Science of the Total Environment xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Multi-layered water resources, management, and uses under the impacts of global changes in a southern coastal metropolis: When will it be already too late? Crossed analysis in Recife, NE Brazil

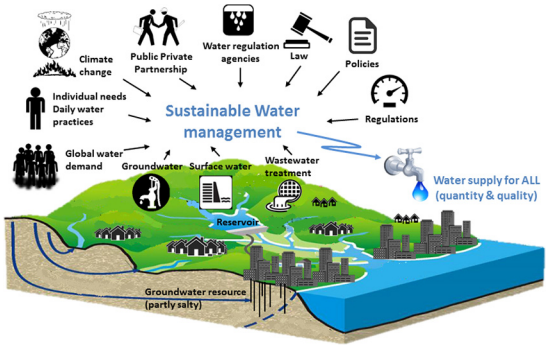
Emmanuelle Petelet-Giraud [a,*], Lise Cary [a], Paul Cary [b], Guillaume Bertrand [c,d], Armelle Giglio-Jacquemot [b], Ricardo Hirata [d], Luc Aquilina [e], Lincoln Muniz Alves [f], Veridiana Martins [d], Ana Maria Melo [b], Suzana Montenegro [c], Eliot Chatton [e], Melissa Franzen [g], Axel Aurouet [h], the COQUEIRAL team [1]

[a] BRGM, French Geological Survey, 3 Av. C. Guillemin, 45060 Orléans, France
[b] CERIES, ,University of Lille 3, 59650 Villeneuve-d'Ascq, France
[c] Civil Engineering Department, UFPE, 50740 Recife, Brazil
[d] CEPAS, Institute of Geosciences, University of São Paulo, 05508-080 São Paulo, Brazil
[e] OSUR-Géosciences Rennes, Université Rennes 1 - CNRS, 35000 Rennes, France
[f] Instituto Nacional de Pesquisas Espaciais (CCST/INPE), São Jose dos Campos, Brazil
[g] CPRM, Brazilian Geological Survey, Avenida Sul 2291, Recife, PE, Brazil
[h] Géo-Hyd, 101 rue Jacques Charles, 45160 Olivet, France

HIGHLIGHTS

- Global change impacts on coastal water resources in urban areas.
- A transdisciplinary approach was used to assess the present-day water situation.
- Water uses and relations to water, from individual water needs to policy making.
- Deep groundwater resources threatened by overexploitation to fulfill water demand.
- Urgent need of a strong political willingness for a sustainable water management.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 12 March 2017
Received in revised form 7 July 2017
Accepted 25 July 2017
Available online xxxx

Editor: D. Barcelo

Keywords:
Water resources management
Water governance

ABSTRACT

Coastal water resources are a worldwide key socio-environmental issue considering the increasing concentration of population in these areas. Here, we propose an integrative transdisciplinary approach of water resource, water management and water access in Recife (NE Brazil). The present-day water situation is conceptualized as an imbricated multi-layered system: a multi-layered water resource, managed by a multi-layered governance system and used by a multi-layered social population. This allows identifying processes of quantitative, qualitative, and sanitary conflicts between governance and population strategies regarding water supply, as well as the institutional and individual denials of these conflicts.

Based on this model, we anticipate future water-related problematic fates. Concerning the water resource system, the rapid groundwater level decrease due to unsustainable water predatory strategies, and the very low recharge rate have drastically modified the aquifer system functioning, inducing hydraulic connection between

* Corresponding author.
E-mail address: e.petelet@brgm.fr (E. Petelet-Giraud).
[1] The COQUEIRAL team: Helène Pauwels [a], Wolfram Kloppmann [a], Géraldine Picot [a], Tadeu Giglio [b], Jeanne Glaucia Santos [d], Thierry Labasque [e], Anderson Paiva [c], Jonathan Batista [d], Daniel Pierre [h].

http://dx.doi.org/10.1016/j.scitotenv.2017.07.228

Societal relation to water
coastal aquifers
Recife
Brazil

shallow groundwater (contaminated and locally salty) and deep ones (mostly fresh, with local inherited salinity), threatening the deep strategic water resource. Concerning the water governance system, the investments to increase the capacity storage of surface water, the water regulation agencies and the public/private partnership should shortly improve the water supply and wastewater issue. Nevertheless, the water situation will remain highly fragile due to the expected water demand increase, the precipitation decrease and the sea-level increase. Concerning the water access system, the population variably perceives these current and further effects and the possible mitigation policies, and develops alternative individual strategies.

Authorities, policymakers and water managers will have to implement a well-balanced water governance, taking into account the specificities of the PPP, public and private groundwater users, and with a strong political willingness for a sustainable water management to ensure water supply for all the population. In other words, an anticipatory and integrated vision is necessary to reduce the discrepancies in this complex system.

1. Introduction

Global change refers to planetary-scale modifications of the Earth system, i.e. the global environmental changes in interaction with the societal context. All the environmental changes at large scale (e.g. land use, atmospheric greenhouse gases, pollution, water supply and changes of climate patterns) are influenced by the development of the human society that is affected in return. The mitigation of the global environmental changes and society's resilience become a central issue for the future of humanity, and a major scientific challenge.

In this context, coastal urbanized areas are vulnerable zones (IPCC, 2014) presenting intense demographic and societal changes (increasing population, infrastructure limitations, etc.), sensitive to climate variations impacting recharge and sea-level fluctuations (Neumann et al., 2015). Coastal water resources and especially groundwater are threatened by the increasing water demand and the potential subsequent contamination by urban wastewater and salinization due to seawater intrusion. Over the last decades, research studies have been encouraged in coastal areas where industrial and agricultural development has led to a sharp increase in water withdrawals and where surface waters are too limited to fulfill the water demand. Since groundwater is historically used as a complementary resource to surface waters, its depletion may cause its salinization in many coastal aquifers around the world (e.g. Custodio, 2010; Steyl and Dennis, 2010; Barlow and Reichard, 2010; Bocanegra et al., 2010; Werner et al., 2013; Petelet-Giraud et al., 2016). The shallow and unconfined aquifers are also highly vulnerable to contamination by housing and industrial effluents, or by sewage network leakage (e.g. Vengosh et al., 1994; Umezawa et al., 2009; Hosono et al., 2011) especially where demographic pressure increase is larger than water network capacity adaptations.

From the resource management point of view, transformations are noticeable. On one hand, the conception of urban water networks has drastically changed, the sole and centralized model does not appear to be the only way to provide efficient urban services and more flexible models are widely studied today (Petitet, 2012). On the other hand, nowadays institutional arrangements seem to go beyond the public/private opposition, particularly following mixed reviews of privatizations or public/private partnerships (PPP) (Ostrom, 2010; Marin, 2008).

These changes are illustrated for example in Brazil, where water resources management was initially strongly linked to the development of hydraulic infrastructure for hydroelectric production. The Brazilian re-democratization process driven by the 1988 Federal Constitution strongly changed this situation with the introduction of social participation and tax decentralization for states and municipalities. The National Water Resources Management Law (9433/97) was promulgated in 1997 establishing both the National Water Resources Policy and the National Water Resources Management System (Porto and Kelman, 2000). The reformed Constitution introduced a distinction between federally controlled water (rivers across states), and state-controlled water, for rivers and groundwater strictly within state boundaries. The National Water Law incorporates most modern water resource management principles and instruments, and relies on a decentralized management model based on the hydrographic basin and participation management through collegiate structures composed of public power, users and society (Villar, 2013). The National Water Authority (Autoridade Nacional da Agua - ANA) was created in 2000 aiming at implementing the National Water Law and establishing criteria for granting of water usage rights and pricing mechanisms. This national legal framework is completed by several water resource management laws at the state level, most of these laws being very similar.

The Recife Metropolitan Region (RMR, Fig. 1), Pernambuco State, Brazil, illustrates the problems of emerging countries such as urban sprawl (4 M inhabitants), unequal distribution of wealth, strategic urban planning that prioritizes the private sector (Melo et al., 2013), concurrent water uses, deficiencies of supply and sanitation and partly lacking regulatory constraints.

From a social point of view, Brazil, and Recife in particular have undergone massive changes over the past decade with a significant decrease of poverty, growth of a large middle class (Neri and Carvalhaes, 2008) and reduction in inequalities that nevertheless remain very high (IPEA, 2013). However, despite massive public investments, the urban public infrastructure, like sewerage systems, remains particularly weak in Recife. If the Brazilian public actors have been very active to elaborate laws and political decisions on environmental and health issues, these programs suffer from insufficient funding and poorly coordinated actions especially in the sanitation sector (Britto and Cordeiro, 2012). Despite recent social and public health changes in Brazil, this socio-environmental context still produces adverse effects on health (Pontual et al., 2006). The outcomes of Agenda 21 of the Rio conference are still unreached.

Facing recent environmental problems related to climate changes such as severe droughts (1998–1999, 2012–2016), the sustainability of groundwater resources in Recife is a critical issue in an already water-stressed area located in a subtropical climate area and, surrounded by arid conditions inland. Although the legal framework for water resources management in the Pernambuco state includes the basic principles of modern water management (Lopes Filho et al., 2011), strategic aquifers (Cabo and Beberibe aquifers featuring paleogroundwaters stored about 150 m below the city are still being intensively exploited at alarming rates, and the joint effects of socio-economic and climatic changes worsen groundwater overexploitation and quality deterioration, i.e. dramatic piezometric level depletion, aquifer salinization, and contamination (Bertrand et al., 2016; Chatton et al., 2016; Cary L. et al., 2015; Montenegro et al., 2010).

Accelerating global and concurrent social changes present new challenges for researchers. The environmental problems should be anticipated in a dual context: a weaker economic growth and an energy framework of decreasing resource availability with increasing conflicts on use, enhancing the need of scientific transdisciplinary work. This is the aim of this paper that presents an integrated overview of the hydro-geochemical mechanisms, together with a multi-scale

Please cite this article as: Petelet-Giraud, E., et al., Multi-layered water resources, management, and uses under the impacts of global changes in a southern coastal metropolis: When wil..., Sci Total Environ (2017), http://dx.doi.org/10.1016/j.scitotenv.2017.07.228