 m^3/s, on average, and such demand is met using both surface and groundwater taken from Mexico City's basin as well as from other surrounding watersheds (Tortajada, 2006). To date, the government's efforts have been focused in supplying the sufficient quantity of water to serve the whole population of the city and water quality has been relegated as a future task. In some areas of the metropolitan zone of Mexico City (MZMC), the quality of the water supplied to population through either the water distribution network or tank trucks is poor and thus people prefer to consume bottled water rather than tap water. According to the Inter-American Development Bank, up to 480 L per capita of bottled water are consumed in Mexico City each year (IDB, 2011).

In Mexico, water from surface and subterranean sources has to comply with the 44 physical, chemical and biological quality parameters established by the law in order to be considered suitable for human consumption. However, these standards do not include the so-called organic micropollutants, such as pharmaceutically active substances, personal care products, plasticizers, and many other every day consumer products, as well as their potential degradation by-products. Previous monitoring studies have evidenced the presence of organic micropollutants in surface and groundwater nearby urban areas (Loos et al., 2009; Osenbrück et al., 2007; Vulliet and Cren–Olivé, 2011), even in tap water (Valcárcel et al., 2011; Wang et al., 2011).

In both natural and urban environments, water sources can be contaminated by organic micropollutants through a wide range of pathways, including: agricultural irrigation using wastewater (Calderón–Preciado et al., 2011); improper disposal of expired pharmaceuticals (Tong et al., 2011); use of biosolids or animal excreta to amend agricultural soils (Clarke and Smith, 2011); exfiltration of wastewater in sewerage systems (Wolf et al., 2012); and, in some cases areal deposition (Loos et al., 2007); in this regard, Kümmerer (2009) established that wastewater is the main route of organic micropollutants to enter into environment. Since most of the organic micropollutants correspond to complex synthetic molecules, in some cases natural attenuation processes as well as conventional systems used to treat wastewater are unable to entirely remove them; and when conditions are propitious, these pollutants can reach the surface and groundwater sources.

In countries of the European Union, efforts to include some of the organic micropollutants (e.g. estrogenic hormones, carbamates and the anti-inflammatory drug diclofenac) in the list of priority substances in the field of water quality are being carried out through the amending directives 2000/60/EC and 2008/105/EC of the European Commission. Legislation on the matter of the occurrence of organic micropollutants in drinking water sources would be a response to the potential effects caused by some of these substances to the exposed organisms. Effects such as endocrine disruption (Kortenkamp, 2007), systemic damages in aquatic species (Triebskorn et al., 2004) and induction of antibiotic resistance in pathogen microorganisms have been previously reported (Baquero et al., 2008).

In order to identify the risk for water consumers of suffering harmful health effects, it is first necessary to know the concentration of the organic micropollutants in the water sources, which still unknown both in Mexico and in most of Latin-American countries.

The aim of this work was to determine the presence and concentration of 17 organic micropollutants, namely clofibric acid, ibuprofen, salicylic acid, 2,4-dichlorophenoxiacetic acid (2,4-D), gemfibrozil, ketoprofen, naproxen, diclofenac, 4-nonylphenol (4–NP), pentachlorophenol (PCP), triclosan, bisphenol-A (BPA), butylbenzylphthalate (BBP), di-2-ethylhexylphthalate (DEHP), estrone (E1), 17β estradiol (E2) and 17α ethynilestradiol (EE2) in Mexico City's drinking water sources.

2. Materials and methods

2.1. Chemicals and Reagents

All the reagents: analytes, internal and surrogated standards, as well as the derivatizing agents N-*tert*-butyldimethylsilyl-N-methyltrifluoroacetamide (MTBSTFA) with 1% of *t*-butyldimethylsilylchlorane and N,O-bis(trimethylsilyl)trifluoroacetamide (BSTFA) with 1% of trimethylsilylchlorane were obtained from Sigma–Aldrich. The solvents used during the analysis were HPLC grade from Burdick and Jackson (Morristown, NJ, USA). The Oasis HLB extraction cartridges (200 mg, 60 cc) were bought from Waters (Milford, MA, USA). The relevant chemical properties of the target compounds are displayed in Table S1 of the Supplementary information section.

2.2. The Study Zone

The metropolitan zone of Mexico City (MZMC) receives water for human consumption from two different sources: groundwater and surface water. The local aquifer is the main source of water, supplying 66% of the total demand of water; additionally, a local river provides 1%. The rest comes from other basins; 8% is imported from the Lerma aquifer, located 60 km west of the city (Fig. 1); and another 33% comes from a battery of dams known as Cutzamala, 154 km west of and 1,100 m below Mexico City. The Cutzamala System, which is one of the biggest water supply projects in Latin America, is composed of seven reservoirs and one drinking water treatment plant with a capacity of 20 m^3/s. Water from both inside Mexico City's basin and the Cutzamala system can be either directly injected into the water distribution network or mixed in storage tanks before distribution. Depending on the quality of raw water, drinking water treatment may consist on either direct chlorination after extraction, which is applied to most of the groundwater extracted, or a more complete purification in water treatment facilities, which is used for surface and groundwater of lower quality.

2.3. Sampling of the Water Sources

Water samples were taken from surface and groundwater sources that supply to near of 60% of Mexico City's population (Table S2 in Supplementary information). Samples were taken in three sampling campaigns during the rainy season, from May to August 2008, and in the dry season, from January to June 2009. In total: 7 wells, 4 dams and 15 storage water tanks were monitored. At each site, grab water samples were taken in triplicate from sampling ports already in place. Samples for the determination and quantification of the target organic micropollutants were taken in 4 L amber glass bottles that were previously cleaned with solvents; while water used to determine the physicochemical quality parameters was taken in 1 L plastic bottles. Each bottle was sealed with aluminum foil and then capped to avoid contact between samples and caps. All samples were transported to the laboratory in coolers and stored overnight at 4 °C until analysis. In order to minimize contamination with personal care products, the use of such substances by the personnel was discouraged during the sampling campaigns.

2.4. Analytical Methods

The physicochemical quality parameters of water samples are shown in Table S3 of the Supplementary information section. These parameters were determined following standard procedures (APHA–AWWA–WEF, 1998).