Circum Saharan Transboundary Aquifers: Inventory and challenges for Management

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ABSTRACT

The circum-Saharan trans-boundary aquifers have a large structural configuration, with a thick sedimentation in a border of the crystalline basement cratons. These multi-layers aquifers have an extension exceeding the political boundaries of many circum-Saharan countries. They content the major water resources of the area.
During the Pliocene and early Quaternary, the paleo-climate conditions contribute to have a good recharge of these aquifers and a big reserves take place. The major part of these aquifers water resources are non renewable. Recently, the increasing of exploitation deregulates the hydrodynamic equilibrium. In many cases, are noted dropping of springs flow, reduction of flowing wells storage, degradation of water quality and reduction of irrigated soils production.
A sustainable management of these water resources aquifers needs a real consultation between the countries sharing the aquifer system, based on a good and updated evaluation of the water resources, a monitoring of the piezometry and the exploitation of the aquifers and a shared vision to the development options.
The Project of Northern west Saharan Aquifer System (NWSAS) shared by Algeria, Libya and Tunisia, gives a good example of the approach used to have updated data and to start the consultation mechanism for the shared management. This approach is applied in the circum-Saharan area, in others cases like Illumeden Aquifer system (IAS) and Nubian sand Stone Aquifer (NSAS).

Key words: circum-Saharan, multi-layers, non-renewable, management, consultation.

1 – INTRODUCTION

The circum-Saharan aquifers extend on both sides of the Sahara: in North Africa and in the Sahel. These aquifers, which are usually located in large sedimentary structures, come in the form of multi-layers systems with relatively important geological reserves extending over several countries. Under arid conditions, their recent recharge is very limited and most often they are the exclusive water resources. Their exploitation has been steadily increasing with the ever-growing water demand. The abstraction of these aquifers reflects a severe competition between users, with extensive impacts observable over the countries boundaries.

The information about the hydrodynamic functioning of the circum-Saharan aquifer systems is sketchy and focused on the abstraction areas. Only some of those aquifers are well studied over all the extension of the basin and the available data is usually scarce and insufficient for precise modeling or analysis.

This paper syntheses the state of the knowledge about the circum-Saharan aquifers and discusses the issues related to their sustainable management.

2 – MAIN CARACTERISTICS

The main trans-boundary aquifer systems of the circum-Saharan area are (*cf.* Fig. n°1):

- in North Africa: North West Saharan Aquifer System (NWAS), Nubian Sandstone Aquifer System (NSAS), Murzuk Aquifer System, Djeffara Aquifer System, Tindouft Aquifer System,
- in Sahel area: Senegalo-mauritanian Aquifer System, Illumeden aquifer system (IAS), Tanezrouft- Taoudeni Aquifer System.

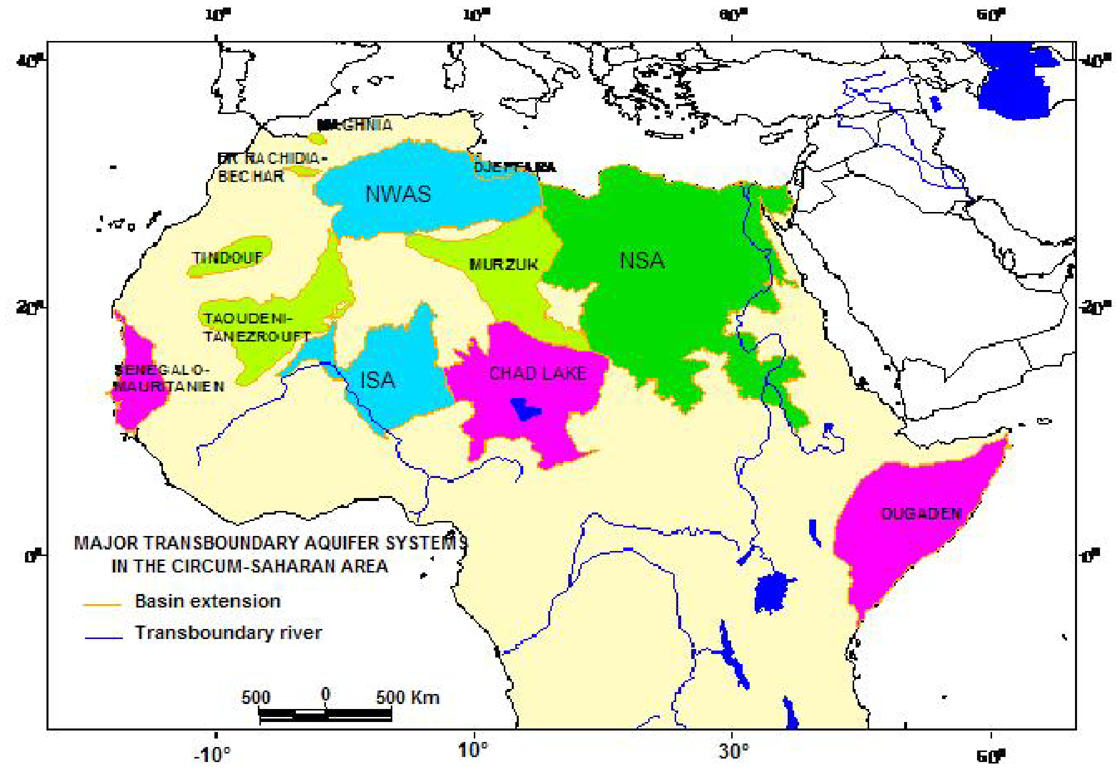

Fig. 1. : Location of the main circum-Saharan trans-boundary aquifer systems

2.1 – Geological Structure

The main aquifer systems surrounding the Sahara have a large extension (i.e., 500 000 - 2 000 000 km²) and stretch over several countries. Their geological structure comes in the form of large sedimentary basins with thick layers. Their spatial continuity has been continuously perturbed by the tectonic evolution from the Precambrian era until now.

Three main categories of structures are present in this region (ISARM/OSS, 2005):

- Complex structures with many blocs where the water resources are mainly renewable by recent recharge. The management of these resources is tightly linked to the climate conditions and to the increase of abstraction. These resources are mainly located on the substratum areas (e.g., Hoggar, Aïr and Tibesti) and do not support intensive exploitation.
- Structures focused on large rivers (e.g. Nil, Niger, Senegal and Chari) with water resources depending on the exchange between the river and the aquifer system and important geological water reserves, such as the Sahelian aquifer systems (e.g. Senegalo- mauritanian, Taoudeni-Tanezrouft,

Illumeden and Chad basin). The intensification of these aquifer systems exploitation have an appreciate security in the geological water reserves, but it generates several negative impacts

- Structures in large sedimentary basin without surface water courses, and with multiple interlinked aquifers, such as the Saharan aquifer systems in North Africa (e.g. NWAS, NAS, Murzuk and Tindouft). The intensive exploitation of these aquifer systems is clearly engaged and many negatives impacts are observed.

Generally, the circum-Saharan aquifer systems have large extension and inter-connected multi-layers. The knowledge of their geological structure is -except in the case of petroleum exploration in the area – limited. Without a precise simulation of the aquifer system structure, it is difficult to have an exact appreciation of the water reserves volume and the conditions of flux on the basin boundaries.

2.2 – Hydrodynamic functioning of the aquifer system

The recharge areas of the circum- Saharan trans-boundary aquifer systems are often located on the borders of the sedimentary basin. Most often, the recharge area is in the upstream country and the outlet is in the downstream country, with a large distance separating them. In this case, the recent recharge is weak and thus it is difficult to evaluate it, except in the areas near the outcrops of aquifer beds and in shallow aquifers (e.g. Nubian aquifer system in Sudan and Chad and Illumeden aquifer in Mali and North of Niger).

Usually, it is also difficult to identify the real boundaries conditions of the aquifer systems because of their large extension and the lack of data. However, only a precise conceptualization of the functioning system taking into account the real exploitation conditions and the entire extension of the aquifer basin, would make it possible to identify the intensive abstraction impacts.

The efficient localization of the abstraction fields depends on the opportunities to tape the deep aquifers by wells or by boreholes. These fields are established near users (e.g., agriculture, water supply and industries) in order to minimize the transfer costs. Focused in small zones, the abstraction has been growing continuously with the increasing demand, which generates negative local and extended environmental impacts (e.g., the drying of springs, the dropping of flowing wells and the degradation of the water quality).

The hydrodynamic evolution of the functioning of the big aquifer systems reflects first the continual piezometry decline and in a second stage the drop of the flowing springs and wells. The impacts of these phenomena may extend beyond the boundaries between countries. In comparison, the degradation of the water quality is a slower and a more localized phenomenon. This later reflects more the vertical interconnection (i.e. leakage) between the aquifer system's layers, than the large spatial extension of its hydrodynamic decompression.

Many similar situations of decompression or depletion are observed in the cases of North West Saharan Aquifer System (OSS, 2003), Nubian Sandstone Aquifer System (CEDARE, 2002), Senegalo -Mauritanian Aquifer System (Diagana B., 1997), Illumeden Aquifer System (OSS, 2007).

Because of their intensive exploitation, the multi-layer aquifer systems have shown a gradual decompression with increasing depletion. Their water quality degradation is an ultimate indicator of their over-exploitation. In fact, after an excessive abstraction of the shallow aquifers, confined aquifers (i.e., deep aquifers) have been tapped and intensively exploited, because of their higher water production. These deep aquifers contain mainly non-renewable water resources. Therefore, their depletion represents a crucial issue since it is difficult to find substitute alternatives.

3 – EXPLOITATION IMPACTS

The water management of the big aquifer systems, particularly their non renewable resources, is strongly linked to their hydrodynamic and the technical-economical conditions of their exploitation. This management imposes a strategic vision taking into consideration their depletion. Usually, their exploitation targets first the shallow aquifer. However the progress of the drilling and pumping technologies makes it possible to abstract a higher volume of water at a reduced cost. Axed on the springs and flowing wells storage, the exploitation of deep aquifers focuses initially on the best water quality resources until they are exhausted. Resources with lower water quality are then abstracted in order to respond to the demand. Such a strategy leads to localized and intensive exploitation of the existing deep aquifer resources. Gradually, competition conditions between partners' uses are established, which increases the aquifers exploitation costs and its negative impacts.

The intensive exploitation impacts appear through the piezometry decline, the drop of springs and flowing wells storage and the degradation of water quality. The decline of piezometry is clearly observed in confined aquifers and it indicates a general decompression. Usually, this phenomena has a large extension and stretches aver several neighboring countries and it causes deep modifications in the abstraction conditions of the groundwater (e.g., drying of springs and drop of flowing wells storage). On the other hand, the water quality degradation is started by leakage between different layers in the aquifer system or through its top or bottom, which limit the water resources use options.

In North Africa, the NWSAS has been intensively exploited for more than fifty years, which has caused a general depletion of its water reserves (OSS, 2003). The main springs have dried and the exploitation of many flowing wells requires their pumping. Near the chotts' depressions[1], in Algeria and Tunisia, the degradation of water quality can be clearly observed. Similar situations were reported in large regions of the Nubian Sandstone Aquifer System in Libya and in Egypt (Bakhbakhi M., 2006). These phenomena have been extending across the countries boundaries.

In the Sahelian zone, the intensive exploitation was started in the late eighties with a limited abstraction level. The first signs of the negative impacts of this excessive exploitation can be currently observed through the decompression of the confined aquifers and the decline of springs' flow. Let us note here, that no water quality degradation was reported yet in these areas.

In all the previously described situations, the partner countries are conscious that they have to share the negative impacts of the intensive exploitation of their common aquifer resources, even if they have not all contributed to their generation.

4 – MANAGEMENT AND CONSULTATION

[1] Chotts : Saharan salty depressions.

The management of the trans-boundary aquifer system resources incites the concerned countries to work together to attenuate the common negative impacts of the excessive aquifer abstraction. A sustainable management strategy should take into account all the risks associated with the competitive exploitation of the shared basin, which requires a precise knowledge of the aquifer system and the development policies of the different countries. Such as strategy need to be continually reviewed and adjusted in order to adapt to the aquifer system evolution.

The updated knowledge of the aquifer system requires the establishment of a monitoring system in order to control, at the regional level, the piézometry, the abstraction and the water quality variations. The instauration of such monitoring system is more easily accepted when the negative impacts are clear and shared by all the partners. Otherwise, the countries' are reticent to share their data or information.

On the other hand, the review of the national policies has to ensure that the economical interests of each country will not induce negative impacts on the other partners. Only a consultation mechanism is able to give all the partners the opportunity to be well informed about the national policies and thus to adopt adequate decisions in order to reduce the risks and ensure a sustainable development. The expression of a regional collaboration is confirmed when the partners work together to achieve the same objective. The main target of the consultation mechanism is to optimize the management of the water resources in the shared basin. Strategic options for the water management must be based on a referential appreciation of the aquifer system state. The consultation aims to reduce the negative impacts and to ensure a sustainable development through the reconciliation of the aquifer system capacities and the partners' exploitation policies ambitions. The technical data provided by the monitoring of the aquifer system offers objective criteria to the decision makers to choose the adequate policies.

Three examples of consultation Mechanism establishment are attempted for the circum-Sahara aquifer systems: NWSAS (OSS, 2008), NSAS (Alker, W., 2006) and SAI (OSS, 2008a). A log process with many stapes is necessary to have the countries agreement on the strategy to adopt and how to execute decisions. Only the case of the NWSAS has given real concrete results represented by an operational monitoring system and a steering committee.

5 – CONCLUSION

The main trans- boundary aquifer systems of the circum-Saharan region contain nonrenewable water resources. The exploitation of these resources is a major element for the development in the area. The intensification of abstraction in the concerned countries has generated risks of decompression of aquifers and degradation of their water quality. In North Africa, where this intensification is higher and older than in the Sahalian zone, these negative impacts are inciting the countries to establish a consultation framework. This consultation ensures the exchange of data and the discussion of the water management policies.

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