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Caplina aquifer, after 100 years of exploitation as a sustenance for agriculture in arid zones

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Abstract

This article is a historical review of the events that occurred in the exploitation of the Caplina coastal aquifer, located in an arid zone, located at the head of the Atacama Desert. The period in which the exploitation has been in a balanced regime (recharge - extractions) until the 1970s and unbalanced after the 80s has been identified. Likewise, favorable and unfavorable management measures are identified in the conservation of the aquifer system Future engineering measures were identified, leading to the recovery and conservation of the aquifer that consist of the incorporation of hydraulic barriers.

Keywords: Caplina aquifer, balanced exploitation, unbalanced exploitation

1. INTRODUCTION

In some regions of our planet, climatic and environmental changes have been examined during the last 2 centuries, using systematic records of rainfall and indirect information about lakes and rivers and the occurrence of famines and droughts (Nicholson, 2001). An estimated eight to ten million cubic kilometers (km^3) of fresh groundwater accounts for most of the total liquid fresh water on Earth, or to be more precise: approximately 98 to 99% of it, as shown in Figure 1 (Shiklomanov & Rodda, 2004); In comparison, the overall volume of fresh water in the lakes is less than 1% of the total volume of groundwater (Shiklomanov & Rodda, 2004; Schneider et al., 2011).

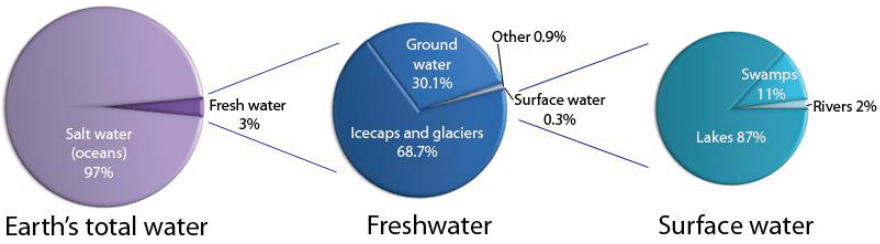


Figure 1. Earth´s water distribution

Throughout the period of exploitation of the aquifer that dates back more than 100 years, there is information on three water balances carried out. The institutions responsible for the annual balances reported are: National Institute for Mining Research and Development (INIFM) in 1965 reporting 36 Hm^3 in positive balance, Special Tacna Project, National Development Institute (PET-INADE) in 1989 reporting -15.5 Hm3 in negative balance and the Geological Mining and Metallurgical Institute (INGEMMET) in 2009 reporting -44.0 Hm^3 in negative balance, after 2009, no balances are recorded in the aquifer.

In the Caplina basin (Figure 2), where this aquifer is located, the sources with the greatest influence on water quality were determined, being the geothermal Aruma and Paralocos that emanate waters with a high content of Arsenic, Lead and Sodium in concentrations above the values of the Environmental Quality Standard (ECA), including the transfer of water from the Barroso Chico source to the Ancoma Creek with a high iron content (Pino et al., 2017). This aquifer, being located in geologically active environments, has a distribution of water types that is often influenced by long-term geological processes (for example, sea level fluctuations). From the point of view of water management, coastal aquifers are vulnerable to salinization by marine intrusion (Post, 2005).

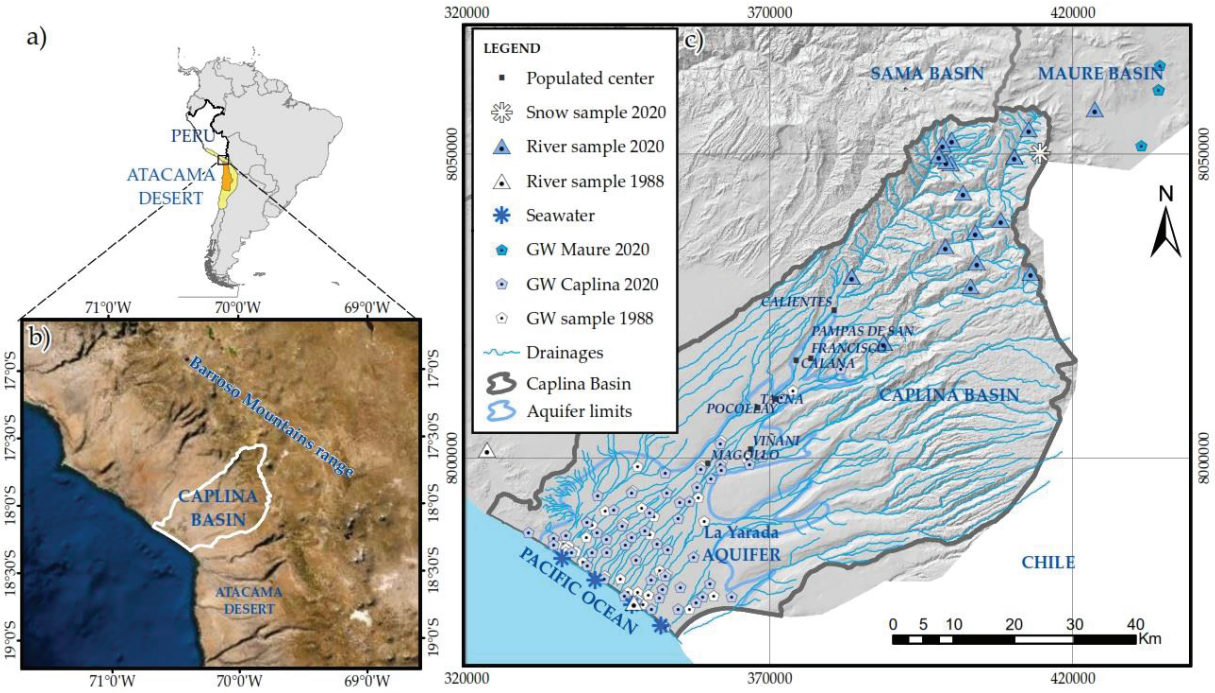


Figure 2. Location of the study area. (a) Atacama Desert in Chile and Peru, (b) Barroso Mountain range, a separation boundary between Caplina and Maure basins, (c) Caplina coastal aquifer in the Caplina basin. In this work, we seek to review the history of more than a century of exploitation of the Caplina coastal aquifer as a livelihood for agriculture in arid areas and to determine what the future will be regarding its exploitation and its conditions in terms of quantity and quality.

2. FINDINGS AND RESULTS

2.1 The beginnings between the years 1900 and 1910

Between the years 1900 to 1910, the first oil-oriented explorations were carried out, being that, in 1910, it was when the first underground water exploitation well was drilled, in charge of the so-called Arica Advancement Board, not registering activities intervention in the aquifer system after 1928, the culmination date of the Chilean occupation in Tacna.

2.2 In the 1930s and 1940s

Between the years 1930 to 1940, the Ministry of Development and Public Works carried out the study for the consolidation of water resources in Tacna, the first excavations were carried out and the first study for the use of groundwater was carried out, carried out by García in 1937.

2.3 In the 1950s

Starting in 1950, the development of private irrigation projects began, with the agricultural concessions of Ing. J. Grande and the execution of drilling works for tubular and deep wells. In 1957, the investigations of groundwater began by the U.S Geological Survey and by Dr. M. Solignac, a French expert in groundwater from the FAO (Food Agricultural Organization) at the request of the Ministry of Development and Public Works of the Peruvian Government.

2.4 In the 1960s

It is from 1960 that the execution of hydrogeological studies in the La Yarada aquifer begins, the first of its kind was developed by Eng. G. Pérez, culminating in December 1966 commissioned by the National Institute for Mining Research and Development (INIFM). Among its main conclusions it is mentioned that the exploited volume amounted to 11.38 Hm^3 / year, of 63 drilled wells, only 34 wells were in activity (27 tubular and 7 open pit) and that the total reserve of the napa was unknown.

2.5 In the 1970s and 1980s

Starting in 1970, the increase of the irrigated area began and with this the increase of wells, groundwater was exploited for the new surfaces of Settlements 3 and 4 and Settlements 5 and 6. In this period the first piezometers were drilled with the purpose of initiating aquifer monitoring and control programs. In 1980, the company Aguas Subterráneas Consultoría y Servicios SA (ASCOSESA) investigated the effect of the marine interface against the implementation of catchment works in the vicinity of the coastline corresponding to the coastal strip of the Caplina river dejective cone, determining the position and form of progress in this interface against the operating conditions.

2.6 In the 1990s

In this decade, already with an aquifer with clear signs of overexploitation, reflected in the decreases in piezometric levels, Ministerial Resolution No. 621-94-AG was issued, dated October 5, 1994, which authorizes the National Institute of Natural Resources (INRENA), to complete the hydrogeological study of the pampas of La Yarada and Hospicio, which is approved by Ministerial Resolution No. 0696-98-AG, dated December 14, 1998, in which the gradual and permanent drop in the water table and irreversible marine intrusion, recommending maintaining the ban on increased exploitation of groundwater, prohibiting the execution of all types of work for exploitation.

2.7 In the 2000s

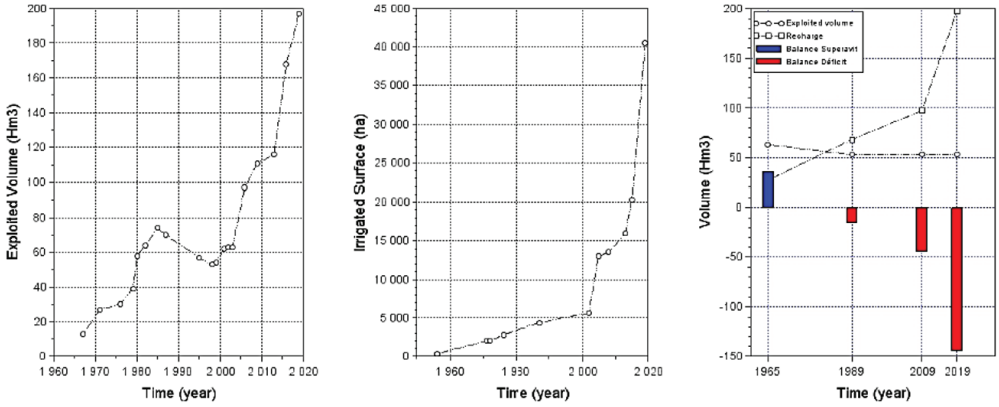
As a result of the studies and alerts of the previous decade, in 2004, the aquifer control was programmed in an agreement between the Tacna Special Project (PET) and the Tacna Regional Directorate of Agriculture (DRA-Tacna). INGEMMET and PET carried out the Hydrogeological Compatibility Study of the La Yarada Aquifer Reservoir in 2008. INRENA in 2003 develops the Valle del Caplina Hydrogeological Study.
In 2009, the National Water Authority (ANA) carried out the Hydrogeological Characterization study of the Caplina - La Yarada valley aquifer. Regarding aquifer management issues, the S.D. N ° 065-2006-AG, which establishes the closure in the aquifer, prohibits the execution of works destined to the exploitation of underground water resources, as well as increasing the exploitation volumes. With R.J. N ° 0327-2009-ANA, the closure declaration given with the Supreme Decree is ratified. No. 065-2006-AG.

2.8 In the 2010s

In 2010 the ANA developed the study Hydrogeochemical Characterization of the Caplina Aquifer. Likewise, in 2011, Technical Report No. 03 on Water Quality in the Caplina Basin. The PET in 2013, elaborates the situational diagnosis of the Caplina aquifer in the area of the Yarada sector. The ANA, seeing that the stability of the system is compromised, and the process of marine intrusion in the aquifer being evidenced, initiates studies aimed at identifying surface and underground alternatives, aimed at improving the water supply for the aquifer in 2013. In the year 2013 In 2014, in order to contain the marine intrusion, the work plan for the implementation of a hydraulic barrier and the diagnosis for its preliminary location are proposed.

2.9 Findings and results

According to the regulations and studies carried out for the Caplina aquifer, during the more than 100 years of exploitation, it is known that, until the 1970s, the exploitation of the aquifer system was balanced between recharge and extractions (Figure 3). From the 80's, it is concluded that the overexploitation of the aquifer has caused decreases in the water table and that the water potability decided to change to mediocre, evidencing the displacement in the water quality; which is directly related to the increase in agricultural activity and drilling and the operation of new wells, progressively decreasing secondary recharges of good quality water, damaging some areas of the aquifer, these are limited to receiving the main recharge of the river Caplina, where there is volcanic activity in the basins of the basin: a fact that results in a change in water quality; However, despite all this, the classification of water for irrigation remains unchanged over the years (Pino & Coarita, 2018).
National Water Authority (ANA) in the last decade, they propose mediated remediation via artificial recharge of the aquifer with the use of alternatives to increase said recharge such as: transfers, hillside treatment, wastewater reuse, desalination, as well as moving forward to start new lines of research that develop the technique of artificial recharge of aquifers. It also proposes to study and present certain criteria of environmental education, awareness and dissemination, applied to the artificial recharge of aquifers. Finally, it proposes a series of actions to bring this alternative of water management to the general population, universities, institutes and colleges.



(a) (b) (c)

Figure 3. Water balance Caplina aquifer

It is also proposed to prepare the studies and implement a hydraulic barrier consisting of a battery of wells that allow to attenuate and intercept the process of marine intrusion in the aquifer of La Yarada. It focuses on sufficient geological and geophysical studies to fully characterize the aquifer environment in the area of implementation of this barrier. It also focuses on chemically characterizing groundwater and identifying the freshwater-salt water interface area. In turn, it is proposed to establish the location and number of wells of which the hydraulic barrier would be composed, establish guidelines and costs for operation and maintenance. Finally, it presents a diagnosis for the preliminary location of a negative hydraulic barrier pilot in the La Yarada aquifer, in order to contain marine intrusion. Negative hydraulic barriers that intercept salt water flow by pumping near the coast have been proposed as a corrective measure for seawater intrusion in cases where low piezometric loads must be maintained (Pool & Carrera, 2010). Corrective measures should be optimally designed to improve water quality and minimize changes in the existing pumping regime (Abarca et al., 2006).

3. CONCLUSIONS

Revised the history of tests on the Caplina aquifer, after 100 years of continuous exploitation in a balanced and unbalanced regime, it has been identified that unbalanced exploitation has been taking place since the 1980s, where the extraction volumes exceed recharge. On the part of the water managers in the aquifer, accurate measures have been taken, stories such as closed seasons and not accurate stories such as the issuance of regularization decrees of unused wells, which incentivized drilling indiscriminately with fines to legalize them. When identifying the technical problems regarding the overexploitation of the aquifer, current and future guidelines have been given to establish policies regarding its exploitation and its conditions in terms of quantity and quality. In the future, correct measures were proposed such as the use of negative, positive and mixed hydraulic barriers, specifically justified in order to mitigate the effects of marine intrusion, which has been contaminating the groundwater of the aquifer.

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