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Full Length Research Paper

Overview of the aquifer system in the Senegalese and Mauritanian sedimentary basin

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Abstract:

The Senegalese and Mauritanian sedimentary basin extends from Guinea Bissau to Northern Mauritania through Senegal and the Gambia territories. It contains a diversity of aquifers units that are the main sources of drinking water supply for over 80 % of the population. Some of them are shared by 2 or 3 countries, and their management should receive attention by the various countries. With increasing pressure on water resources, groundwater use will augment progressively to provide sources of water and to satisfy the new demand with regard to the population growth, the living standard improvement, and new trend of irrigated agriculture development, as well. This paper is intended to characterize the groundwater potential in the sedimentary basin that bears groundwater contained in various (spatially and stratigraphically) aquifer units, with two major transboundary aquifers: the deep Maastrichtian aquifer and the alluvial aquifer in the Senegal River basin. Belong the necessary characterization of this aquifer system, the paper will aim to discuss the institutionalized groundwater management bearing in mind the existence of River Basin Organisations in the regional.

Keywords: management, groundwater, sedimentary basin, transboundary aquifers, deep Maastrichtian, alluvial aquifer.

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1. Introduction

The Senegalese-Mauritanian sedimentary basin extends from Mauritania to Guinea Bissau (Figure 1). Its total area is about 340 000 km^2. It contains important aquifers that are main potable water sources for more than 80% of the population; some of them are transboundary ones.

Transboundary rivers also flow through the sedimentary basin, their catchments resources are managed by Basin Organizations (BO) such as OMVS (for Senegal river) and OMVG (for Gambia, Kayanga-Geba, and Koliba-Corubal rivers). The Senegalese-Mauritanian sedimentary basin is listed as a shared aquifer system. However, from the hydrogeological point of view, this issue is more complex; indeed, the basin contains within it "national" and "international" aquifer units, usually hydraulically independent.

The aim of this presentation is to show the hydrogeological diversity of the sedimentary basin, in addition to the context of rivers basins managed by BO, to characterize the aquifers potential and to present the institutional management issue of transboundary groundwater.

2. Geological Setting

The sedimentary terrains lay on the ante-Mesozoic basement composed of metamorphic and plutonic rocks that can be seen on the eastern edge of the basin. They consist of the Triassic, middle to upper Jurassic, Cretaceous, Tertiary and Quaternary formations. They can reach a thickness of several thousand meters near the ocean domain [1]. From the perspective of hydrogeological interest, the most interesting sedimentary formations are layers within Maastrichtian and Quaternary (Figure. 1).

2.1. The Upper Cretaceous

It is mainly represented by Maastrichtian rocks which are in a sandy facies with frequent interbedded sandstones and clays in the eastern part of the basin (east of 17°50). It outcrops in the western part of the Senegalese sedimentary basin, but also in eastern part of the Mauritanian basin.

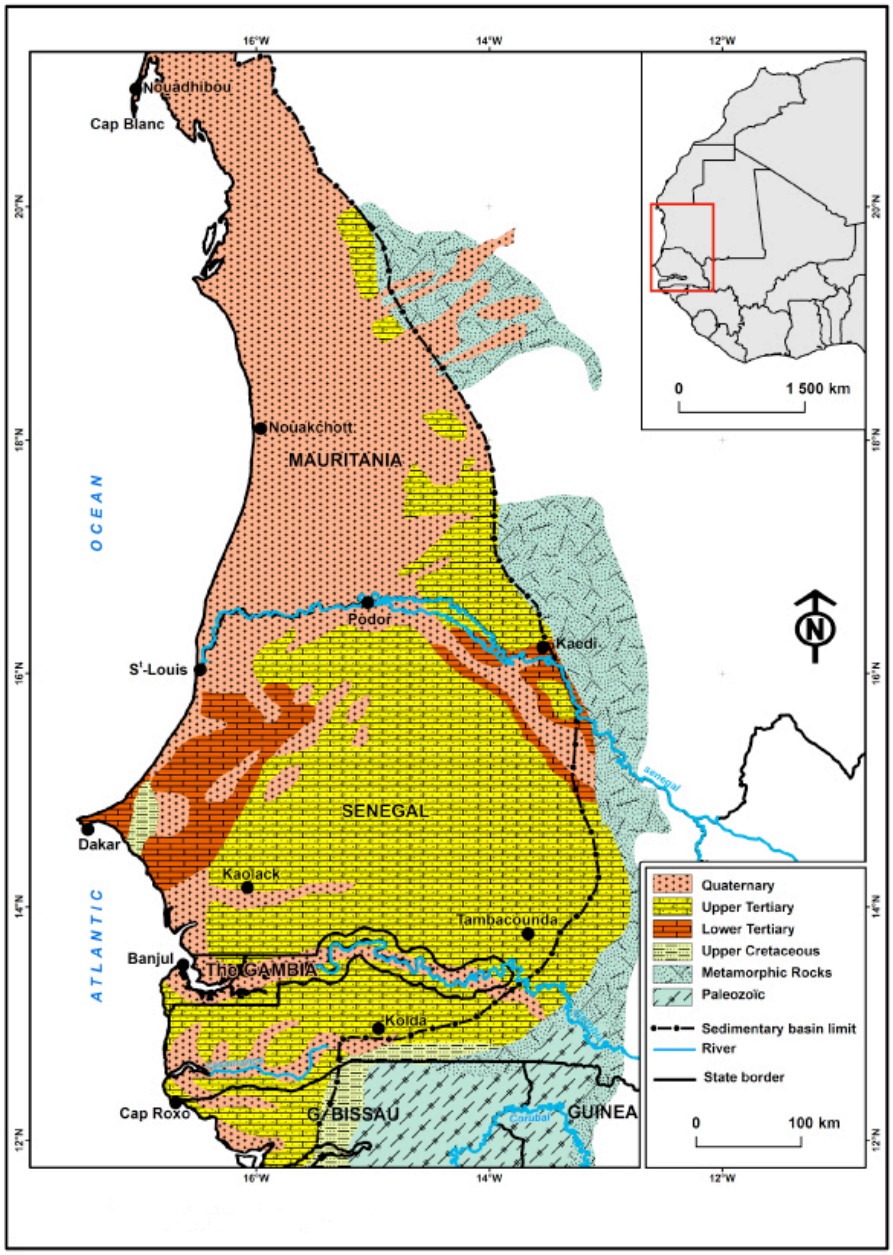

Figure 1. Geological map of the sedimentary basin (Atlantic resources LTD, unpublished *in* Siby, 1997, modified) [2]

2.2. The Lower Tertiary

It is represented by :

- Paleocene, essentially consisting of limestone, and sometimes calcareous marl, that is karstifiedin the western part of the basin;
- Eocene, composed of clayey and marly facies, or, limestone with phosphate, especially in the West.

2.3. The Upper Tertiary

The Upper Tertiary is represented by :

- Oligocene consisting of sand and clay in the center of the basin ;
- Continental Terminal, composed of detritic formations consisting of sandy and clayey series from Miocene and sand and clayey sandstone

from Pliocene.

2.4. The Quaternary

It is in different facies :

- aeolian sands,
- river alluvium and marine deposits on the deltas and along the rivers (*mainly Senegal River*) ;
- calcareous deposits.

3. Hydrogeological Setting

The hydrogeological context is characterized by the occurrence of several "national" aquifer units, whose extension is limited to a single country, and "international" aquifer units whose extension is on 2 or 3 countries.

3.1. "National" aquifer units

They are mainly located in Mauritania and Senegal; the most significant ones are presented hereby :

- In Mauritania :

The Continental Terminal aquifer (AQ M1) : the groundwater is occurring in the Oligocene and Miocene detritic sediments, with variable thickness (60-150 m). It extends in almost all the Mauritanian part of the basin, and supplies some large cities such as Nouadhibou; also it was potable water source for Nouakchott, the capital city, before it was supplemented by surface water fromSenegal River. Borehole production rates may be up to 100 m^3/h,and drawdown about 3.5 m. However, groundwater in the western side of the aquifer is highly mineralized, with salt water intrusion occurrence [3]. **The aquifer of Amechtil (AQ M2)** : the Eocene limestone bears groundwater; it is taped by production well with depth not exceeding 100 m. The boreholesrates can reach 10 - 30 m^3/h [4]. **The aquifer of Brakna (AQ M3)** : The aquifer is located along eastern Mauritanian sedimentary basin. It is taped by dug wells with 20-30 m depth, and it corresponds to Middle Eocene sands [5].

- In Senegal : [1,6-7]

The coastal sands aquifer (AQ S1) : Groundwater is occurring in Quaternary sandy deposits or clayey sand layer. They are found along the Atlantic coast, over an area of 5000 km2. The thickness of saturated layers is variable and may be up to 50 m. The groundwater is developed in connection with Lutetian limestone aquifer, at a rate of 100,000 m3/day; it contributes to supply Dakar, as well as most of towns and mining industries located in North coast area of Senegal. **The Lutetian limestone aquifer (AQ S2)** : The Lutetian limestone groundwater covers an area of about 2,600 km^2, located in the north-eastern of the coastal sands aquifer, with which it is connected hydraulically. Its thickness is mostly greater than 20 m with a maximum of 120 m. Because of its karstic setting, the aquifer performance is very good, production wells can provide up to 300 m^3 / h with less than 1 m drawdown. It contributes to domestic water supply of Dakar. **The Paleocene's limestone aquifer (AQ S3)** : The Paleocene groundwater is best known and developed in the western area of the country in Dakar vicinity; it occurs in karstified limestone, and is highly productive. Layers thickness is nearly 100 m in some areas; it produces nearly 60,000 m^3/d, that is used mainly for water supply to Dakar.

3.2. Transboundary Aquifers

Transboundary aquifers are:

- **The deep Maastrichtian aquifer (TBA 1)** : the deep (average 250 m) and confined Maastrichtian aquifer is shared by four countries: Gambia, Guinea Bissau, Mauritania and Senegal; it extends in the entire sedimentary basin, excepted in the Dakar peninsula. The reservoir is composed mainly of coarse sands and sandstone. The aquifer provides for more than 40 % of the total drinking water extracted in Senegal despite the fluoride and chloride occurrence. And more than 1,000 boreholes, yielding a rate of 100-250 m^3/h, tap groundwater; in Guinea Bissau, more than 150 boreholes reach the groundwater at 100 to 400 m depth, and yield 100-200 m^3/h. In Mauritania it is salty and not used, the situation is the same in Gambia where the presence of 2 to 5 mg/litre of total dissolved solids including fluoride make the water unsuitable for drinking [1-8].
- **The alluvial aquifer (TBA 2) :** the alluvial aquifer is the main shallow aquifer in the Senegal River basin; it bears transboundary groundwater shared by Mauritania and Senegal. It extends roughly in all the flood plain at various depths, with a groundwater level generally less than 2 m. Its mean thickness is about 25 m. These Quaternary formations consist mainly of clays and fine sands, or coarse or gravelly alluvium interbedded with clayey sand. The alluvial aquifer ensures rural water supply through individual dug-wells; some secondary towns located near the river bank are using this groundwater for their domestic needs, over drilled wells [9-10].
- **The Oligo-Miocene / Continental Terminal Aquifer (TBA 3)** : it is a transboundary aquifer, occurring in the center of Senegal, and almost in the entire Gambia territory, and probably in the northern part of Guinea Bissau. Groundwater is contained in sands interbedded with clay layers, dating from the Oligocene / Miocene or Miocene - Pliocene (known locally as Continental Terminal); its thickness is between 30 and 40 min the center of Senegal and Gambia (where it is called Shallow Sand Aquifer).

The aquifer is taped by numerous boreholes at depth between 90 and 150 m, which can yield 60 m^3/h, with drawdowns from 5 to 10 m [11].

4. River Basins Managed by Basin Organization (RBO)

There are two RBOs that manage river basins resources in the Senegalese-Mauritanian sedimentary basin.

4.1. The Organisation for Senegal River Basin Development (OMVS)

The Senegal River is the second longest river of West Africa (length 1,800 km), which have its source in the Fouta Djallon Mountains (Guinea). The managing RBO is the Organization for Senegal River Basin Development (in French: *Organisation pour la Mise en Valeur du Fleuve Sénégal* – OMVS). The Senegal River constitutes the boundary of Mauritania and Senegal, and its basin area is estimates to be about 289,000 km^2. The high plain in Northern Guinea covers 31,000 km^2 (11 % of the basin), 155,000 km^2 are localized in Western Mali (54 %), 75,500 km^2 in Southern Mauritania (26 %) and 27,500 km^2 in Northern Senegal (10 %). The Organization for the Development of the Senegal River (OMVS) is a river basin organization with a mandate to manage and develop Senegal River basin resources. Four riparian States (Guinea, Mali, Mauritania and Senegal) are members of the River Basin [10].

4.2. The Organization for the Development of the Gambia River (OMVG)

The Organization for the Development of the Gambia River (OMVG) was established on June 30, 1978. This regionally-oriented RBO includes Gambia, Guinea, Guinea-Bissau and Senegal. The executing body is the Executive Secretariat; its mandate is to manage integrated programs for rational and harmonious development of natural resources in the three rivers basins: Gambia, Kayanga-Geba and Koliba-Corubal, which have their sources in the Fouta Djallon Mountains (Guinea).

Gambia River flows through Guinea, Senegal and Gambia over a distance of 1150 km, with a drainage area of 10,556 km^2, of which 13.7% in Gambia, 15.4 % in Guinea, less than 1% in Guinea Bissau, and 70.9 % in Senegal. Kayanga River flows nearly 150 km in Guinea, and then it penetrates Senegal territory and heads south-west to join the Guinea Bissau where it is called Rio Geba. As for Corubal River, it is known as Koliba or Tominé in Guinea; it drains a 23,840 km^2 basin of which about 65 % are located in Guinea Bissau [12].

5. Institutionalised Management of shared Aquifers

At international level significant progress has been made in the understanding of transboundary aquifers in Africa, with UNESCO's initiative of International Shared Aquifer Resources Management (ISARM), including the global evaluation and hydrogeological mapping program (WHYMAP), and the International Groundwater Resources Assessment Centre (IGRAC). Recently a survey was carried out [13], which provides updated map and key characteristics of African transboundary aquifers. The Senegalese-Mauritanian sedimentary basin was identified as aquifer system; it shows huge diversity and hydrogeological complexity from the perspective of integrating shared aquifers management within existing RBOs, namely OMVS and OMVG.

5.1. The current situation of shared aquifers

As shown in Figure 2, three transboundary aquifers are present in the sedimentary basin. The Maastrichtian (TBA 1) and Oligo-Miocene / Continental Terminal (TBA 3) aquifers have no established hydraulic links with the current surface water bodies (Gambia and Senegal Rivers), while the alluvial aquifer (TBA 2) is connected hydraulically with the Senegal River along the border between Mauritania and Senegal. It is clear that apart from the alluvial aquifer, no other aquifers coincide with rivers basins areas. The deep Maastrichtian aquifer (TBA 1) shares geographical areas with Senegal River basin, which is managed by OMVS, as well as with Gambia River basin, managed by OMVG. The Oligo-Miocene / Continental Terminal aquifer (TBA 3) shares only a geographical area with the Gambia River Basin (OMVG). The following table summarizes the current situation of transboundary aquifers in the Senegalese-Mauritanian sedimentary basin

Table 1. Hydrogeological context in relation to Rivers Basins

Aquifer	Countries sharing aquifer	River Basin	Basin Organization	Countries devepping GW
Maastrichtian (TBA1)	Guinea Bissau, Gambia, Mauritania, Senegal	Senegal and Gambia	OMVS and OMVG	Guinea Bissau, Senegal
Alluvial (TBA2)	Mauritania and Senegal	Senegal	OMVS	Mauritania and Senegal
Oligo-miocen/Continental terminal (TBA3)	Guinea Bissau, Gambia and Senegal	Gambia	OMVG	Gambia and Senegal

5.2. The issue of transboundary aquifers management in the Senegalese-Mauritanian sedimentary basin

The need for integrated groundwater resources management by the Basin Organizations, within their mandate to manage river basin resources, has become a consensus in Africa, following AMCOW recommendation in Brazzaville, in 2007. RBOs play an important role in shared water resources management. They are powerful instrument for cooperation between neighboring countries; they thus offer a suitable platform to promote transboundary aquifers management. The experience gained in international cooperation between states sharing the same water surface, has provided them with a potential to facilitate partnership in groundwater management.

However, in the Senegalese-Mauritanian sedimentary basin context, constraints are obvious, and they must be taken into account for mutually beneficial management, institutionalized via existing RBOs, like OMVS and OMVG :

1) Common interest, with regard to different transboundary aquifers, is not often shared :
   - the deep Maastrichtian aquifer (TBA 1), which covers almost the entire sedimentary basin, is only used as water supply source in Guinea Bissau and Senegal. In Mauritania it is not used, because it is salty. In Gambia, it is rather salty with relatively high fluoride occurrence ;
   - the alluvial aquifer (TBA 2) offers a "minor" interest for Mauritania, as well as Senegal where it is used locally by some communities along the Senegal River ;
   - Oligo-Miocene / CT groundwater is widely used in the central and southern Senegal, and in Gambia, where it is the main drinking water source; while "minor" use is encountered in Guinea Bissau ;
   - it should be mentioned that Guinea (OMVS and OMVG member) and Mali (OMVS member) are not "interested" in the Basin aquifers.
2) The presence of two River Basin Organizations (OMVS and OMVG) increases the complexity for institutionalized management of transboundary aquifers in the sedimentary basin :
   - the 2 RBOs have different institutional capacities and experiences, as well, in transboundary cooperation ;
   - two countries (Guinea and Senegal) are members of the two RBOs, and 4 others (Gambia, Guinea Bissau, Mali and Mauritania) are only members of one RBO.

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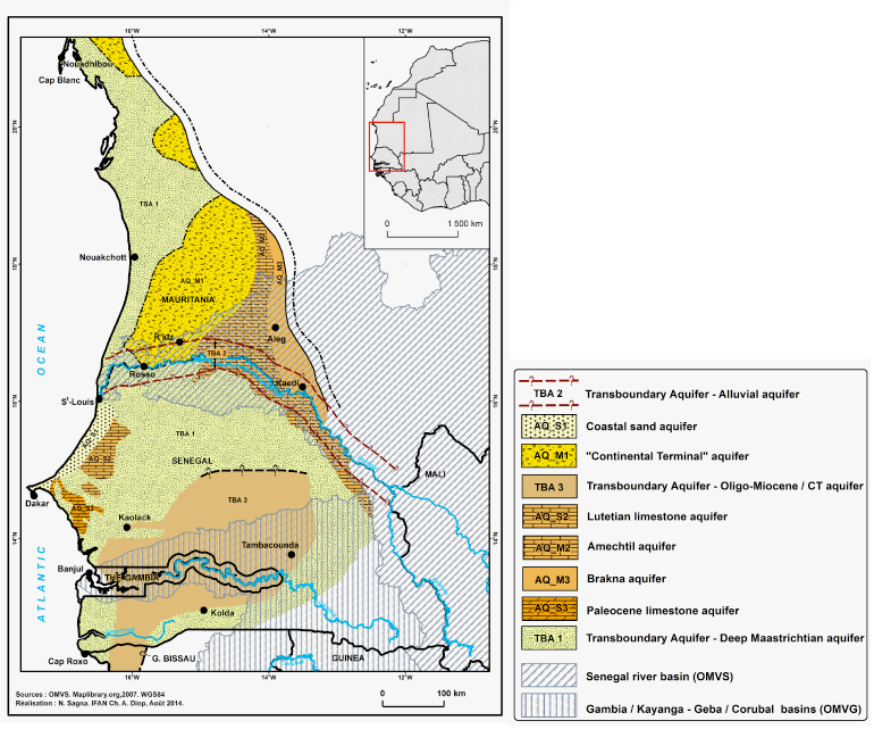

Figure 2. Hydrogeological map of the sedimentary basin

6. Conclusion

The Senegalese-Mauritanian sedimentary basin has several "national" aquifer units, and three "international" ones, which often do not have hydraulic link. The perspective of institutionalizing aquifers management over existing RBOs (OMVS and OMVG), should take into account the hydrogeological complexity of the sedimentary basin that is not an aquifer system in the true sense of the word. It should also take into account the diverse interests that riparian countries have with regard to shared groundwater.

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