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A review on physicochemical and microbiological contamination of roof-harvested rainwater in urban areas

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ABSTRACT

This work proposes to consider the quality of roof-collected rainwater as the sum of three main stages. In the first one, rainfall washes out the urban atmosphere and scavenges contaminants from aerosols, gases and thin volatile particles. The second stage refers to the catchment, in which occurs contamination due to the wash-off of particles settled on the roof's surface as well as the scavenging of roofing materials. The third stage refers to the first-flush, storage and plumbing system. In each stage, different processes take place and add specific contaminants to the initial precipitation. Only in the third stage, after the discard of the high-polluted initial rainwater, some physical processes (sedimentation and pH increase) can also improve the quality of the rainwater harvest. With this approach, it is offered a clear view of the overall contamination processes that take place in a rainwater harvesting system.

The most common microbiological and physicochemical contaminants that can be found in rainwater harvesting system were regarded, together with the eventual presence of waterborne pathogens and emerging chemical contaminants, according to an extensive review of 172 previous scientific and technical works.

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1. Introduction

The growth of urban areas demands a continuous increase in the amount of supplied fresh water. As most urban springs and aquifers are overexploited or polluted, water must be imported from distant reservoirs with the corresponding energy cost and losses due to leakages. Conflicts regarding the use of the overexploited water resources have arose in many regions of the world, confronting their different uses: human supply, irrigation and cattle, industry. Even hydroelectricity, especially in semi-arid regions threatened by recurrent droughts, has been involved in water conflicts (DeJong et al., 2013).

In this context, any technology that deploys locally (in the urban areas where it is consumed) a certain amount of water with an acceptable quality, is more than welcome. Desalination is a technological option that is still costly and produces brine reject of potential environmental risk (Sánchez et al., 2015). Together with water conservation programs, the interest for water sources that are alternative to traditional, centralized water supply systems has soared in recent decades. Among these alternatives, water reuse, water reclamation and rainwater harvesting have gained special attention. Therefore water harvesting, that a few decades ago was only a valid resource in rural areas with no water mains coverage, has started to be regarded as a convenient option for urban and already developed areas.

Rainwater presents a series of advantages regarding some of its physicochemical parameters, when compared with water from the mains or with groundwater. It has lower hardness and total suspended solids which makes it suitable for some uses such as laundry or cooling towers. Gardening and landscaping are traditional uses for rainwater in urban sites. Urban stormwater presents low sodicity and thus is suitable for irrigation. According to Kabir et al. (2014) although urban dusts are highly polluted with metals, 75% of metal pollutants leached by stormwater runoff can be retained by green water infrastructures, which use vegetation, soils, and natural processes to soak up and store water. Other non-potable uses regarded are toilet flushing and surface washing in buildings, which suppose a large part of the water demand of urban buildings. Well-designed rainwater harvesting systems with clean catchments, covered cisterns and storage tanks, as well as simple treatment supported by good hygiene practices can offer water for these non-potable uses with very low health risk. Common available treatments for harvested rainwater are: the application of settling tanks, disinfection combined with membrane filtration, reverse osmosis (Wang et al., 2014a,b), heat treatment (Spinks et al., 2006), solar disinfection-SODIS (Amin et al., 2014a, 2014b; Ahammed et al., 2014) and slow sand filtration followed by chlorination (Moreira Neto et al., 2012). Silver ions combined with conventional filtration and settling mechanisms is another type of affordable treatment that offers good results (Adler et al., 2011). In addition, point-of-use systems such as UV lamps (Jordan et al., 2008) and ozone disinfection (Ha et al., 2013; Lopez, 2014) are a growing trend in rainwater treatment for drinking purposes. The improvement of roof-harvested rainwater until reaching potable quality standards is gaining popularity in urban environments with small-scale point-of-use systems, while in rural sparse areas where water mains is not available this option may fill this gap and thus greatly increase the local sanitary conditions. Sazakli et al. (2007) noted that the low fluoride concentrations in rainwater may force consumers to take a fluoride supplement to prevent dental decay if rainwater serves as the primary potable water source.

Given this context, there is a growing need for information and guidelines about the most common sources of pollutants of roof-harvested rainwater in urban environments.

The literature addressing this issue is wide. It assesses various tangential but connected issues: the detection of specific chemical or microbiological contaminants in rainwater; comparative rainwater analysis around the world; the deposition of atmospheric pollutants in urban surfaces, their scavenging, build-up and wash off; and the influence of roof and storage material, among others. This review aims to summarize and analyze a good portion of relevant scientific works that have addressed the different parts of this problem, compiling them to better understand the mechanisms and pollution sources that influence the final quality of roof-collected rainwater in an urban environment. Traditional and emerging chemical contaminants, together with the most common bacterial and waterborne pathogens are regarded. This review also represents an update of previous review works (Lye, 2009; Abbasi and Abbasi, 2011; Ahmed et al., 2011; Kwaadsteniet et al., 2013).