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Review

Nubian sandstone aquifer system

Essam Hassan Mohamed Ahmed, PhD

Lead Author, AR5, WG III, IPCC, GHG Inventory, National Expert, UNFCCC, Climate Change and Sustainable Development Consultant
E-mail: esamhasan62@yahoo.com; Mobile: (+2) 0100-511-3933

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The Nubian Sandstone Aquifer System (NSAS) is the world's largest known fossil water aquifer system. It is located underground in the Eastern end of the Sahara Desert and spans the political boundaries of four countries in north-eastern Africa. The aquifer is largely composed of hard ferruginous sandstone with great shale and clay intercalation, having a thickness that ranges between 140-230 meters. The groundwater is of meteoric origin (the term meteoric water refers to water that originated as precipitation; most groundwater is meteoric in origin). Many groundwater aquifers and surface bodies of water traverse borders and boundaries without regard to politics, those that don't are frequently interrelated with the larger regional hydrologic system and are thus interconnected to surface or groundwater in neighboring states.

Keywords: Sandstone, Aquifer, Fossil, Sahara desert, Meteoritic origin, hydrologic system

INTRODUCTION

The Nubian Sandstone Aquifer System (NSAS) is the world's largest known fossil water aquifer system. It is located underground in the Eastern end of the Sahara Desert and spans the political boundaries of four countries in north-eastern Africa. This Aquifer covers a land area spanning just over 2.2 million km^2, including north-western Sudan with an extension of 376.000 Km^2, north-eastern Chad with an extension of 235.000 km^2, south-eastern Libya with an extension of 760.000 km^2, and most of Egypt with approximately 80% and extension of 826.000 km^2. The geographical position between latitude 14°-33° north; longitude 19°-34° east. It contains and stored water volume 150.000 km^2. (Figure 1)

The aquifer is largely composed of hard ferruginous sandstone with great shale and clay intercalation, having a thickness that ranges between 140-230 meters. Groundwater type varies from fresh to slightly brackish (salinity ranges from 240-1300 ppm). The ion dominance ordering shows that sodium caution is most commonly predominating over calcium and magnesium – whereas chloride is predominant over sulfate and bicarbonate. The groundwater is of meteoric origin (the term meteoric water refers to water that originated as precipitation; most groundwater is meteoric in origin). High concentrations of sodium, chloride, and sulfates reflect the leaching and dissolution processes of gypsiferous shale and clay, in addition to a lengthy duration of water residence.

Since 2001, the Nubian Sandstone aquifer situated between the Toshka and Abu Simbel areas of Egypt underwent intensive drilling and development as part of a land reclamation project. Many studies were made looking for the hydrogeological setting of the area's aquifer, its results indicated that lithological characteristics and tectonic settings are having a substantial effect on groundwater flow patterns and the area's overall aquifer potentiality, which is considered relatively low compared with the neighboring areas in eastern Oweinat or Dakhla.

Figure 1. Nubian sandstone aquifer system

International water law and groundwater resources

Under international water law, countries must utilize transboundary water resources in an equitable and reasonable manner, that for the concept to get a cost-benefit analysis which attempts to maximize the beneficial use of limited water resources while minimizing the burdens. Thus, riparian states-states with direct access to a transboundary river-must take into account the interests of all other riparian states in the use of the shared waters, as well as any necessary conservation objectives when implementing projects to use or develop the resource. Furthermore, in their use of transboundary water resources, countries must not cause significant harm to the interests of other states relying on the resource.

Many groundwater aquifers and surface bodies of water traverse borders and boundaries without regard to politics, those that don't are frequently interrelated with the larger regional hydrologic system and are thus interconnected to surface or groundwater in neighboring states. Consequently actions of one country that affect the water resources within its territory can vary often result in significant consequences to the quality or quantity of water in another country.

The international legal regime regulating the use of transboundary water resources has, until quite recently, focused predominantly on surface bodies of water. Most legislators, policymakers, and international legal scholars considered underground water resources as dissimilar from surface waters with respect to rights and usage; groundwater was, and often still is regarded as akin to a mineral resource and thus omitted from the rubric of international water law.

This neglect and misconstruction of the nature of groundwater can be ascribed, in large part, to insufficient understanding among those same legislators, policymakers, and legal scholars of the basic physics of the relationship of surface and groundwater within the hydrologic cycle.

The usage of Nubian sandstone aquifer

Globally, the agricultural sector accounts for ~70% of all freshwater withdrawals (~5000 km^3/year). In sub-Saharan Africa, freshwater withdrawals for agriculture are much less than in Asia, Europe and North America, as <5% of the arable land is under irrigation (Giordano, 2005). Soil water sustains almost all food production but is excluded from measures of freshwater availability based on river flow.

In addition, estimates of freshwater demand assume annual withdrawals for irrigated agriculture (and industry) which are 20 times that required for domestic water use. Consequently, current metrics of water scarcity serve to underestimate freshwater availability and inflate freshwater demand in sub-Saharan Africa. It does not follow that water scarcity is necessarily exaggerated in Africa but simply that current metrics do not adequately represent its spatial and temporal dimensions.

Current metrics are also insensitive to projected hydrological change. The projected increase in rainfall intensities as a result of global warming will give rise to more variable river discharge and soil moisture.

The former will exacerbate intra-annual freshwater shortages and the risk of flooding, whereas the latter threatens food security through reduced crop yields. However, current evidence, highlighted above, suggests that the shift toward more intensive precipitation enhances groundwater recharge.

Figure 2. Nubian sandstone aquifer usage

As a result, groundwater in many parts of sub-Saharan Africa can play a strategic role in adapting to changing freshwater availability and improving food production and security through groundwater-fed irrigation. Since small-scale farming accounts for 70% of agricultural production in sub-Saharan Africa, discrete low-yielding aquifers in weathered crystalline rock and mudstones that underlie more than 50% of sub Saharan Africa may prove “fit for purpose” as they are self-regulating, naturally restricting the impacts of local overdevelopment and solving the age-old problem of allocation. (Figure 2)

There is a long history of low-intensity groundwater development for domestic rural water supplies in Africa. Low recharge fluxes (<10 mm/year) required to sustain such development, are expected to occur in regions where rainfall exceeds 200 mm/year. In humid regions, there is little evidence of regional water-level decline from such low-intensity abstraction; localized depletion is often due to anomalous geological conditions or faulty infrastructure rather than broad-scale resource depletion. In many arid and semi-arid areas of Africa, however, it must be recognized that substantial recharge has not occurred in modern times so that groundwater resources are essentially non-renewable.

Intensive development of groundwater for domestic water supplies in Africa began primarily over the second half of the 20th century in association with urbanization.

Groundwater is a common low-cost alternative to surface water for urban water supplies as it is widely distributed and is generally of potable quality, thereby avoiding the expense and management of sophisticated treatment systems. However, despite growing dependency upon groundwater for urban water supplies, concerns remain over the sustainability of these supplies, in terms not only of the magnitude of abstraction but also their quality.

Sub-Saharan Africa is the most rapidly urbanizing region in the world with a projected tripling of urban populations from 2000 to 2050. This rate of growth presents substantial challenges to the provision of not only safe water supplies but also sanitation. First, few reliable groundwater data exist upon which abstraction policies can be based.

Indeed, there has been comparatively limited investment in monitoring infrastructure for groundwater resources relative to surface water resources. Recent research from two well instrumented sites in Uganda highlights the importance of aquifer storage at the borehole catchment scale in determining the sustainability of intensive abstraction for town water supplies.

Second, inadequate community hygiene in many rapidly urbanizing centers makes urban water supplies derived from shallow groundwater increasingly vulnerable to contamination. For coastal aquifers, there is the added threat to the quality of abstracted groundwater posed by projected sea-level rise which will decrease the depth of the freshwater lens through seawater intrusion.

Water consumption

The main use of Nubian Sandstone Aquifer System water for irrigation purposes and as drinking water. The actual withdrawal rates as follows; Egypt draw 1029 Million m^3/yr; Libya 851 Million m^3/yr; Sudan 406 Million m^3/yr and Chad Million m^3/yr.

There’re two different systems because of different water bearing strata; The Nubian Aquifer System (NAS) that has the characteristics;

- Spreads over the whole area defined for the NSAS.
- Medium to coarse grained sandstone.

- Comprises Paleozoic and Mesozoic deposits, overlies the Precambrian basement complex.
- Lower one of the systems over 400 m thick.
- Semi-confined or partially confined aquifer.

The second system is the Post Nubian Aquifer System (PNAS) that has the characteristics;

- Only in the northern part down to the north of 26 th latitude (EgyptandLibya).
- Comprises Tertiary continental deposits and tertiary carbonate rocks.
- Sands, gravels and silts.
- Upper one of the systems, 10-300 m thick.
- Higher permeability than NAS, unconfined aquifer.

The usual consumption of Nubian Sandstone Aquifer for agriculture, settlements live in areas near by the groundwater used to draw from NSAS for their needs, drinking, preparing food, feed their animals and chattels, and agriculture. We can see these activities in many areas in Egypt, Sudan, Chad and Libya. In Libya e.g. we could find in Al Kufrah; most of the NSAS water is used for irrigation, around 750 km inland use that aquifer, but the production costs much higher than world price. The drawdown is assumed to be 60 m but it fluctuated from 35 to 100 m.

In irrigation command areas serviced by pump-operated wells, on the other hand, water distribution is more formalized. Irrigation times are tied to pump working hours, which correspond with a ten-hour work shift for a government employee, who supervises and operates the generator at the well.

As water supply is controlled by the pump, the supply can be tailored to better match demand, for example, by season or crop requirements. Irrigation hours vary immensely as the operator runs the well for as little as five hours in the winter and up to 12 hours in the summer due to the respective perceived water excesses and shortages, allowing for more efficient irrigation in these command areas. The downside, however, is the need for additional energy to operate the pump, which also causes some oil to spill into the irrigation water. Challenges to efficient and sustainable water use.

The Nubian Aquifer System is a source of fossil water, as it was accumulated over thousands of years and experiences “negligible recharge in the present arid conditions”. This means that the water is a non-renewable resource. It is not clear how long ground water will be available for extraction from the aquifer, especially as extraction rates are intensifying in most North-African countries that tap the aquifer system. Currently, about 0.6 billion m^3 of water are pumped from deep aquifers in Egypt alone.

Within Abu Minqar, the pressure on the aquifer is also increasing as new wells in and around the community is dug, partly by private companies and investors, with future plans for numerous additional wells. How such increased pressure on the finite water resource will impact the sustainability of agricultural production and livelihoods as well as the social cohesion within new settler communities remains a topic for future research.

The Great Man-made River Project (GMRP) of Libya

One of the great project that consumption a huge amounts of Nubian Aquifer Groundwater that made by Libya and called “The Great River”. It constructed in the mid of the 1980’s work started on the world biggest engineering project, the objective of that project is to deliver water from Libya’s aquifers underlying the xeric regions to the countries big cities on the coast. The project subdivided into 5 phases, the end of phase1 inaugurated in 1991, the last phase completed in 2005.

The pipelines in total almost 4000 km with 4m radius. Wells around 3000 depth of 450m-650 m, pumping rate around 100m^3/day. The total withdraw capacity is 6.18 Miom^3 (~71.5 m^3/S), the estimated cost of the total project is 25 billions$, the cost per m^3 is 0.35 US$, the lowering of piezometric head after first year is 15m, the estimated duration until final exhaustion of the aquifers is 50 years.

Withdraw water for municipal, industrial and agricultural use should be enough to produce adequate water and food to meet the countries own needs, it reduces the dependency on imports from foreign market.

CONCLUSION

The vision of the groundwater aquifer is not clear till now in particular in Africa, countries who sharing in one aquifer don’t have a good agreement to explain how they could use and satisfy their needs without neglecting the rights of other countries who have the same rights. So we have to manage and implement a good convention for states that sharing in the same aquifer to manage and control their draw and to implement a good plan to recharge the same aquifer using floods and other resources. The Great River in Libya consumed huge amounts of water without coordination with the boundaries, Egypt, Sudan and Chad, these amounts lead to change the geological construction of the aquifer system and also the underground layers, that lead to increase the salination of the agriculture lands nearby these areas.

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