Towards a concerted Management of hydrogeological risks in the Iullemeden Aquifer System (SAI)

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Summary

The Transboundary Diagnostic Analysis (ADT) recommended by Global Environment Facility (GEF) was applied to groundwater of the Iullemeden Aquifer System shared by Mali, Niger and Nigeria. Three major transboundary risks were identified: reduction in the water resource, the degradation of water quality, and the impacts of variability/climate changes. Their identification required also the development of a database gathering more than 17.200 water points, a Geographical Information System and a Mathematical model. The model, among others, highlighted the overexploitation of the resource as from 1995 and the interconnection between the Niger River and the groundwater. The good governance of this strategic resource led the riparian countries to adopt a draft-agreement for the establishment of a legal consultation framework for a concerted management and an equitable and rational exploitation of their common resources.

Key words

Shared aquifers, Transboundary Risks, Transboundary Diagnostic Analysis, Management tools, Legal framework, concerted management, West Africa.

1. INTRODUCTION

The Iullemeden Aquifer System consists of a number of sedimentary deposits containing two large aquifers: the cretaceous Continental intercalaire (Ci) in the bottom, overcome by the tertiary Continental Terminal (CT) **(fig. 1)**. It is shared by Mali, Niger and Nigeria and covers a total area of approximately 500.000 km ². It is crossed by part of the Niger River hydrographic network.

The SAI constitutes a strategic resource for the sustainable development of the concerned countries. However, it is:

- *exposed to a fragile and constraining environment*: 1) lower rainfall of about 20 to 30% since 1968; 2) reduction of the runoff of about 20 to 50% with sometimes severe low water levels moving to stop; 3) silting and establishment of sand dunes in the aquifer's areas recharge and in the Niger river hydrographic network;
- *facing several constraints in particular*: 1) difficulties of accessing groundwaters by places because of high depth (more than 600 meters); 2) degradation of water quality (pollution, withdrawing high mineralised deep waters); 3) shortcomings in shared groundwater management among riparian countries.
- *subjected to:* 1) increasing water demand linked to population growth (about 6 million inhabitants in 1970, 15 million in 2000 and a projected 30 million inhabitants in 2025); 2) an exponential rise in abstractions which went from 50 million m^3 in 1970 to 180 million m^3 in 2004.

To identify, analyze and evaluate the hydrogeological risks which can affect groundwater of the Iullemeden Aquifer System, the risk-based management approach was adapted and applied.

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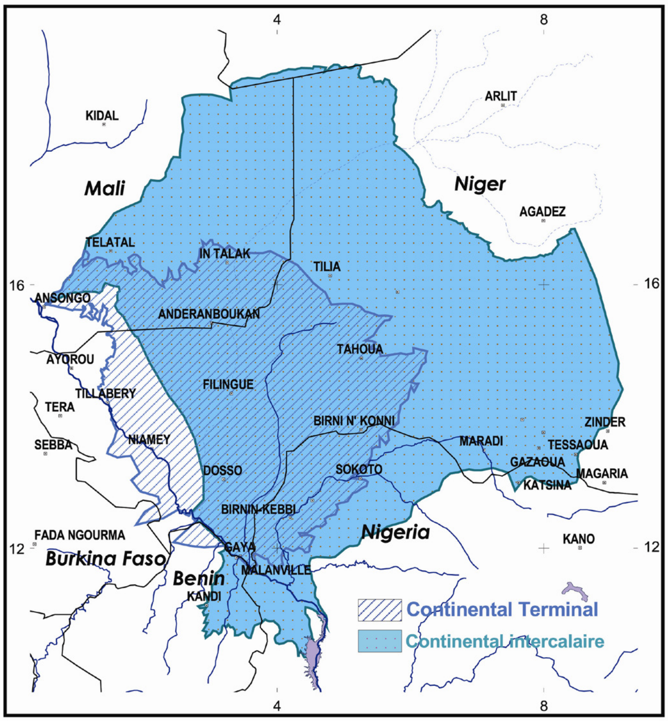

Figure 1: Limit of the Iullemeden Aquifer System

2. OBJECTIVE

The objective of this note is to present the identification of the transboundary risks and their analysis conducted to the groundwater resources of the Iullemeden Aquifer System by using GEF's Transboundary Diagnostic Analysis (TDA) process, which is the first step in GEF's TDA/SAP process that leads to the preparation of a Strategic Action Program (SAP).

The Transboundary Diagnostic Analysis (TDA) is an objective evaluation of the scientific and technical facts based primarily on the use of the best technical and scientific information available and checked. The TDA is used to determine the relative relevance of the sources, the causes and the impacts of the transboundary water issues. Therefore its objectives are:

- identifying, quantifying and fixing priorities for the environmental transboundary issues;
- to identifying their immediate, fundamental and root causes.

The TDA process involved several steps mainly the "prioritisation" of the risks, the causal chain analysis, and the water governance.

3. RESULTS

The analysis of each risk identified by each country (Mali, Niger, Nigeria) through several brainstorming undertaken by their respective national committees consolidated by the contribution of the experts, requires to insure in particular on: (1) the transboundary nature of the identified risk; (2) the outreach of the risk compared to the national priorities and to regional and international conventions as well as the various global initiatives; (3) the impacts of the risk on the economy, the environment and the human health; and (4) the expected profits from the examination of the risk.

The first fundamental sep to make sure of the transboundary characteristic of the risk is to understand the dynamics of groundwater flows in the shared Ci and CT. Important investigation were developed in these aquifers within their natural limits covering the three countries in order to integrate the information and data collected as well as the identified and quantified risks. The main results and outputs achieved are:

a) **Digitalized topographic map:** A topographic reference was elaborated on 1/100.0000 scale with *Arcview* software. The digitalized topography is accompanied by a Digital Elevation Model (DTM). The topographic map extends between the longitudes 0° and 15°E and the latitudes 10° and 22°N. The digitalized area is 2.219.000 km ^{2}. It gathers the SAI and part of the lake Tchad basin to examine all the assumptions on the hydraulic relations between the SAI and the other basins.

b) **Digitalized geological map:** The topographic map was used to digitalize the SAI geological map in the same area based on the existing geological maps at 1/500.000 scale in Algeria, Mali and Nigeria and 1/500.000, 1/2000.000 and 1/1000.000 scales of Niger.

c) **Database of the SAI:** The data resulting of more than 17200 water points (boreholes and well) collected in Mali, Niger and Nigeria, were structured, organized and stored in a relational database to the three countries in order to facilitate its use (updates, data retrieval). The Database has five sections: climatology, hydrology, hydrogeology, administrative districts and water use. This Database is linked to the Geographic Information System and the mathematical model in order to facilitate processing of the enormous mass of data.

d) **Geographical information system of the SAI:** From the data and information collected, the GIS layers are prepared in the form of thematic maps which make it possible to present data in a specific projection system. These maps, prepared to the scale of the Basin, make it possible to visualize the information and facilitate its processing. They include the map showing water point distribution per decade (1940 to date), North-South and East-West cross-section maps of the Basin, and piezometric maps of the Continental intercalaire and the Continental Terminal. These maps clearly present the water flow in the aquifers from Mali to Niger and from Niger to Nigeria.

e) **Hydrogeological Model of the SAI: For the first time in the Iullemeden Ba**sin, a mathematicl model was develpoped based on certain assumptions, notably those relating to water abstraction. The model yielded the first results on groundwater flows and estimates of groundwater exploitation status. Its initial results are as follows:

- revelation and quantification of groundwater supply to the Niger River flows; The Niger River receives about 46 million m^3/year from the Continental intercalaire and 79 million m^3/year from the Continental Terminal. River Rima (or Goulbi de Maradi in Niger), a tributary of the Niger River, supplies about 20 million m^3/year to the Continental Intercalary and receives about 12 million m^3/year from the Continental Terminal before its confluence with the Niger River. Hence, the latter is one of the main natural outflows of the system;

- a threshold of overexploitation crossed in 1995, year as from which the taking away (152 m3/an million) exceed the refill estimated at 150 m3/an million) in 1970 **(fig. 2)**.

- highlighting that the **overexploitation threshold was exceeded in 1995,** the year from which abstraction (152 million m^3/year) exceeded recharge which is estimated at 150 million m^3/year in 1970 (red line on fig. 2).

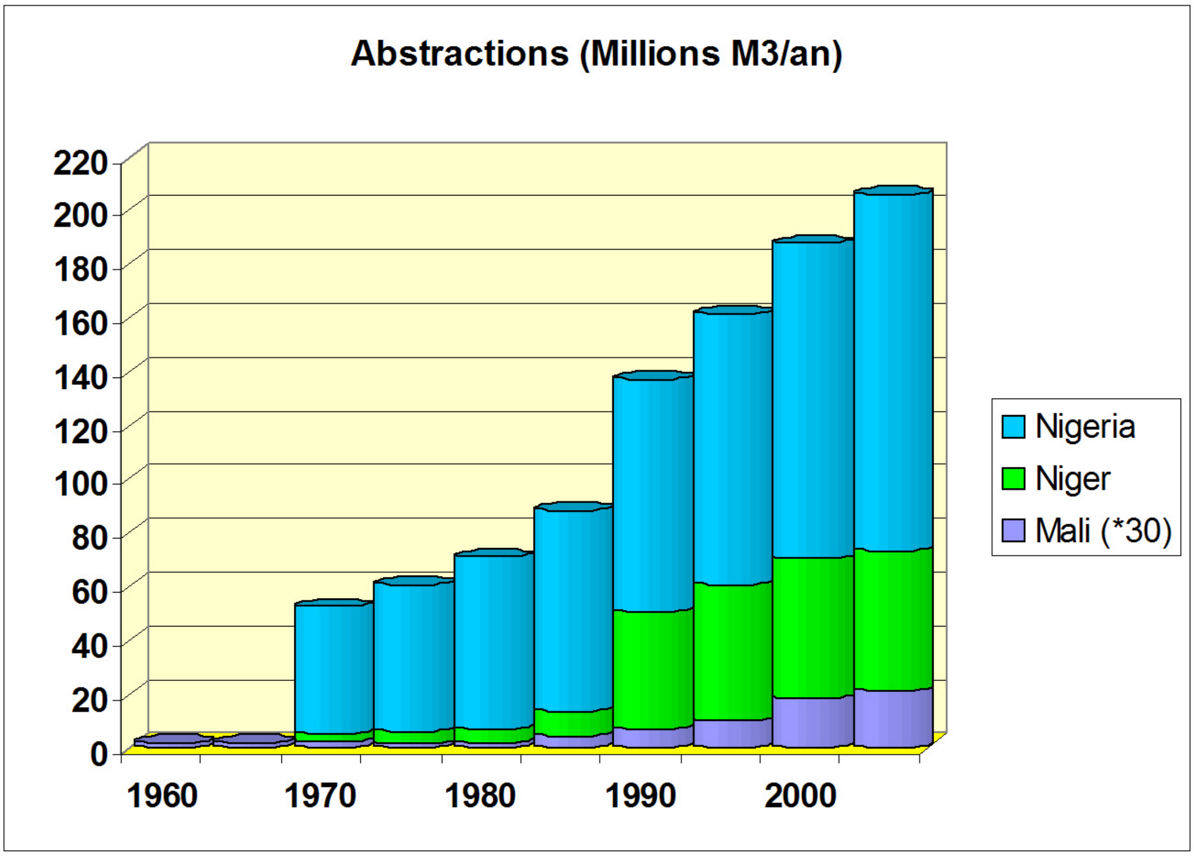

Figure 2: The overexploitation threshold was exceeded in 1995 according to the first estimates.

f) **Hydrochemical data on degradation of water quality:** The deterioration of the groundwater quality the SAI took place naturally because of the presence of undesirable chemical elements like excess of Fluorine contained in the fluorapatite, Ca5 $(PO4)_{3F}$ in the Continental intercalaire aquifer in the political border zone between Niger and Nigeria where the fluorine contents reach values ranging between 9 with 12mg/l (the standard being of 0,7 mg/l and 1,5 mg/l for respective values of temperature ranging between 8°C and 12°C, and 25°C and 30°C). That generated bony and dental fluorosis affecting in particular children less than the teenage. The groundwater quality and the Niger river in general can be also deteriorated because of the human activities (Adelana and al, 2003; Adelana, 2006; Traoré and al, 2006) and the exchanges between the hydrographic network and the shallow aquifer (Orange and Palangié, 2006; Ousmane and al, 2006). It is the case of the Niger River interior delta in the Malian part. The increasingly use of agricultural fertilizers affects the shallow aquifers in particular near to the principal main Niger River watercourse.

Thus the three major transboundary risks, for which one country can not find a sustainable solution, are described as follow:

1. **reduction in the water resources:** This type of risk is characterized by the modification of the groundwater potential in terms of water reduction or water scarcity. This reduction can be due to the combined effects 1) from the progressive water abstraction, and 2) the reduction of the recharge of the aquifers because of the reduction in rainfall. The results of the mathematical modelling of the Iullemeden Aquifers System made it possible to quantify this risk: the **overexploitation threshold was exceeded in 1995,** the year from which abstraction

(152 million m^3/year) exceeded recharge which is estimated at 150 million m^3/year in 1970 (red line on **fig. 2**)..

2. **the water quality degradation:** it was identified as the pollution of the groundwater (shallow aquifer mainly) because of (1) the infiltration of waste water with chemical concentration beyond the quality standards, and (2) the abstraction of (deep) groundwaters with high contamination (i.e. excess of fluoride) conducted by the geochemistry of the geological formation;
3. **(impacts of) the variability and of the climate changes:** This kind of risk is characterized in particular by 1) the silting process in the hydrographic network of the Niger River which reduces the groundwater supply (exchanges between River and groundwater) resulting from the Continental intercalaire (Ci) and the Continental Terminal (CT), supporting therefore frequent floods, 2) the establishment of sand dunes in the recharge areas and on land cover reducing the infiltration of rainwater in particular, 3) the destruction of the areas of hydraulic exchanges due to the migration of the population from arid zones of the wetland areas.

These three major risks t were analysed by using the Causal chain Analysis through their immediate causes, fundamental causes and roots causes **(tabl. 1)**. The root cause also integrates the water governance.

The development of strong foundations for water governance of these strategic resources took place through the development and the adoption, by the concerned countries of a draft-agreement with the enclosed roadmap in order to implement their consultation mechanism.

4. DISCUSSION

The Transboundary Diagnostic Analysis is certainly an effective method for identifying major transboundary issues based on technical and scientific information available, to examine the state of their environment and the fundamental causes of their degradation without being unaware of the concerns and the national priorities. The ADT is a participative approach involving all the stakeholders. For this purpose, it contributes to strengthen solidarity and confidence between them.

However, if it is true that the Transboundary Diagnostic Analysis offers flexibility in its concept, it was conceived, preferably, towards transboundary International visible waters namely: marine water, rivers (rivers and rivers), lakes, and wetlands).

The transboundary International surface waters are well monitored since several decades what is not the case for transboundary groundwater because of their "invisible" character. The monitoring of water level fluctuations is carried out mainly through the projects but not financed by the national budgets. When they are available, their data make it possible to build the common management tools (Database, Geographic Information System, Mathematical model, several thematic maps) which reinforce confidence and solidarity among riparian national teams and allow assessing and quantifying some risks.

Therefore, TDA application and adaptation to International transboundary groundwater need a revue of the ADT/PAS process while starting initially by studying and understanding the hydrodynamic groundwater flows of the systems aquifers shared by the countries concerned. In most cases, the aquifer systems shared by the riparian countries are studied within the political borders in each country without considering their natural limits.

5. CONCLUSIONS

The application of the Transboundary Diagnostic Analysis to transboundary groundwater of the Iullemeden Aquifer System of made it possible to identify three major risks which are: (1) the reduction of resource, (2) the water quality degradation, and (3) the negative impacts of variability/climate changes. TDA also promotes the development of management tools (database, Geographical, Mathematical model Information system) in order to assess and quantify the risks and their impacts on the groundwater resources.

These main risks will be well characterised through the development of the Strategic Action Programme.

6. AKNOWLEDGEMENTS

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Table 3: Causal chain analysis applied to the water resources of the Iullemeden Aquifer System (SAI)

Immediate causes	Major transboundary risks	Fundamental causes	Root causes
• Reduction of the rainfall • Reduction of the runflows in the Rivers • Reduction of recharge (filling of the recharge areas due to silting, etc.) • Réduction de la recharge (colmatage des aires de recharge par ensablement, etc..) • Frequently droughts	Reduction of the water resource	• Increase in water abstraction (increase in the water points) • Increasing water demand (growing population, activities in the social and economic sectors) • Reduction of the recharge because of silting in human activities the recharge areas– land use and land cover)	• Shortcomings in consultation among the riparian countries • Non-application of the laws and rules • Shortcomings in water governance and awareness • Decreasing livelihood
• Natural degradation controlled by geology (mineral paragenesis: strong concentration fluorine-Apatite, nitrates, etc…)	Water quality deterioration	• Pollution from various origins (domestic, industrial, mining, livestock, all kinds of waste water) • Agricultural activities (manures, pesticides) • Discharge of pollutants in the rivers having hydraulic connection with the aquifers • Land uses and change in land use systems	• Not respect of the current laws (Water code) • Shortcomings and lack of monitoring and assessing water quality • Inadequate water governance • Decreasing livelihood
• Increasing of greenhouse gases in the Troposphere	Impacts of variability & climate changes on groundwater	• Deforestation (production of firewood) • Clearing areas for agriculture and other land uses • Migration of the populations from arid zones to wetland areas • Land uses and change in land use systems	• Shortcomings in awareness at national and regional levels • Weakness or lack of commitment of the countries to their financial contribution in the research studies for sustainable solution • Shortcoming and lack of application of the results and outputs obtained from several studies on the climatic risks

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