Approaches to achieve sustainable use and management of groundwater resources in Qatar

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Abstract

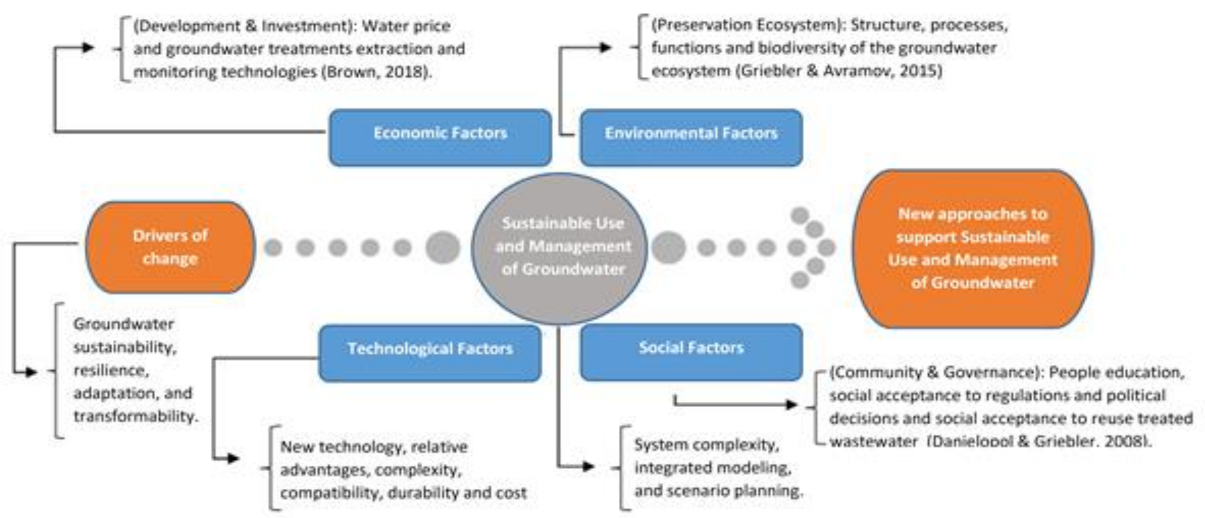
This paper reviews the hydro-geochemical characterization of Qatar's aquifer. In addition, it highlights the opportunities in the current groundwater management practices to achieve a sustainable groundwater use in Qatar such as assessing and monitoring the groundwater quantity and quality. In this review article, the Driver-Pressure-State-Impact-Response framework is used to analyze the water resource system in Qatar; begins by describing the causal chain from driving forces of impacts and finally state the responses. As the main driver is the intensive use of groundwater for agriculture irrigation, this causes high pressure on groundwater abstraction and deteriorate the state of the groundwater environment in term of quantity and quality, which has an impact on the food and water supply demands. Therefore, the final response highlights the need for the enhancing the rainfall infiltration to the aquifers, recharging the groundwater aquifers using treated sewage effluent or desalinated water development of groundwater treatment techniques, the use of efficient water irrigation practices, the reuse of treated wastewater for irrigation and the development of certain water-use tariff structures and awareness campaigns for farmers.

Introduction

- Qatar is a semi-arid country located between latitudes north 24.27˚ - 26.10˚ and longitudes east 50.45˚ – 51.40˚ along the eastern region of the Arabian Peninsula (MDPS, 2017).
- Qatar is mostly located over a uniform limestone bed, and the oldest exposed rocks are the Lower Eocene Rus Formation that contains most of dolomite and limestone with few outcrops of the Miocene (covering about 8%) of the surface area (MDPS, 2015).
- In Qatar, the descriptions of the Middle Eocene age are Dammam formation, Rus formation, while Umm er-Radhuma is the Early Eocene/Paleocene age (Al-Naimi & Mgbeojedo, 2018).
- All the fresh groundwater in Qatar comes from local rainfall, except for the confined slightly brackish water near Abu Samara, which receives inflow groundwater from the west Saudi Arabia (UN-ESCWA & BGR, 2013).
- Recharge from rainfall to groundwater is estimated to be 25 million m^3/year, which is similar to previous studies that estimated 7-10% of annual rainfall in north of Qatar and 3.5-5% in south of Qatar (Baalousha et al., 2015).
- Interactions between groundwater and surface water bodies (known as hyporheic) and with the surface terrestrial environment are the main groundwater contaminant pathways (Smith, 2005).
- The conservation of the quality and quantity of Qatar's groundwater resources contributes in supporting the implementation of the national development strategy (NDS) goals 2018-2022 that "ensure availability and sustainable management of water and sanitation for all" (MDPS, 2017).

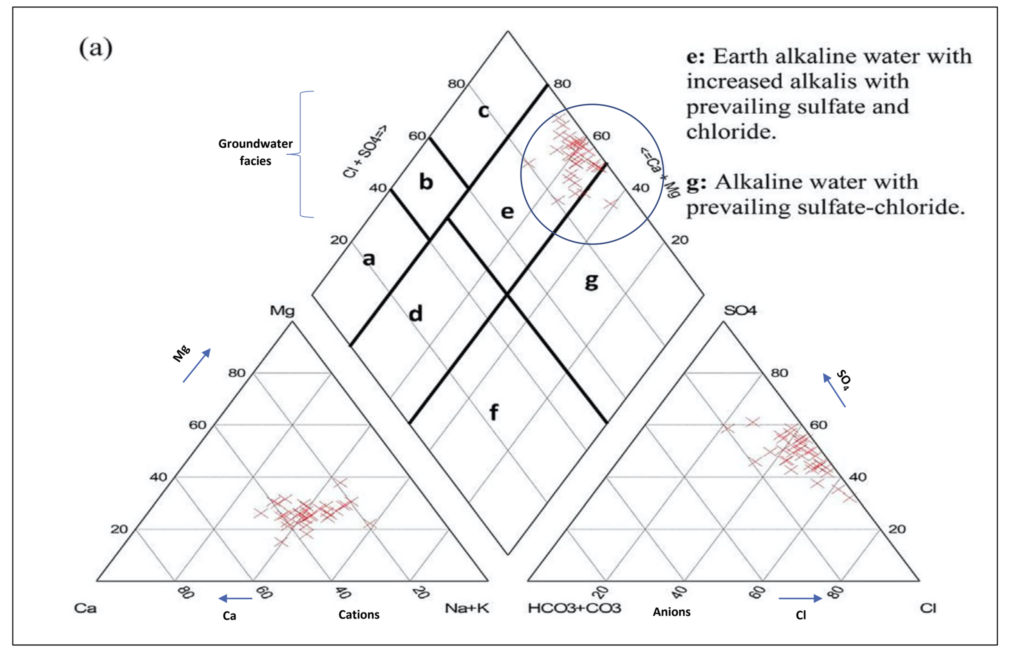
Sustainable groundwater management

- Sustainable use and management of groundwater are very important processes for environmental, economic, technological and social development as shown in Figure 1. For example, due to the greatly spread technologies of extraction and distribution groundwater beside the low prices of these technologies, the quantity and quality of groundwater are changed; so new irrigation technologies should be adopted such as root-zone irrigation, greenhouse technologies or by saving the water consumptions through the reuse of wastewater in homes.

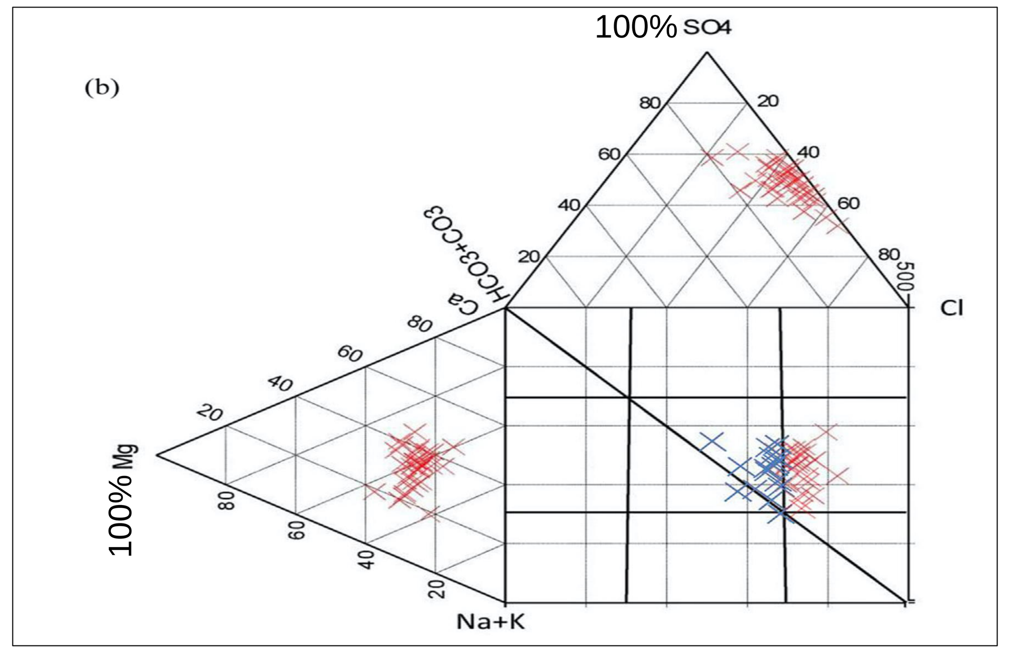


Types of groundwater

It has been indicated from Piper diagram that there are two types of groundwater, which are high alkalis with sulfate and chloride as dominant and alkaline water with prevailing sulfate-chloride ions. While Durov diagrams illustrated that about 40% of water is rainfall water ($Ca(HCO_3)_2$), and $MgSO_4$ and $CaSO_4$ which were dissolute of sulphate and carbonate mineral, and then mixed with the irrigation return flow and 60% of water is $MgCl_2$ and NaCl type, which are derived from the dissolution of Na-Mg-rich host carbonate rocks (Alfy et al., 2017).



Seven categorical subdivisions for natural waters were found. There are two main groundwater categories e and g.



About 40% of groundwater samples (blue) show no dominant anion or cation. The remaining 60% of water samples (red) represent the MgCl2 and NaCl type.

Figure 2. Groundwater categories A. Piper diagram B. Durov Diagram, modified from (Alfy et al., 2017).

Groundwater treatment, modelling and GIS mapping

Groundwater treatment

- Qatar has recently undertaken the challenge to become the most self-reliant and sustainable country of the Middle Eastern region. Today, in Qatar, groundwater is the major renewable water resource comprising around 47.5 million m3/year. Groundwater abstraction is 30 times higher than average recharge rates; this has led to a dramatic drop in groundwater table and the increase in salinity (Water Statistics, 2015).
- Previous research has shown that the total dissolved solids (TDS) in Qatar's groundwater vary from 1000 - 7500 mg/L which can cause reverse osmosis (RO) membrane scaling and therefore, requires expensive pre-treatment methods (Elsaid, 2017).
- Our preliminary results have also shown that the quality of groundwater is deteriorated, and several contaminants including toxic metals and metalloids are exceeding permissible limits. Boron (B), lithium (Li) and molybdenum (Mo) were found to be 1.28, 0.08, and 0.02 mg/L, respectively. These elements are of great concern as they can potentially induce toxicity to agricultural products.
- it is essential to develop novel treatment approaches that are low-cost and environmentally friendly to improve the quality of these water sources in Qatar.
- Various conventional techniques such as advanced oxidation, membrane filtration processes, reverse osmosis, chemical precipitation, ion exchange and sorption are used for eliminating metals from water. However, these methodologies have their advantages and boundaries in application.
- The adsorption methods are of high efficiency in the removal of different pollutants, practical, easy, simple, low cost, low chemical and biological sludge and there is a possibility for regeneration of adsorbent and metal recovery (Dodbiba et al., 2015; Ahmad et al., 2011; Huang et al., 2016).
- The non-conventional adsorbent such as natural materials sorbents are of extensive source, environmentally friendly and low cost. Such as clay, cellulosic materials such as agricultural wastes, sludge and fly ash from industrial by product (Guan et al., 2016).

Groundwater modelling and mapping using GIS

- It should be noted that in groundwater management, the objective is not only to monitor and assess a groundwater but more to make use of the information to construct a good decision.
- Making decisions will almost always have some extent of risk such as the risk of wrong decision or the risk of selecting an unappropriated treatment technique (Vargas, 2004).
- Geographic information system (GIS) is a significant tool for analyzing and visualizing spatially continuous data, resulting in reducing the risk of making the wrong decision and supports management and planning processes.
- Geostatistical analysis incorporates different interpolation methods; each has special advantages and gives different output. Interpolation methods are grouped to deterministic (non-geostatistical interpolation) and geostatistical interpolation.
- Geostatistical interpolation contains several methods, which are all in the kriging family such as ordinary, simple, universal, probability, indicator and disjunctive kriging in addition to cokriging (Magesh and Elango, 2019).
- Groundwater vulnerability and risk mapping models have three types of techniques of vulnerability assessment maps: statistical techniques, process- based simulation techniques and overlay and index-based techniques (Kumar et al. 2015).
- Figure 3 shows the maps generated for A. molybdenum, B. boron concentrations in Qatar's groundwater using the interpolation technique.

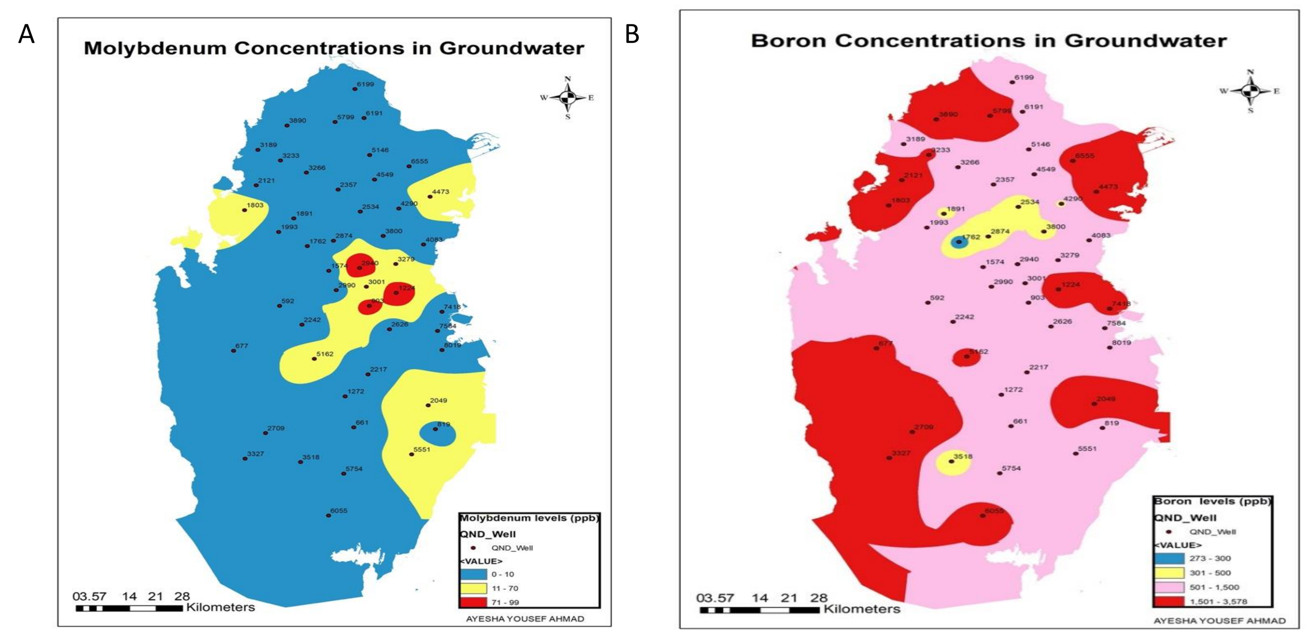


Figure 3. Maps generated for A. molybdenum, B. boron concentrations in Qatar's groundwater using the interpolation technique.

DPSIR framework for groundwater resources management

- Drivers, Pressures, State, Impact, Response (DPSIR) framework was evolved from Pressure, State and Response (PSR) model (OECD, 1993).
- It is an adaptive management tool used for analyzing environmental issues such as water resources and then developing cause-effect relationships between human activities and their environmental impacts.
- Thus, it facilitates the resource managers, hydrologists, and policy makers managing the water resources of the region in more effective and sustainable manner.
- The model of DPSIR was used to analyze groundwater resources of Qatar (Figure 4).
- Generally, "Drivers" term includes all the driving forces acting on regional water resource systems. It is basically comprised of human needs such as water and food.,
- The "Pressure" term of the DPSIR represents the human activities undertaken to fulfil needs and demands.
- The human activities will apply pressure on the environment and available resources, which will lead to changes in "state" of the environment.

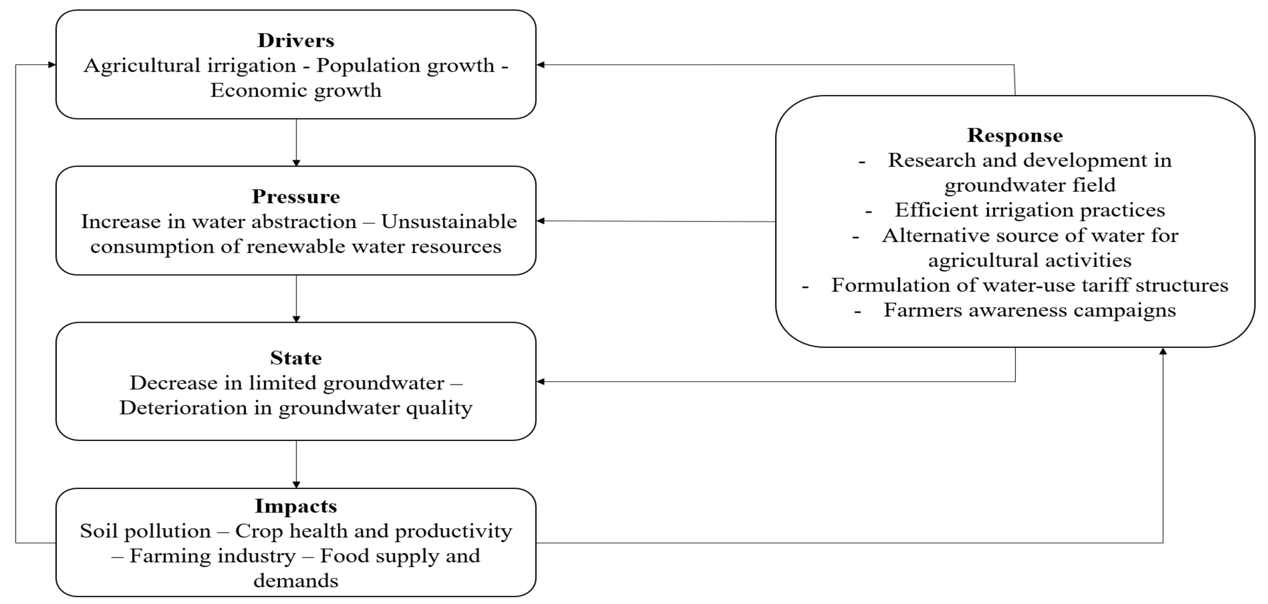


Figure 4. DPSIR framework for groundwater resources in Qatar

Conclusions

The cost-benefit analyses and other decision making within groundwater management are derived from the intersection of ecological characterization such as water quality analyses, engineering such as water treatment technologies, societal demands such as food supply, and people perception of water quality. Thus, to achieve a sustainable use and management of groundwater in Qatar, supply and demand management practices should be adopted. In addition to developing reliable and cost-efficient treatment techniques for low groundwater quality. The supply management should include developed monitoring systems, managed storage, recovery projects and artificial recharge by recharge wells and lagoons using treated wastewater and desalinated seawater. In Qatar with the small groundwater users and low population density make some institutional approaches work significantly to sustain a reliable quantity and quality of groundwater supply. Recently the groundwater characterization and measurement using advanced technology in data analysis, remote sensing and modeling generate significant data and knowledge to decision makers with lower uncertainty.

Acknowledgement

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