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Natural disasters and climate change call for the urgent decentralization of urban water systems

Ian Vázquez-Rowe [a,*], Ramzy Kahhat [a], Yago Lorenzo-Toja [b,c]

[a] Peruvian LCA Network, Department of Engineering, Pontificia Universidad Católica del Perú, 1801 Avenida Universitaria, San Miguel, Lima 32, Peru
[b] Department of Chemical Engineering, Institute of Technology, Universidade de Santiago de Compostela, 15782 Santiago de Compostela, Galicia, Spain
[c] Cetaqua, Water Technology Centre, Emprendia Building, Campus Vida, 15782 Santiago de Compostela, Galicia, Spain

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ABSTRACT

Lima is gradually upgrading its urban water cycle to comply with improved sanitation standards, with the aim of treating the entire flow of water and wastewater that it creates. However, this paper examines the basic characteristics of the main treatment systems that are currently in operation in the Peruvian capital, highlighting the myopic and inefficient nature of these investments. It digs deep in the debate between centralized and decentralized water management systems in a city that is exposed to numerous hydro-meteorological and geological hazards. Previous errors that have occurred in the developed world throughout the evolution process of the urban water cycle should be taken into consideration prior to any infrastructure development in emerging countries. For the particular case of Lima, special emphasis should be given to the resilience of its urban water system in order to guarantee rapid recovery after disaster events.

Devastating downpours, caused by abnormally high ocean temperatures along most of Peru's Pacific coastline in February and March 2017, have left an aftermath of destruction in many areas of coastal Peru (The Guardian, 2017). The Lima-Callao Metropolitan area, henceforth referred to as Lima, the second driest capital city in the world, has also been badly hit by extreme precipitation in the Andean highlands, suffering from burst river banks and mudslides, locally known as *huaicos*. A broad array of infrastructure in Lima was affected by these extreme weather conditions, including collapsed bridges, as well as homes and entire streets close to the banks of the *Chillón*, *Rímac* and *Lurín* rivers that cross the city. For example, the *Chillón* river presented an average monthly flow 93% higher than the historic mean (SENAMHI, 2017). However, probably the most alarming feature of the flooding was the fact that the main drinking water plant of the city was at a halt for several days due to its inability to capture the water flow of the river *Rímac*, which presented turbidity peaks of up to 98,000 NTU (Perú21, 2017). Most of the city's activities were seriously affected between the 16th and 19th of March due to the collapse of water distribution systems and videos of citizens queuing for water from municipal tank trucks went viral on social networks (Fig. 1).

This critical climatic event demonstrated Lima is vulnerable not only to major earthquake and *tsunami* events (Mitchell, 1999), like those which have hit the city in the past, but also to extreme weather conditions, hindering its capability to obtain an ever-greater amount of water for its ever-growing population. Other megacities throughout the world face similar risks linked to their exposure to the effects of climate change, Mexico City and Karachi being two clear examples (Li et al., 2015a; New York Times, 2017a; The Guardian, 2016).

In this context, Lima currently relies on the river *Rímac* for roughly 80% of its total water production for commercial, industrial and residential purposes. The remaining fraction arrives from the river *Chillón* (roughly 8%) and different wells scattered across the city that pump water from aquifers. However, it should be noted that an important portion of water extracted from the *Rímac* does not correspond to water from the Pacific drainage basin, but to that of the river *Mantaro*, a sub-affluent of the Amazon. This implies that ca. 28% of annual water actually corresponds to the Atlantic drainage area, a value that can be as high as 46% during the dry season (Parodi, 2016). Considering its increasing demand for water, it is not surprising that recent reports have arisen delving into the risks linked to water sustainability (SEDAPAL, 2014; Kosow et al., 2013; LIWA, 2009).

Although diverting water from the Atlantic basin has allowed Lima to postpone its extreme vulnerability to water scarcity, and current projects are bound to further delay this inevitable situation, it is important

* Corresponding author.
E-mail address: ian.vazquez@pucp.pe (I. Vázquez-Rowe).

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Fig. 1. Citizens queueing for water in the district of Miraflores (Lima) on March 19th 2017. At the time the photograph was taken water production at the water treatment plant had been at a halt for 48 h due to extreme turbidity in the river *Rímac*, leaving the entire city without any water supply.

to bear in mind that recent studies agree on the fact that South America will suffer from increased water stress due to global warming (Bradley et al., 2006). For instance, glacier retreat has already affected the output of hydropower plants in Peru (Bradley et al., 2006; Vergara et al., 2009), a phenomenon that coincides with a predicted threefold increase in the amount of water needed to support energy production in the region (WEC, 2008). Moreover, Andean countries are expected to suffer considerable changes in rainfall patterns (SENAMHI, 2009), adding to water insecurity through prolonged droughts and increased average temperatures, which imply an augmentation in the amount of energy needed to meet energy demand for cooling and for water treatment (Vergara et al., 2009; Rothausen and Conway, 2011). Therefore, it seems plausible to presume that water supply security may be strongly affected due to a reduction in available water resources, but also due to population growth and urbanization.

Consequently, it is evident that numerous actions must be taken in the short-term to reduce the unsustainability of Lima's water supply. Many of these will be related to the development of new infrastructures to supply the city, while others will focus on improving the urban water cycle, aiming at: a) reducing the dependency on the river *Rímac* for water production; b) limiting the losses in the water network, which are currently estimated at over 8.0 m^3/s (i.e., 29% of total water production), while guaranteeing access to water to impoverished areas of a city where 8% of the population does not have direct access to potable water; or, c) mitigating the approximately 20 m^3/s of wastewater disposed of in the ocean with obsolete or basic treatment technologies (SEDAPAL, 2014).

In the first place, water production is highly reliant on the *Rímac* and on the main drinking water plant: *La Atarjea*. Although a new plant is currently being upgraded to produce 5.0 m^3/s, the water source would still be the *Rímac* (Comercio, 2017). Hence, vulnerability to events such as those that occurred in March 2017 would only be mitigated by a higher storage potential of drinking water, which could last a few additional hours or days. Furthermore, severe damage at *La Atarjea* in the case of large seismic events could potentially leave millions of people without water for weeks. Therefore, decentralization of the potable water system by investing in alternative smaller infrastructures such as desalinization plants, could provide increased resilience and mitigate potential humanitarian crises (Peter-Varbanets et al., 2009; Lundie et al., 2004).

Secondly, a growing city in a desert area where rainfall is rare cannot afford to waste approximately 30% of its water production prior to its intended use (SEDAPAL, 2014). A couple of decades ago one could argue that the capital city of what was at the time a very poor country could struggle with basic infrastructures. Nowadays, however, upgrading the deteriorated water pipeline network, which is the most exposed component of the urban water cycle in Lima to seismic events (ERN – AL, 2012), should be a priority on a par with other on-going investments in infrastructures, such as the subway system or the seismic retrofit of public buildings. Based on a recent report of the World Bank, the exposed value of the pipeline infrastructure prone to be damaged in a seismic event could be as high as 2.2 billion USD (ERN – AL, 2012).

Finally, the wastewater management strategy was almost nonexistent in 2011, with 83.1% of the collected wastewater directly discharged into the ocean or other water bodies without treatment (Moscoso, 2011). Currently, the situation has improved by centralizing wastewater treatment in two very large wastewater treatment plants – WWTPs. These plants were intended to complement a set of small facilities distributed throughout the city. On the one hand, *PTAR Taboada*, in operation since 2013, treats wastewater in the northern sector of Lima. Designed to treat 14 m^3/s, representing 56% of the population, by early 2015 it was treating on average 10.7 m^3/s (Mitchell, 1999). On the other hand, *PTAR La Chira* initiated its operations in May 2016, treating wastewater in most of the remaining districts in the southern sector of the city (Parodi, 2016). The combination of both plants currently treats ca. 17 m^3/s, representing 85.8% of the total sewage collected, with a remarkably restrained use of land use (0.26 ha/m^3 s) as compared to the other solutions applied across the city (Fig. 2). Both plants consist of a pre-treatment step, including coarse screens, degreaser/de-gritter units and rotatory drum screens. Nevertheless, removal of trash from the waters discharged into the ocean and the dilution of the remaining pollutants in the ocean through the creation of the marine outfall only partially solve the lack of an integrated treatment