

# The energy potential of the Albian water in Algeria : exploitation and transformation

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## Abstract

The groundwater of Continental Midsole (CI) is coveted for its water as resources widely mobilized in Algerian Northern Sahara. This groundwater is characterized by a high flow and pressure at output. It goes from 0.05 to 0.4 m<sup>3</sup>/s for flow, and 5 to 40 bars for pressure. The hydraulic energy is completely neglected. An investigation on the Northern Sahara Aquifer System (SASS) was essential to prove the existence of this potential. This energy is reflected by an artesianism which is very convincing in most drillings for a long time. We have noticed the immensity of this energy, the expanded volume of the aquifer and the importance of its use in agriculture. Unfortunately, this potential remains untapped to date.

**Keywords:**Albian, Continental Midsole, Drilling, Turbine generator, Agriculture, Irrigation, Algeria.



## 1. Introduction

Groundwater is in different forms. Some aquifers are found confined between impermeable layers and thus contain water under pressure. At the end of the 19<sup>th</sup> century, the emergence of drilling in the Northern Sahara Aquifer System (SASS) was meant to give new impetus to the development of the Sahara[1].

Qualified in 1945 by "greater hydraulic system of the Sahara" and extensively studied by[2], the groundwater of Continental Midsole (CI), also called the Albian, is still the Saharan agronomists dream. Covering an area of 600 000 km<sup>2</sup> as shown on figure 1, and containing over than 50 000 billion of cubic meter of water, it was made, in the sixties, as the final solution to aridity and underdevelopment in the region[3].

Taking cue from the study by the FUEL MANAGEMENT and BURGEAP in 1963, a more quantified approach of hydraulic phenomena was reached. Other studies have been initiated by several authors on the use of geothermal energy of this water [4-9], but no studies on the use of potential energy (kinetic and pressure) of the

NSAS (Northern Sahara Aquifer System) water has reached any results to this date.

Would it be economically and socially profitable to stop the consumption of this water, or would it be more judicious to rationalise its exploitation?

The water that comes out of this source is too demanding of energy. It requires an engine running at thirty Kilowatt to allow direct use. Yet the energy released from the gushing water drilling is not to be underestimated especially since we already lose it out at the start.

The collection of information on the Intercalary Continental, the study of the behavior of water at the outlet of drilling and quantification of the drilling water energy potential, are milestones and red flash data requiring proper understanding of the situation.

Loss and unused energy from the water that came at a high pressure are the consequences of the use of chillers. After the incorporation of a turbine in the circuit, and the use of the smallest available energy it has made the installation profitable [10].

## 2. Synthesis of knowledge about the Albian

There are two distinct aquifer systems in Algeria[11]. They are separated by thick clayey and evaporite series, from the base of the Upper Cretaceous:

- Continental Intercalaire (CI), deep aquifer composed of sandy sand or clay sandstone;
- Complex Terminal, basin composed of three superimposed layers.

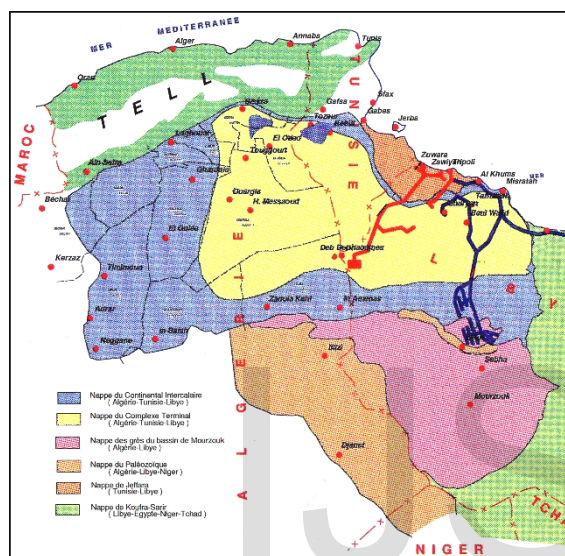


Fig.1: Distribution of Continental midsole aquifer in Algeria [11].

### 2.1. General characteristics

According to [12], the Continental Midsole water quality is good (total mineralization less than 1.5 g/l) to very good (less than 0.5 g/l) in its outcrop areas, saltier near to In Salah and relatively good in Ghardaia, Ouargla and El Oued (less than 2.5 g/l). This increase in salinity is associated with increasing temperature, which exceeds 50°C to depths of around 1500 m. General data concerning the Continental Midsole water are resumed in table 1.

Table.1: General data on the CI in Algeria [13].

Characteristics	Value
Expanse (km <sup>2</sup> )	600 000

Total thickness (m)	50 à 1 000
Depth (m)	60 à 2 400
Depth to the roof (m)	20 à 2 000
Flow (l/s)	50 à 400
Transmissivity (10 <sup>-3</sup> m <sup>2</sup> /s)	10 à 30
Storage coefficient (10 <sup>-4</sup> )	6 à 1200
Average supply (Hm <sup>3</sup> /an)	270
Theoretical calculated reserve (m <sup>3</sup> )	35 000 × 10 <sup>9</sup>
Temperature (°C)	25 à 70
Salinity (g/l)	0.5 à 6

The figure below illustrates the East-West evolution of the CI roof.

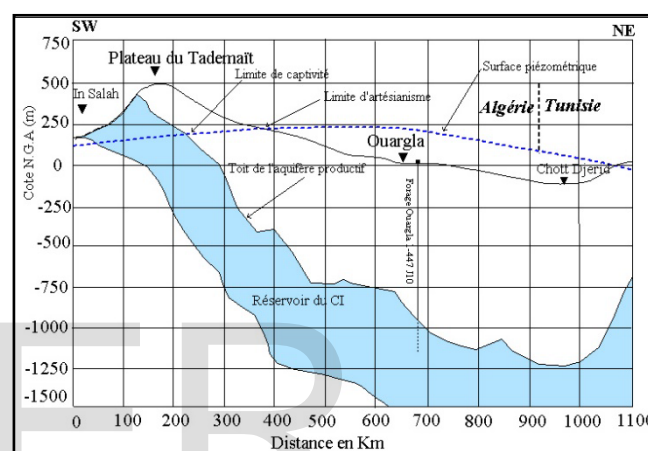


Fig.2: Transverse hydrogeological cross section showing the roof and the piezometric surface of the IC[11].

### 2.2. Water supply

The watergrounds of the Northern Sahara Aquifer System were considered as non-renewable. A recent study [14] showed that rainwater and runoff bring to the system an average of 1.4 km<sup>3</sup> per year, or about 2 mm per year to the resource surface of the watergrounds. This average recharge is about 40% of the 2.75 km<sup>3</sup> taken in total each year in the region [14, 15].

### 2.3. Temperature situation

The IC water temperature has a gradual gradient (increasing) from the Southern Sahara (about 25°C to In Amenas, In Salah, Adrar) to the North (70°C in the Ziban and Ksour).

It should be noted that this gradient also applies to the depth of the aquifer showing the same

trend with shallow boreholes in the South (of the order of 200m) and reaching more than 1500m in the North of the Algerian Sahara.

## 2.4. Geothermal

The first application of geothermal energy from the Albianwaterground was conducted in 1990 for heating greenhouses in southern Algeria [9].



Fig.3 : Water outlet on the cooler.

The exploitation of geothermal energy for greenhouses heating is too modest compared to the great potential geothermal resources in southern Algeria [7].

## 2.5. Water allocation

The utilization of this aquifer water tends exclusively to agricultural use, with 1.95 billion cubic meters. The consumption of drinking water stays modest. It represents a low percentage (10%) of total operating [13].

In the decade (1995-2005), the supply of drinking and industrial water increased considerably, despite drought restrictions[13].

## 2.6. Exploratory simulations and reflections

The model of the Continental Intercalary as conducted by the PDGDRS's study has long established several simulations of various operating assumptions of the Albianwaterground. We have recapped the report of[16] to show the necessary elements, noticeably, the persistence of artesianism for a

protrated time in some areas of the Northern Sahara (up to year 2038).

The conditions adopted by[16], in which the calculation was conducted, are:

- Term provided by the simulation: 40 years corresponding to the period 1999-2038;
- Initial state: peizometric position of the waterground at the beginning of January 1999;
- Exploitation: 1998 samples maintained stable.

## 3. Current status of drilling

The National Agency of Water Resources (ANRH) completed in 1998, the inventory of all water points in the Northern Sahara, and evaluation of collected volumes. The results of this survey are presented in table 2.

Table.2: Current status of albian drilling [12].

Wilaya	Current use			
	Used drills		Untapped drills	
	artesian	pumped	Abandoned	Resealed
Ouargla	15	9	3	1
El Oued	11	-	1	3
Ghardaïa	25	51	2	11
Touggourt	1	4	1	1
In Salah	17	64	29	10
Illizi	29	10	14	4
Adrar	-	442	90	2
GaciTouil	7	-	2	-

## 4. Technical problems related to the exploitation of the CI

### 4.1. High water temperature

The water of the albien at a temperature between 25 to 70 °C, making it inconvenient for use, especially in summer.

This heat could be used in winter to heat the apartments and crops under greenhouses, resulting in an energy gain. Nevertheless, its use in supplying drinking water and irrigation requires a cooling.



Fig.4: CI water cooling system.

The ERESS study carried out in 1970 retains two types of cooling:

- Natural ventilation cooling (old system);
- Cooling with forced ventilation.

#### 4.2. Excess drilling depth

In the absence of regular monitoring and ongoing maintenance by specialized teams equipped with adequate equipment, deep drilling can create very serious environmental problems when they collapse (so that in Berkaoui And Zaccar, Ouargla).

The management of clogging wells, particularly in vulnerable areas (sand), has avoided any risk of collapse.

#### 4.3. Environment impact of the use of groundwater resources

The use of the current frequency of groundwater resources in the long term will create a major disturbance in the Northern Sahara.

These levies will entail:

- The gradual disappearance of artesianism;
- Drying of shallow wells and foggaras;
- Drying out of outlets;

- Degradation of water quality, particularly at Terminal Complex, mainly in the Chotts and OuedRigh areas;
- The rise of ground water to the surface (harmful to crops).

### 5. Drilling potentiality

We focused our attention on a newly constructed drilling without major problems affecting its production (Djamaa in the Wilaya of El Oued). The water from this drilling reaches the station head at a pressure of 18 bars, a temperature of 50°C and a flow of 100 l/s. The drilling includes a cooling tower with 16 meters in height, comprising an exhaust fan for hot air, with 5 meters diameter, powered by an electric motor of 30 kW. Electricity is supplied to the drilling from the conventional distribution network.

### 6. Water quality of the drilling

The water from this drilling is generally high, in relation to the Algerian water quality standards published in the Official Journal of 16 July 1983, of high salinity and not suitable for consumption as drinking water or for domestic purposes, Agricultural and industrial. Of these facts, a desalination treatment of these waters is recommended.

Table.3: Analysis of the drilling water[17].

Parameters	Unit (mg/l)
Calcium	218
Magnesium	112
Sodium	235
Potassium	42
Iron	-
Bicarbonate	153
Carbonates	-
Chlorides	50
Sulfates	708
Nitrates	35

## 7. Study of the energy potential of the drilling

The exploitable potential represents the hydraulic power available, calculated from the product of pressure and flow of water. Equation (1) is deduced from the fundamental equation of power.

$$P_{exp} = p_r \cdot Q_t \quad (1)$$

With:

$P_{exp}$  : exploitable potential (W)

$Q_t$ : turbinable flow (m<sup>3</sup>/s)

$P_r$ : pressure (Pa)

We have to use the pressure that is upstream on the cooling tower (PE). This pressure is calculated from (2), derived from the Bernoulli equation, taking into account all existing losses. We get 16 bars of usable pressure (we admit, after calculation, a total charge loss of 2 bars).

$$\frac{P_A}{\rho \cdot g} + Z_A + \frac{v_A^2}{2 \cdot g} = \frac{P_E}{\rho \cdot g} + Z_E + \frac{v_E^2}{2 \cdot g} + \Delta H_{A-E} \quad (2)$$

With :

Index "A" : the station head.

Index "E" : exit point at the top of the cooling tower.

$P$  : pressure (Pa).

$v$  : velocity (m/s).

$Z$  : height (m).

$g$  : gravity (m/s<sup>2</sup>).

$\rho$  : density (kg/m<sup>3</sup>)

$\Delta H_{A-E}$  : charge loss between A and E (m).

The turbinable flow is the amount of water arriving at the turbine inlet (in the output of the upstream water cooler). In our case, it is about 100 l/s.

The various cases we may encounter in the field are presented in table 4. In another words, drilling with a reduced potential and others with high potential, compared to the drilling of our studies with an average potential.

Table.4: The exploitable potential of Albian drilling.

Drilling parameters	Reduced potential drilling	Drilling of our study	High potential drilling
Flow (m <sup>3</sup> /s)	0.05	0.1	0.3
Pressure (Pa)	10 .105	16 .105	28 .105
Energy (KJ)	50	160	840
Hydraulic Power (kW)	50	160	840

A low potential drilling release a hydraulic power equivalent to 50 kW, the power needed to run a complete cooling tower (to lower water temperature from 70 to 35°C).

Whatever the characteristics of available drilling, they are able to provide a significant energy potential to be used for self-sufficiency in neighbouring farms.

## 8. Energy transforming device integration

### 8.1. Inverted pump (PATs)

The outcome of the turbine operation is very satisfying. However, pumps converted into turbine would badly support speed variations, and/or flow or the rotation's direction.

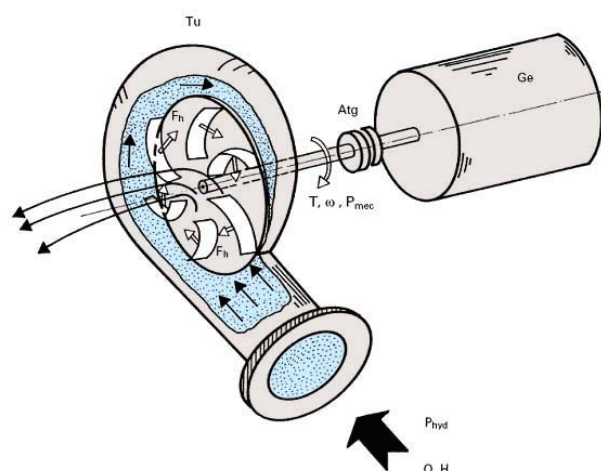


Fig.5 : Forces, torque, rotational speed and mechanical power of a turbine[18].

The choice of the inverted pump was a first approach, in order to visualize in a practical way

the evolution of the phenomenon and to circumvent it in a scientific way.



Fig.6 : The first device (PATs)

From this trial, we drew the following conclusions:

- It is essential to have a sufficient power to adapt the device;
- The idea of using PATs was very satisfactory. This allowed us to have a glimpse of the principle of operation and its effectiveness;
- The adaptation of an existing turbine or the purchase of a specific turbine was considered necessary for the experiment.

### 8.2. Modelled turbine

We tried to figure out the possible primitive turbine by its geometry which, however, has standard operating characteristics. While working out on the subject, it has given rise to a water wheel.

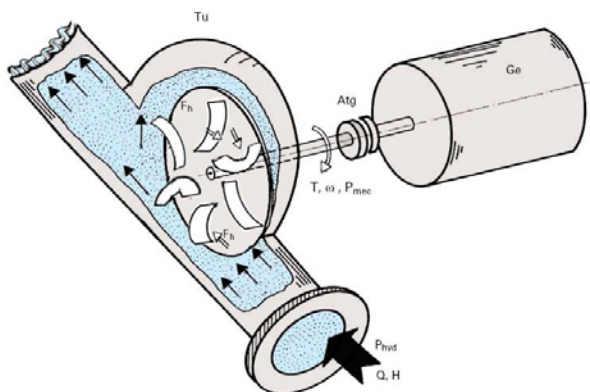


Fig.7 : Forces, torque, speed and mechanical power of a turbine.

We opted for the manufacture of a turbine that meets our expectations but that will meet also the requirements.

The blades of this turbine are of a very primitive geometry. This geometry serves us only to demonstrate the principle of operation of this type of turbine. Thereafter, the geometric shape of the blades will be optimized to better absorb the maximum energy of the water that befall them.



Fig.8 : Modelled turbine.

The turbine dimensions are essentially derived from experimentation. After establishing some hypotheses (on the diameters to be chosen from the standard diameters), we obtained different dimensions.

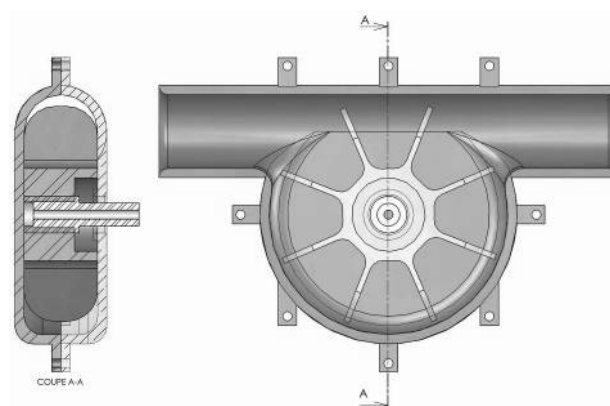


Fig.9 : Transverse section of the turbine.

Turbo-generator units are, for the most part, installed on the roof of the cooling tower. It will therefore be necessary to modify the current system in order to allow an acceptable and durable pressure upstream of the turbine. At the

inlet of the turbine, a by-pass valve are of great use.

The introduction of a turbine into an installation is not without risk. It is for this reason that we thought to secure the installation by slightly modifying the pipelines, to obtain a Strap System.

This technique allows operation in turbine mode at full load and when a problem arises, the safety valve, equipped with sensors, opens automatically to allow the evacuation of the water without consequent damage. The valve is motorized and in some cases equipped with communication light.

### 9. Summary of the situation

It is difficult to determine a type of turbine (impulse or reaction) to use on this aquifer because water from the Albian drilling has both mass and kinetic energy. To simplify understanding the problem, we should consider an experimental test with a turbine to highlight this potential; the integration of a turbogenerator group is essential. The following figure summarizes the prospects of development.

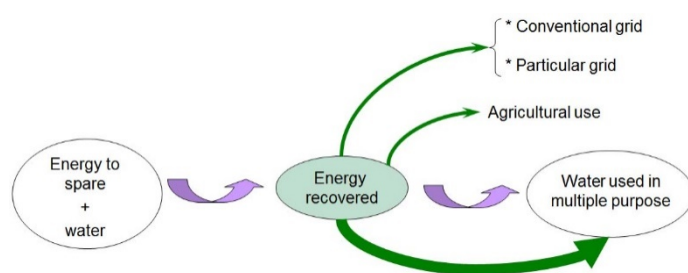


Fig.10: Summary of the situation.

Before the incorporation of the turbine, the water exited at a high pressure followed the path of the pipes at the cooler, passed through the partition plates and ended up in a basin at atmospheric pressure.

The loss and unusability of all the initial energy of the water are the consequence of this circuit. After insertion of the turbine, the use of the

smallest available energy makes the installation very profitable over time.

### 10. Conclusion

The Continental Intercalaire is an asset for economic development of the Algerian Sahara especially in areas where it is shallow and gushing. It seems necessary to draw attention to these energies, not to develop mass production, but to save, control and guide the conventional energy distribution; sustainable development is respected.

From the point of view of culture, irrigation, breeding, processing or personal comforts, Farmers still need energy to develop their farms. The need for light, aeration, cooling, conditioning milk and other products requires energy.

Farms in the areas of the Continental Intercalaire are mainly dependent on albian drilling. Their location in relation to the farm is very important to minimize energy and financial expenditure.

The Albian aquifer is a huge battery providing energy without restraint and that for a long time. The lifetime of this energy is limited to 40 years, according to the simulations already made.

However, we must consider that the available hydraulic energy will gradually diminish over time due to the aging of the wells, the construction of other productive drilling and the increasing interference of neighboring drilling (M'ghaier, Djamaa and Touggourt) and therefore the sizing of these groups will have to consider these factors.

As mentioned above, the available hydraulic energy will gradually diminish, and it is for this reason that the adaptation of this device to drilling is essential today, since the cost-effectiveness of its installation depends on the time.

The energy generated by drilling in current use is about a hundred kilowatts. The minimum estimate is 35 kW in almost all artesian points.

The turbomachine is the most effective way to convert this energy.

This work will serve as a model for future work concerning the exploitation of water in the aquifer of the Continental Intercalaire. It also served as a basis for launching creativity and innovation. For example, the creation of a new model of a very low-gauge hydraulic energy utilisation device with high efficiency. This new model applies not only to the waters of the aquifer, but also to urban water supply.

## 11. References

- [1] PNUD-UNESCO, "Etude des ressources en eau du Sahara Septentrional. Rapport sur les résultats du projet Reg 100. UNESCO, Paris, 78p.," 1972.
- [2] D. Dubost, "Ecologie, Aménagement et développement Agricole des oasis algériennes. Ed Centre de recherche scientifique et technique sur les régions arides," Thèse Doctorat. 423 p, 2002.
- [3] A. Cornet, "Initiation à l'hydrogéologie saharienne. Hydraulique et équipement rural. Service des études scientifiques. Rapport, Alger, Algérie, 108p.," 1961.
- [4] M. Hellel, O. Bellache, and A. Chenak, "Chauffage par énergie géothermique des bungalows d'un complexe touristique," *Revue des énergies renouvelables*, vol. 9, pp. 333-340, 2006.
- [5] M. Benhammou and B. Draoui, "Simulation et caractérisation d'un échangeur géothermique à air destiné au rafraîchissement des bâtiments fonctionnant dans les conditions climatiques du sud de l'Algérie," *Revue des énergies renouvelables*, vol. 15, pp. 275-284, 2012.
- [6] S. Ouali, A. Khellaf, and K. Baddari, "Etude géothermique du Sud de l'Algérie," *Revue des énergies renouvelables*, vol. 9, pp. 297-306, 2006.
- [7] S. Ouali, Z. Benaïssa, M. Belhamel, A. Khellaf, K. Baddari, and M. Djeddi, "Impact of Integrated Clean Energy on the Future of the Mediterranean Exploitation of albian geothermal water in South Algeria," *Energy Procedia*, vol. 6, pp. 101-109, 2011.
- [8] D. E. Zouakh, D. Ferhane, and A. Bounouni, "Intégration de la pisciculture à l'agriculture en Algérie : Cas de la wilaya de Ouargla.," *Revue des Bioressources*, vol. 6, 2016.
- [9] H. Saibi, "Geothermal resources in Algeria," *Renewable and Sustainable Energy Reviews*, vol. 13, pp. 2544-2552, 2009.
- [10] F. Pugliese, F. De Paola, N. Fontana, M. Giugni, and G. Marini, "Experimental characterization of two Pumps As Turbines for hydropower generation," *Renewable Energy*, vol. 99, pp. 180-187, 2016.
- [11] F. Hellal and D. Ourihane, "Etude hydrogéologique du Continental Intercalaire et du Complexe Terminal de la région de Touggourt. Aspect hydro-chimique et problèmes techniques posés.," *Ingénieur, Institut des Sciences de la Terre., USTHB, Alger*, 2004.
- [12] CDARS, "Etude du Plan Directeur Général de Développement des Régions Sahariennes. Lot 1 : Etudes de base Phase II A3 : Monographies spécialisées des ressources naturelles. Ressources en eau. Volume 1 : Connaissances d'ensemble," 1999.
- [13] A. Khadraoui, "Eaux et sols en Algérie," *Gestion et impact sur l'environnement. ANRH*, 2006.
- [14] J. Gonçalvès, J. Petersen, P. Deschamps, B. Hamelin, and O. Baba-Sy, "Quantifying the modern recharge of the "fossil" Sahara aquifers," *Geophysical Research Letters*, vol. 40, pp. 2673-2678, 2013.
- [15] OSS, "Système Aquifère du Sahara Septentrional (Algérie, Tunisie, Libye). Gestion concertée d'un bassin transfrontalier," *Collection Synthèse n°1.*, p. 48, 2008.
- [16] CDARS, "Etude du Plan Directeur Général de Développement des Régions Sahariennes. Lot 1 : Etudes de base. Phase II A3 : Monographies spécialisées des ressources naturelles. Ressources en eau. Volume 2 : Modélisation du Continental Intercalaire," 1999.
- [17] S. M. Oussedik, "Déméralisation de l'eau saumâtre du forage Albién "Aïn Sahara" pour l'alimentation en eau potable de la ville de Touggourt," *Desalination*, vol. 137, pp. 103-111, 2001.
- [18] C. J.-M. G. J., *Turbines Hydrauliques. Petites centrales hydrauliques.: Programme d'action PACER – Energies renouvelables, Office fédéral des questions conjoncturelles*, 1995.