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# Determination of pharmaceuticals in groundwater collected in five cemeteries' areas (Portugal)

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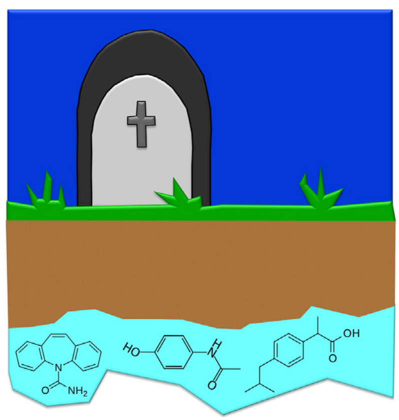
## HIGHLIGHTS

- Analysis of 33 pharmaceutical in groundwater from five cemetery areas;
- Assessment of three different therapeutical classes of pharmaceuticals;
- NSAIDs/analgesics and psychiatric drugs were detected,
- The highest concentration was obtained for salicylic acid and carbamazepine.

## GRAPHICAL ABSTRACT



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## ABSTRACT

There are growing public attention and concern about the possibility of ecosystem and human health effects from pharmaceuticals in environment. Several types of environmental samples were target of studies by the scientific community, namely drinking water, groundwater, surface water (river, ocean), treated water (influent and effluent), soils, and sediments near to Wastewater Treatment Plants or near to others potential sources of contaminations. Normally, studies in the cemeteries areas are for historical and architectural research and questions of the potential risk for adverse impact of cemeteries in environment have never received enough attention. However, this risk may exist when cemeteries are placed in areas that are vulnerable to contamination.

The objective of the present work was the determination of pharmaceuticals (nonsteroidal anti-inflammatory/analgesics, antibiotics and psychiatric drugs) in groundwater samples collected inside of the cemeteries areas. Acetaminophen, salicylic acid, ibuprofen, ketoprofen, nimesulide, carbamazepine, fluoxetine, and sertraline were the pharmaceuticals achieved in the analysed samples. None of the studied antibiotics were detected. The highest concentration was obtained for salicylic acid (in the range of 33.7 to 71.0 ng/L) and carbamazepine (between 20.0 and 22.3 ng/L), respectively. By the cluster analysis similarity between carbamazepine and fluoxetine was achieved.

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## 1. Introduction

In the mid-twentieth century, the question of death began to be the target of sociological and interdisciplinary studies in anthropology, art, literature, medicine, philosophy, religion and psychiatry (Oliveira et al., 2013).

Since ancient times, the soil has been used by man for disposal of their waste, including his own body after death. In general, due to its mineral composition, weathering, and microbiological content, the soil layer is fit to degrade organic matter buried discreetly and out of human sight. Therefore, the ground has a capacity of undeniable natural purification in normal aeration (Rodrigues and Pacheco, 2003). Cemeteries may have serious environmental consequences, particularly on quality of adjacent groundwater. This is because the infiltration and percolation of rainwater through the soil graves allows migration of a number of organic and inorganic chemicals which can pollute aquifers (Bouwer, 1978).

The protection of groundwater from the risk of possible contamination is important because pollutants could cause health problems in human and animals beings, reduce the quality of farming and agricultural products, make the water unsuitable for certain industrial processes and pose a threat to our countryside and environment, including their suitability for recreational purposes. The contamination of groundwater can not only have health and environmental impacts, but also serious economic and social consequences (Bouwer, 1978; Rodrigues and Pacheco, 2003; Üçisik and Rushbrook, 1998; Żychowski and Bryndal, 2015). Because of this, monitoring of groundwater in the vicinity of cemeteries is of utmost importance in environmental studies (Bouwer, 1978).

Old cemeteries that once were situated in distant locations of cities are now part of the city, due to the increase of the population (Oliveira et al., 2013). It is important when planning their locations that adequate site investigation and risk assessment be undertaken.

Normally the studies in the cemeteries areas are for historical and architectural research (de Almeida, 2007; Queiroz, 2002). Today, the most important cemeteries are considered museums, as very important places of history and art. In fact, the most important 19th century Portuguese cemeteries, also called romanticist cemeteries, were conceived to be galleries of remarkable men, pantheons of noble families, archives made of masonry and ironwork. Its pompous mausoleums reflect a particular attitude towards death, so emphasized in the 19th century: the preservation of one's memory (Queiroz, 2003).

Scarce information is found in literature on whether cemeteries should be regarded as potential sources of pollutants. This may be due to the challenge of overcoming psychological effects, as well as social and cultural values.

At the end of the nineteenth century, the adverse impact of cemeteries on groundwater caught the attention of scientists. In 1879, the French Society for Hospital Hygiene noticed the relationship between typhoid fever and groundwater contaminated by leachates from a cemetery in Paris (Migliorini, 2002). This kind of adverse impact was also confirmed by Mulder in the summer of 1954 (Bouwer, 1978). He found somewhat sweet-tasting water and an unpleasant smell exuding from wells situated close to cemeteries in Paris. A more serious consequence was the increased number of typhoid fever cases observed among people living around a cemetery in Berlin between 1963 and 1967. These people were using the groundwater from its vicinity (Bouwer, 1978), and other cases were like these were registered along the years.

In 1998, the World Health Organization (WHO) published a short review of soil and groundwater contamination by cemeteries with the aim of evaluating its impacts on the environment and public health. The main conclusion was that buried corpses have different microbial organisms, and the materials used in funeral practices may be sources of chemical compounds and heavy metals. Nuclear waste from medical treatments or devices and prosthesis may also be found. If the cemetery is on vulnerable soil or if the soil reaches its depurative limit, the pollution may reach the groundwater (Üçisik and Rushbrook, 1998).

In literature there are very few studies embracing the subjects "cemetery" and "groundwater", and most of these articles cover the studies of the presence of metals (Mapani and Schreiber, 2008; Oliveira et al., 2013; Rodrigues and Pacheco, 2003; Üçisik and Rushbrook, 1998) or bacteria and viruses (Collins et al., 2005; Hyun-su and Kangjoo, 2012; Oliveira et al., 2013; Rodrigues and Pacheco, 2003; Üçisik and Rushbrook, 1998; Żychowski and Bryndal, 2015) in the groundwater near to the cemeteries. In 2003 Rodrigues, L. and Pacheco, A. (Rodrigues and Pacheco, 2003) published a study in Portugal, which investigated at same time both the impacts of physical and chemical parameters (temperature, pH, electrical conductivity, nitrites, nitrates, ammonium ion, chloride, oxidizability, total phosphorous, calcium, magnesium, hardness, sulphates, sodium, potassium, total zinc, total lead and total organic carbon) and microbiological indicators (total and fecal coliform, fecal streptococcus, heterotrophic bacteria (22 °C and 36 °C), clostridia and proteolytic bacteria). Several tests were conducted in three cemeteries during one year and two month for the first cemetery and 4 month for remain cemeteries. Samples were collected every two months, and groundwater samples were collected in several bored wells placed in the area of cemeteries (Rodrigues and Pacheco, 2003).

Recently, Żychowski and Bryndal (2015) published a review article related to the impact of cemeteries on contamination of groundwater by bacteria and viruses, which revealed that cemeteries may have large adverse impacts on groundwater as well-being possible sources of dangerous infectious diseases.

Knowing that many of the deaths occurring after a period of more or less prolonged illness where drugs were administered it will be interesting to assess how the cemeteries contribute to the presence of these substances in the environment.

In the present study 33 pharmaceuticals covering three therapeutic groups, nonsteroidal anti-inflammatory (NSAIDs)/analgesics, antibiotics, and psychiatric drugs, and some of their main metabolites were analysed in groundwater samples. The therapeutic classes were chosen taking into account the consumption and the detection of these pharmaceuticals in the environment. NSAIDs/analgesics are the most used class of drugs for treatment of acute pain and inflammation. They are topically and available as prescription and over-the-counter (non-prescription) pharmaceuticals, and NSAIDs/analgesics are used throughout the population. Only recently has the environment been clearly implicated in the risk of antibiotic resistance to clinical outcome, but to date there have been few documented approaches to formally assess these risks. The growing consumption of psychiatric drugs in the last years is raising concerns among physicians regarding the manner and frequency with which the tablets are being prescribed.

To the best of our knowledge, it was the first time that groundwater samples collected in taps inside of cemetery areas, with the warning message "Do not drink, Non-potable water" or "Unfit for consumption", were used for pharmaceuticals determination.

## 2. Materials and methods

### *2.1. Cemeteries information and sampling collection*

The cemeteries of Portugal are targets of different manage, namely: public municipal, public parochial and private cemeteries. Information's in the cemeteries area are restricted by municipalities and churches that manage cemeteries. It was verified that there was some reluctance to give out information about plant and underground areas where cemeteries are located, most likely due to concerns with respect to matters involving the dead.

In some cemeteries a warning message "Do not drink, Non-potable water" or "Unfit for consumption" are on the taps. Some questions were raised about the origin of the water (treated water or

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