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Towards sustainable water management in Algeria

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ABSTRACT

Algeria aspires to protect its water resources and to provide a sustainable answer to water supply and management issues by carrying out a national water plan. This program is in line with all projects the Algerian Government is implementing to improve its water sector performance. The water strategy focuses on desalination for the coastal cities, medium-sized dams to irrigate the inland mountains and high plateau, and ambitious water transfer projects interconnecting Algeria's 65 dams to bring water to water scarce parts of the country. Waste water treatment and water reclamation technologies are also highly sought after. The main objective of the country's water policy consists on providing sufficient potable water for the population supply. This objective is undertaken by increasing the water resources and availability.

Keywords: Algeria; Water strategy; Desalination; IWRM; Water scarcity; Climate change

1. Introduction

Algeria, with a total area of 2,285,263 km^2, is located in North Africa. It is bordered by the Mediterranean in the North, Morocco, Western Sahara and Mauritania in the west, Mali and Niger in the south, and by Libya and Tunisia in the east.

Algeria population is 37.4 million in 2012. Approximately, 87% of the Algerian population in the cities has access to clean drinking water, not including the 13 million living in the rural areas.

It is a desert country without rivers. The climate is semi-arid and is prone to water scarcity [1]. In Algeria, water is rapidly becoming the key development issue. The country has one of the highest average population growth rates in the world (around 1.17%) [2] and scarce natural water supplies. As a result, renewable available water in Algeria dropped from an average of 1,500 cubic meters per person per year (m^3/p/y) in 1962 to 630 m^3/p/y in 1998 and is expected to decline to 430 m^3/p/y by 2020 [3].

The average availability for domestic consumption is 55 liters per inhabitant/day and the water is usually cut off in almost all the cities [4].

Agricultural irrigation is the primary water consuming sector followed by the domestic and industrial sectors. Water allocated for irrigation has dropped from 80% in 1960 to around 60% in 2002 [5].

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Over the last few decades, the promotion of the rational use of water resources and the adoption of appropriate water policies to encourage good integrated resources management water have become a critical issue in Algeria. Many stakeholders believe that access to water is an inalienable human right, a social necessity, and that water is critical for maintaining a stable and healthy social and economic environment [6].

In Algeria, mobilization and management of water resources is one of the most fundamental challenges of the Ministry of Water Resources. Algeria is in the poor countries in water resources under scarcity threshold set by the UNDP or the scarcity by the World Bank to 1,000 m^3/person/day.

Algeria is classified in 14th place among countries poor in water. Several reports show that the lack of water resources does not constitute a major cause of the insufficiency in many cases. Most than often, the problem is linked to the bad management of the resources. In this context, the Algerian Ministry of Water Resources has implemented a strategy to mobilize and ensure water resources (groundwater, desalination, and surface water) with the aim to achieve a sustainable integrated water resources management.

The main problem with water in Algeria is not only that, on average, there is a little and its temporal distribution is unfavorable, but that the demand is growing if this growth is a need, than it has to be met for water resources management to be suitable [7].

Algeria has adopted a demand management strategy given the limited equilibrium between water needs and resources. In addition, this strategy consists of the adoption a new water management strategy based on progressive pricing, integrated and participative management by watersheds, education and awareness of water issues, and large-scale use of wastewater after treatment leaving enough initiative for encouraging water savings [6,8].

The paper aims at providing an overview on the taken actions towards developing National Integrated Water Resources Management (IWRM) plans in Algeria. It describes the major stakeholders involved in water resources planning and presents the main features of the water policies, strategies, and/or plans for the selected countries.

2. Overview of water resources in Algeria

The potential water of resources in Algeria is of 19.2 billion of m^3 (surface water 12.4 billion of m^3 and underground water 6.92 billion of m^3 mainly in the Sahara) [9].

The underground aquifers situated to the north of the country are exploited to 90%, with 2 billion of m^3 per year. Some aquifers are becoming overexploited. In the Sahara region, the extracted volume is valued to 1.7 billion of m^3 [6].

Concerning water quality, the national report of Algeria, without making distinction between surface water and ground water, indicates that "in the global inventoried water, 44% would be of good quality, 44% of satisfactory quality, and 12% of poor quality."

The supply of fresh and potable water is provided by the following three sources:

- Surface water (rainwater reservoir).
- Underground water.
- Unconventional sources of water.

2.1. Underground water resources

The renewable groundwater resources contained in the underground aquifers situated in the north of the country are estimated at 2 billion m^3. These aquifers are fed essentially by rainfall whose distribution is irregular both in time and space. It is estimated that every year approximately 1.5 billion cubic meters is produced and consumed. In Algeria, 75% of the renewable resources are concentrated in 6% of the territory [6,10].

There are large quantities of underground water in the south of the country. The usable reserves are estimated to reach 5 billion cubic meters per year, of which approximately 1.6 billion cubic meters is utilized. This water resource provides the country with approximately 66% of its annual requirement [8].

2.2. Surface water resources

Algeria receives rains in an annual average of 89 mm, what allows a flow of 211 Km^3. Renewable resources (75%) are concentrated in 6% of the territory. But taking into account the aridity of the major part of the country, a small proportion constitutes the renewable water resources. The surface water resources are evaluated to 12.345 Km^3, distributed according to five water shades as specified in Table 1 and Fig. 1 [11].

The MRE has built 103 dams in different areas of Algeria to control surface water. Surface water stored behind these dams is estimated to be 12.4 billion cubic meters. Approximately 50 of these dams have a capacity in excess of 10 million cubic meters each. These dams are illustrated in Table 1.

This water resource provides the country with approximately 17% of its annual needs.

Table 1
Surface water by water shade in Algeria [6]

Water shade	Oranie Chott Chergui	Chéliff Zahrez	Algérois Soumam Hodna	Constantinois Seybouse Mellègue	South	Total
Mm^3/year	1,025	1,840	4,380	4,500	600	12,345
Percentage	8.7	15.7	37.3	38.3	0.48	100.0

During the last 20 years, the Algerian Government spent approximately USD 130 million per annum on this subsector.

2.3. Rainfall

Northern Algeria lies within the temperate zone and its climate is similar to that of other Mediterranean countries. Rainfall in Algeria is reliable. Algeria can be divided according to rainfall into four agro-ecological zones: the coast, with rainfall ranging between 600 and 1,000 mm annual rainfall; the highlands, with rainfall ranging between 400 and 600 mm; the steppe, with rainfall ranging between 100 and 400 mm; and the Sahara, with rainfall less than 100 mm. The coastal and highland regions together comprise the Tellian region [12].

Fig. 1. Geographical water shade distribution in Algeria.

Along the coast, mean annual precipitation is 384 mm at Oran (35˚43´N/0˚43´W), increasing to 762 mm at Alger (36˚42´N/3˚08´E) and to 1,038 mm at Cape Bougaroun (37˚10´N/6˚30´E) (Fig. 2).

In the high plains region, considerable frost and occasional snow on the massifs are recorded in the winter season. In this part of Algeria, prevailing winds are westerly and northerly in winter and easterly and northeasterly in summer, resulting in a general increase in precipitation from September to December and a decrease from January to August; there is little or no rainfall in the summer months. Some 60 km inland from Oran, at Mascara (35˚20´N/0˚09´E), 590 m up on the seaward slopes of the Tell

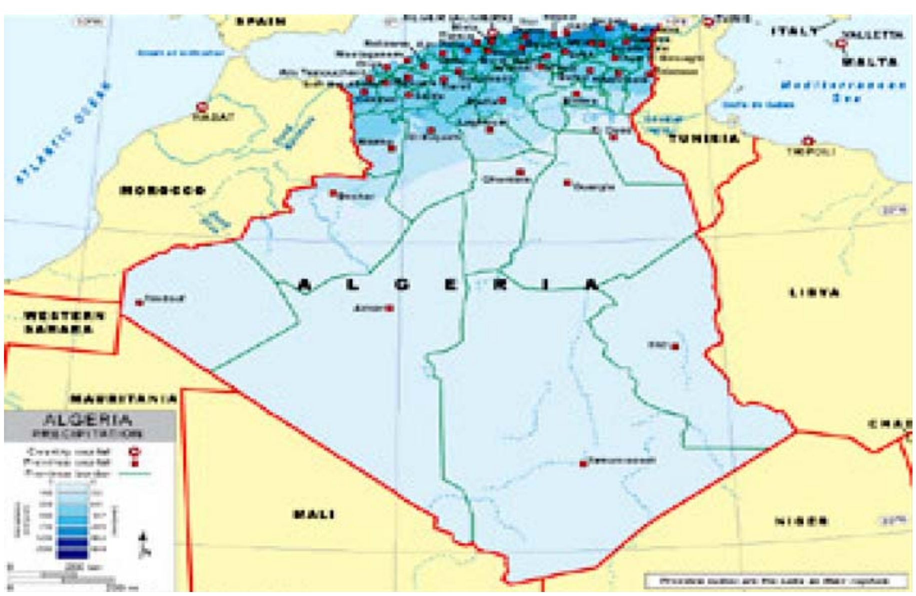

Fig. 2. Average rainfall in Algeria.

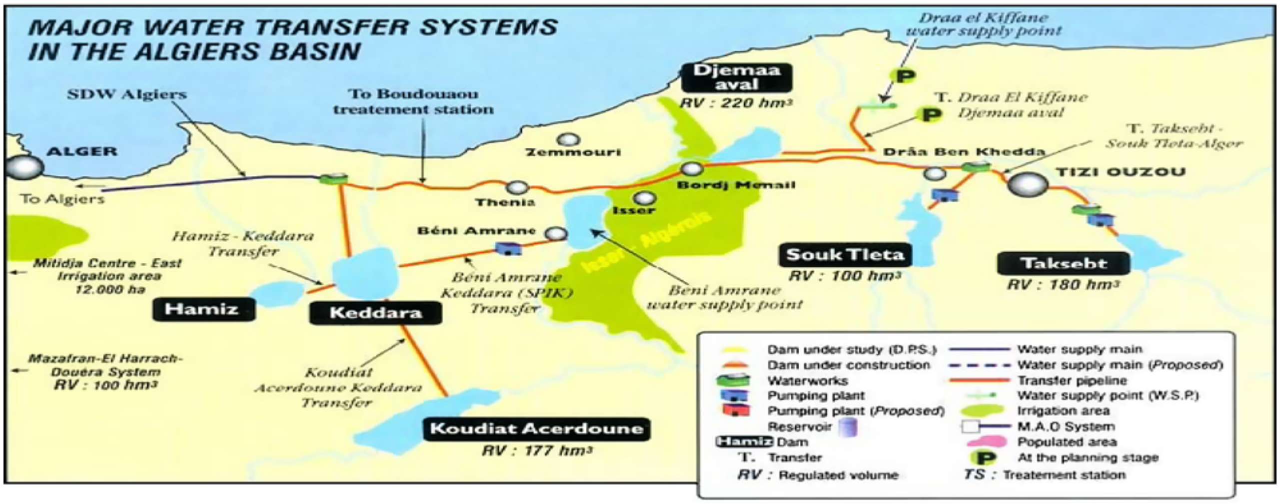

Fig. 3. Map of Taksebt dam and transfer.

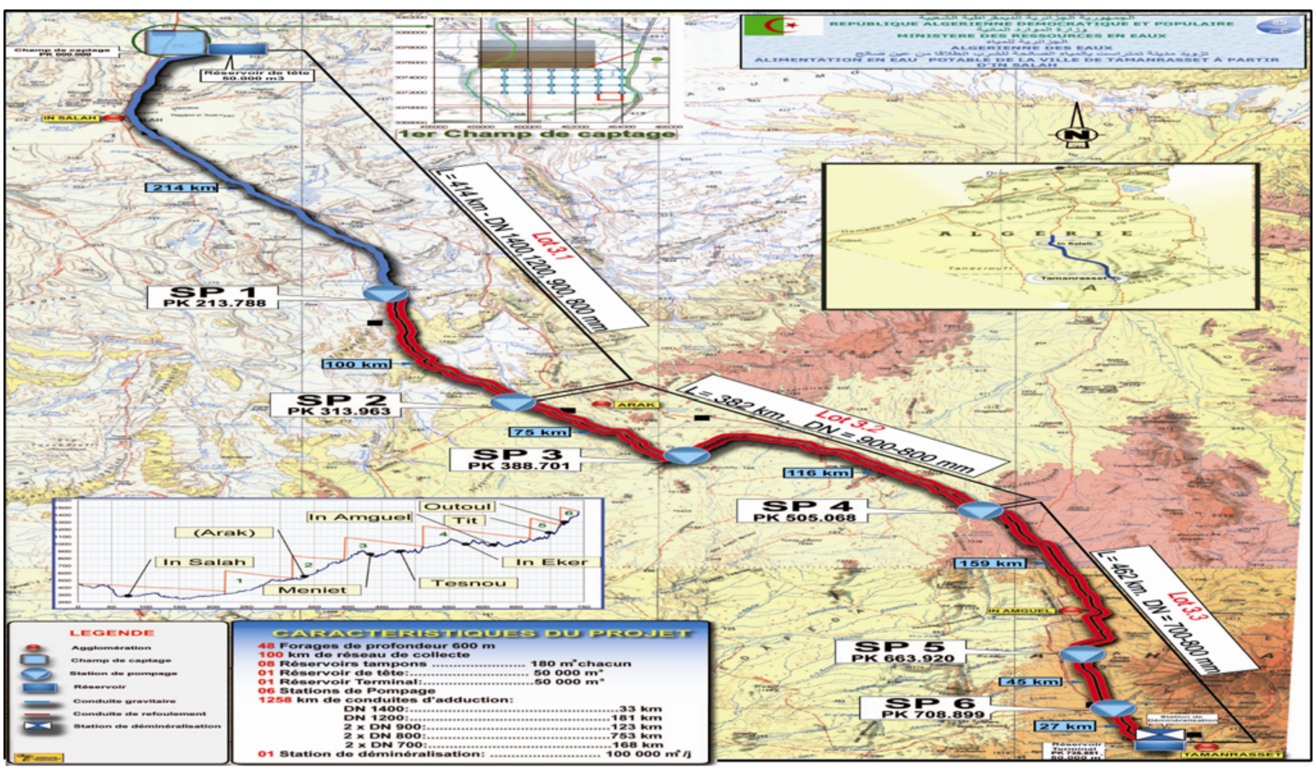

Fig. 4. Map of In-Salah Tamanrasset transfer.

Atlas, mean annual rainfall (34˚06´N/0˚02´E) on the shores of the Chott Ech Chergui on the Highs Plateaus, it is 155 mm, while towards the eastern end, at Djelfa (34˚30´N/3˚20´E), it is 308 mm.

In the Sahara desert, rainfall is irregular and unevenly distributed. At Laghouat (33˚50´N/2˚59´E), it is 167 mm. In the central desert, Timimoun (29˚15´N/0˚14´E) has a mean annual rainfall of 10 mm; Ouallene Bordj (24˚37´N/1˚13´E) receives 36 mm/yr, while Bordj Omar Driss (28˚04´N/6˚39´E) receives a mean total of 28 mm/yr [13] (Fig. 2).

Fig. 5. Map of MAO project, modeling of water resources in western Algeria.

3. Use of available water resources by sector

Algeria is the most arid country of North Africa with 373.2 cubic meters of water per inhabitant per year. Thus, the consumption of water by the agricultural sector is less important than it is in other countries of the region. However, it still represents two-thirds of total freshwater available for a contribution to the GDP of less than 10%, while the industrial sector withdraws 14% of freshwater and contributes to more than 56% of the GDP [14].

4. Water supply and demand

The water supply and demand balance in Algeria is in serious deficit. The country is already facing a water balance deficit. The availability of conventional water resources is affected by growing water demands and the deterioration of surface and groundwater quality. Moreover, climate change is further exacerbating the situation.

In order to meet this deficit, Algeria can manage his existing water resources more efficiently through demand side management tools or by increasing their supply of freshwater through the development of conventional and nonconventional water resources. A combination of both water supply and demand side options is often pursued in order to fill the gap in the water balance [10].

5. Reasons affecting water resources in Algeria

Climate change is having a significant impact on weather patterns, precipitation, and the hydrological cycle, affecting surface water availability, as well as soil moisture and groundwater recharge.

The climate change and dryness which occurred for several decades in Algeria had negatively affected the water resources of the country. The current situation is characterized by imbalance between the needs and the available resources. For example, the measured water inflow of the Beni Bahdel dam was 74 million cubic meters during the period 1910/1998 or 67 million cubic meters during the period 1945/1998, however, since the last quarter of a century this inflow reduced to 36 million cubic meters [10].

Moreover, pollution of the water resources by the domestic, agriculture, and industrial wastes exceeds by far the processing capacities of the systems of

Table 2
Details of dams installed in Algeria

Location of dam	Year built	Initial capacity in Hm^3	Capacity in 2000 in Hm^3	Utilized volume p.a. Hm^3
Ain Defla	1932	228	126	50
Ain Defla	1984	115	110	35
Ain Defla	1984	70	69	35
Ain Defla	1938	280	145	72
B.B. Arreridj	1986	125	122	35
Bechar	1968	350	296	100
Biskra	1950	47	19	13
Biskra	2000	56	56	14
Blida	1985	188	182	70
Bouira	1985	30	29	20
Boumerdes	1985	146	144	94
Boumerdes	1988	16	6	0
Boumerdes	1935	21	16	13
Chlef	1983	280	279	90
El Bayadh	2001	123	0	12
El Tarf	1998	52	52	28
El Tarf	1965	171	167	100
Guelma	1987	220	216	75
Khenchela	1930	3	1	3
Khenchela	1985	41	41	12
Mascara	1992	82	81	34
Mascara	1985	100	99	0
Mascara	1948	73	48	70
Mascara	1970	18	4	0
Medea	1934	55	37	0
Medea	1989	10	9	6
Mila	1987	45	44	8
M’sila	1977	30	25	25
Relizane	1984	55	47	50
Relizane	1988	450	437	100
Relizane	1978	235	214	120
S. Ahras	1987	82	76	34
S. Ahras	1995	157	157	32
S.B. Abbes	1954	22	21	4
Skikda	1977	31	25	20
Skikda	1984	125	124	30
Skikda	1993	40	40	22
Skikda	2001	120	120	40
Tiaret	1963	56	44	32
Tiaret	1987	41	39	6
Tipaza	1960	0.3	0.25	0
Tipaza	1992	97	96	50
Tissemsilet	1989	13	11	9
Tizi Ouzou	2001	175	0	180
Tlemcen	1952	63	55	30
Tlemcen	1963	15	15	10
Tlemcen	1988	110	110	38
Tlemcen	1999	177	177	50
Total		1.066000	−1.119000	517.0

purification. These degradations reduce volumes of water likely to be used [15,16].

Also years of drought have depleted ground water supplies and dam reserves. Additionally, Algeria suffers from substandard management of water utilities and other existing networks [3].

6. Water reuse

Purification of sewage water is another resource of water. The volume of sewage water in Algeria is estimated to be 600 million cubic meters per year. This number is expected to grow to 1.2 billion cubic meters in the year 2020 [17].

The number of water purification plants in Algeria exceeds 60, with a total purifying volume of approximately 1 million cubic meters per day. The Government of Algeria investments in this subsector over the last 30 years amounted to USD 15 billion [18].

The government's five-year development plan for the years 2009–2013 provides for the construction of additional five plants (Table 2) and expect to reach total capacity treatment of 554.512, m^3/d, in addition to the 20 plants already under construction or achieved (Tables 3 and 4).

Table 3
Actual and forecast wastewater plants

Name	Wilaya	Year of service	Capacity (m^3/d)	Treated volume
BBA	BBA	2008	2,500	30.000
Ibn Ziad	Constantine	2009	5,000	69.120
Ain Hout	Tlemcen	2009	9,300	30.000
Ghriss	Mascara	2012	1,000	3.700
Baraki	Alger	2013	76,712	150.000
Annaba	Annaba	2013		116.000
			554.512	648.820

Table 4
Complete desalination projects [9]

Project name	Capacity	Cost
Skikda Desalination Plant	100,000 m^3/d	USD 136 Million
Hamma	200,000 m^3/d	
Beni Saf	200,000 m^3/d	
Souk tlata	200,000 m^3/d	

7. Main stakeholders of water resources

The Ministry of Water Resources [6] holds the main responsibility in the provision of water infrastructure and services. The MRE is responsible for policy orientation, planning, the water resources studies, hydraulic schemes regulation, and the development of water resources plans and supervision of activities. Other agencies are responsible for the planning, design, construction, and maintenance of infrastructure, and water supply and sanitation and irrigation services delivery.

Five organizations have been established:

- Algerian Energy Company (AEC): Responsible for forming joint ventures with foreign companies for the implementation of desalination projects.
- National Agency of Dams and Large Transmission Mains (ANBT): Responsible for implementing surface water resource and water transfer projects.
- Algeria Water Company (ADE) for the distribution of drinkable water: Responsible for providing water services.
- Office of National Sanitation (ONA): Responsible for providing wastewater services including wastewater treatment.
- Office of National Irrigation and Drainage (ONID) and National Agency of Water Resources (ANRH): Responsible for water resource planning (www.uktradeinvest.gov.uk).

In addition to the above mentioned, five watersheds agencies (*Agences de Basins Hydrographiques*, ABH) were created in August 1996, these agencies translate into practice the principle of joint and integrated management of water resources throughout the watershed.

8. Main features of water strategy and/or policy

Given the deficit situation in satisfying water needs and despite the importance of heavy investments in the sector, the water resources sector has undertaken since the early 1995 comprehensive procedures to enhance the system of organization and management of the sector. A new water policy was initiated and is based on integrated water resources management principles. The main features of the policy are:

- Scarcity of the resource.
- Integrated management across the river catchment and applying economic and environmental management.

9. Policy goals and instruments: new strategy

The broad objectives of this policy can be summarized as follows:

- Systematic mobilization of all exploitable water resources.
- Protection and preservation of existing resources and rehabilitation and completion of treatment systems.

The current policy depends on the following factors and instruments for the policy achievements:

- With regard to demand management, a major multidimensional outreach program on saving water will be implemented to achieve:
  - Reduction in the drinking and industrial distribution networks losses.
  - Modernization of irrigation methods and cultivation of low water requirements crop varieties.
- With regard to integrated water management and protection of the resource:
  - Use of nonconventional water resources to secure water supply for major urban centers and agriculture through:
    - Seawater desalination.
    - Desalting of brackish water and reuse of treated wastewater.
- With regard to development of planning tools and dynamic management, some inconsistency in planning and programing investments have been identified. A review of the study on the "National Water Plan" has been undertaken which was designed to have a clear vision to ensure an interregional balance between "needs" and "resources."

With regard to institutional and organizational reforms, the following principles will be applied:

- Water resources are public property.
- Integrated river basin management.
- Economic management.
- Preservation of environmental quality of the resource.
- With regard to legislative reforms, a new water law was developed in 2005. This law allows for public–private partnership in construction and management of public drinking water, sanitation, and irrigation systems.

10. Larger dams and water transfers

10.1. Taksebt dam

Taksebt Dam, located 7 km southeast of Tizi-Ouzou, is a quite classic structure built using materials found on or near the site, and thus inexpensive. The vertical core is made of impervious clay buttressed by fill consisting of alluvial materials and fragmented rock excavated prior to construction. The permeable alluvial foundation is cut by two diaphragm walls [19].

This project supplies drinking water from the Taksebt Dam to a population of four million people along the Tizi Ouzou-Algiers corridor in Algeria. Previously, water was only being delivered a few days a week to the cities along this corridor, including the city of Algiers.

The water transfer project covers a distance of approximately 80 km and is the largest project of this type involving both the treatment and transportation of water in Africa (Fig. 3).

The Algeria's National Agency for Dams and Transfers (*Agence nationale des barrages et transferts*, ANBT) contracted SNC-Lavalin to design, build, and operate the water treatment and transfer operations for the US $700-million project. The huge project—605,000 m^3

Table 5
Ongoing desalination projects [32]

Project name	Capacity	Cost
Tahlyat Myah Magtaa—Magtaa Desalination Plant	500,000 m^3/d	USD 632 Million
Almiyah Attlemcania—Tlemcen Desalination Plant	200,000 m^3/d	USD 251 Million
AEC/Inima/Aqualia—Cap Djinet Desalination Plant	100,000 m^3/d	USD 251 Million
AEC/Inima/Aqualia—Cap Djinet Desalination Plant	200,000 m^3/d	USD 251 Million
AEC/Inima/Aqualia—Cap Djinet Desalination Plant	200,000 m^3/d	USD 251 Million

capacity—was completed in 37 months in 2009. SNC-Lavalin will operate the plant for five years.

10.1.1. Project description

The project target is the reinforcement of the water supply system for the greater area of the city of Algiers and the Tizi-Ouzou to Algiers by the transfer of water by the Taksebt system which will be supplied by the existing Taksebt dam and reservoir. The system includes inter alia the following works:

- Water supply conduits (90 km) DN1800 and DN2000.
- Pumping station (7.1 m^3/s).
- Water treatment plant (605,000 m^3/day capacity).
- A rechlorination station at Boudouaou.

10.1.2. Reservoirs

- Tizi Ouzou reservoir (5,000 m^3).
- Draa Ben Khedda reservoir (5,000 m^3).
- Draa Ben Khedda treated water reservoir (22,000 m^3).
- Boudouaou treated water reservoir (28,800 m^3).

10.1.3. Tunnels

2.5 m internal diameter and totaling 11.4 km;

- Tizi Ouzou tunnel (2,500 mm diameter, 3,000 m length).
- Draa Ben Khedda tunnel (2,500 mm diameter, 1,319 m length).
- Naciria tunnel (2,500 mm diameter, 2,621 m length).
- Thenia tunnel (2,500 mm diameter, 4,820 m length).
- Tele-transmission (SCADA system); a centralized fiber optic telecommunications system.
- Operation of the system.

10.2. Project for the supply of drinking water to Tamanrasset

Underground water is pumped into the artesian layer at a distance of more than 750 km and passes through a total of 1,256 km of pipeline. The system's capacity of 100,000 m^3/day can supply a population which, according to projections, will reach 340,000 inhabitants by 2050 [20]. Nearly, 50 billion dinars (about € 572) have been released to finance the work [21].

This project was divided in six different missions:

- Study of the water demand.
- Delimitation of the In Salah well fields.
- Water quality.
- Preliminary studies.
- Detailed studies.
- Preparation of the tender documents.

The studies carried out to date highlight the considerable difficulties of such a large project:length of the pipeline (730 km), difference in elevation (1,200 m), as well as the particular features and conditions of the project, located in the heart of the Sahara desert (Fig. 4).

10.3. MAO

The transfer of water in the east of the country. This project ensures the transfer of an annual volume of 155 million cubic meters of water to the corridor of Mostaganem–Arzew–Oran (Fig. 5).

The water transfer system includes:

- A diversion dam on the wadi Cheliff and a pumping station.
- A storage dam at Kerrada.
- A water treatment plant and feeder pipe along the MAO corridor.

10.4. Beni Haroun

The dam of Beni Haroun (Mila department) is one of the world largest gravity RCC dam (120 m height), 1.75 Mm^3 of RCC is in operation since 2001. The dam location being lower than the supply destination, a 180 MW pumping station was built, having a design discharge of 23 m^3/s and 800 m of gross head; it is presently one of the largest in the world. The pumping station includes a battery of fixed-cone valves installed to act as emergency protection against water hammer pressure fluctuations and as drainage outlets during normal operation [6,8]. It was carried out the works, Spanish company Dragados, with a storage capacity of some one billion cubic meters (960 millions), the dam of Beni Haroun, completed in the last quarter of 2001, represents the key work of the transfer of Beni Haroun, which contributes to supplying regularly 425 million cubic meters per year. This dam is the key point of the great transfer project, an interconnection intended to supply with drinking water up to 310 million cubic meters per year that is 150 L per inhabitant per day at least, the areas of Constantine and the Aures includes six provinces, namely Batna, Khenchela, Mila, Oum El Bouaghi, Constantine, and Jijel–Mila region. They shall receive the water from the dam through pumps. To do so, a station of 180 MW is currently being built. It must also meet the needs in irrigation water (194 million cubic meter/year) of the new farming perimeters (Teleghma, Chemora, and Touffana). The dam of Beni Haroun, which shall be operational late in 2002, shall help to get the national surface water capacities from 5 billion cubic meters to more than 6 billions.

10.5. Setif-Hodna-El Eulma transfer

The Setif-Hodna-El Eulma transfer project is consisting of two systems. The west system enables the transfer of an annual volume of 122 million cubic meters of water to the 550,000 inhabitants of Setif and the irrigation of 13,000 hectares of plains in Setif. The east system will allow the transfer of an annual volume of 190 millions cubic meters of water to the 700,000 inhabitants of El Eulma city and the irrigation of 30,000 hectares of land in El Eulma [6].

11. Towards unconventional water resources for better IWRM

11.1. Analysis and challenges

Appling the revised National Water Plan and implementing the different policy instruments, it is expected to gradually bring the water resources sector to the implementation of the principles of IWRM. This shall improve the performance of the water resources system through the involvement of users in decisions and the use of economic incentives, in addition to the implementation of flexible regulatory means.

The improvement of public services in drinking water and sanitation calls for institutional reforms for effective control and water management. The establishment of public institutions of an economic nature is a first response to progress towards sustainable management of the water supply and sanitation sector.

The National Water Plan aims at achieving development in the different segments of the national economy (industry, agriculture, and tourism) based on the maximum mobilization of conventional and unconventional water resources. The implementation of the plan and its associated institutional reforms requires state financial support of about 1.3 billion $ per year.

One of the challenges facing Algeria is the efficient use of water and the reduction in water losses from distribution networks. The new water code gives the legal basis for providing a reliable public service of water supply and sanitation and allows for managing water in an integrated manner at the watershed level through regional agencies and committees.

12. Mega scale desalination projects

12.1. Seawater desalination

Due to the shortage of natural water resources, climate changes, and rapid urban development to preserve subterranean resources for inshore city use and for agricultural purposes, the increased population of Algeria dictated the search for new sources of water. To meet this need and taking into consideration the factors hereunder, the government, in the year 2000, decided to award a built, operate, and transfer (BOT) project for the desalination of seawater. Accordingly, the Algerian Government has opted for a program of large desalination plants designed to reach a volume of 1,000,000 m^3/day in the next five years and a volume of 4,000,000 m^3/day by the year 2020 [22,23] (Table 5).

12.2. Brackish water desalination

See Table 6.

Table 6
Actual and forecast brackish water plants [32]

Desalination Plant Name	Capacity	Status
Bredeah	10,000 m^3/d BWRO	
El Oued	300,000 m^3/d BWRO	Tender launched
Tamanrasset	100,000 m^3/d BWRO	Tender process expected soon
Tindouf BWRO	27,000 m^3/d BWRO	Awaiting tender
Touggourt	37,000 m^3/d BWRO	Tender launched

13. Virtual water and climate change

13.1. Virtual water

Food production is a water-intensive activity. For Algeria, lack of water poses a direct constraint to food production. By the same token, importing food from outside can effectively reduce the water demand locally. Table 7 gives estimates of the volumes of virtual water embedded in food imports in Algeria. The country imports a large portion of cereal grains for his

Table 7
Data of virtual water in Algeria

Indicator	Algeria	Source
Virtual water imports in crops (1,000 million m^3)	9.8	[33]
Virtual water imports in livestock (1,000 million m^3)	1.1	[34]
Total virtual water (1,000 million m^3)	10.9	[33,34]
Water withdrawal, m^3/per capita, per year	181	
Water resources, m^3/per capita, per year (2002)	460	

domestic supply. The actual volume, however, is 100 kg/per. Other cereal crops imported include barley and rice.

For the production of 1 kg of dry wheat under optimal conditions, roughly 1 m^3 of water is needed. In the estimation of virtual water embedded in the cereal imports, an aggregate ratio of 1 kg of grain to 1 m^3 of water is used.

Taking per capita annual renewable water resources as reference (Table 7), Algeria imports a volume of virtual water nearly 40% of its renewable resources. It is noted that the volumes of virtual water imports in Algeria appear in an inverse relationship with its physical water endowments. The lower the per capita renewable water resources, the larger the volume of virtual water imports and vice versa.

The ''virtual water'' embodied in food imports will remain a valid means for water-scarce country as Algeria to maximize the value of his limited water supplies.

13.2. Climate change

Climate change will result in significant impacts on Algeria water resources and some of the effects are already visible now. Algeria is expected to be negatively affected by impacts ranging from increased frequency and intensity of floods and droughts, worse water scarcity, intensified erosion and sedimentation, sea level rise, and damage to water quality and ecosystems. Moreover, climate change impacts on water resources will have cascading effects on human health and many parts of the economy and society, as various sectors directly depend on water such as agriculture, health, and tourism—as does the environment. Adaptation to climate change is therefore a moral, economic, and social imperative [24,25].

Conducted study carried out by the Algerian Government estimates that a 1˚C rise in mean annual temperature would lead to decreases in precipitation by 15% and in influx of surface waters by 30%. Subsequently, water demand would exceed available water resources by 800 million m^3 [26].

With escalating concerns of climate change, water management should be a central element into the planning strategy of water resources management in Algeria.

14. Water distribution and leakages

The water distribution pipeline networks in Algeria extend to more than 58,000 km, with a capacity to transfer 570 million cubic meters per year. The capacity of water storage tanks exceeds 5 million cubic meters [6,8].

It is worth noting that most of the water distribution network is old thus causes a high level of wasted potable water. The government is aware of the need to allocate adequate funding to renew and modernize the distribution systems in the country.

15. Environmental impact

Algeria is ranked 42 out of 153 countries according to the Environmental Sustainability Performance Index for 2010 [27]. Algeria's significant environmental problems include water shortages and pollution. The small amount of water available in Algeria is threatened by regular droughts. The problem is further complicated by lack of sewage control and pollutants from the oil industry, as well as other industrial effluents. The Mediterranean Sea has also been contaminated by the oil industry, fertilizer runoff, and soil erosion.

16. Energy and costs

The desalination of seawater on a large scale is feasible due to the availability of energy and his cheaper price comparatively with the average price in Euro-Mediterranean area. This Alternative could offer an efficient solution to the problems of certain coastal areas such as the Oranais. The government encourages the desalination program of seawater.

The water distribution and sanitation system is highly dysfunctional. Appropriate investments and the adoption of regional billing rate schedules should provide the needed solutions. Actually, the Algerian households benefit from a price water subsidy. A new water tariff policy has been applied in Algeria since 2005. Prices are then computed on one side, for domestic users on different thresholds according to the level of consumption and on the other side, for industrial consumers on a uniform basis. It is worth mentioning that the water cubic foot is billed based

Table 8
Water tariffs and subsidies in Algeria 2005

Tariff/uses		Price in Algerian Dinars	Price in USD	Percentage of subsidies
Domestic	Average	31	0.30	57
	Threshold 1	28.3	0.27	60
	Threshold 2	24.9	0.24	65
	Threshold 3	31.6	0.30	56
	Threshold 4	46.7	0.44	35
Administrative		51.8	0.49	28
Commerce and services		57.2	0.54	20
Industry and tourism		65.5	0.62	8
Average		40	0.38	44

on governmental instructions and on a selective and progressive system that provides for an overall subsidy of 45–50%, without taking into account the real cost of water. Fifty-three percent passing from 26, 2 DA/m^3 (0, 37$) to 40 DA/m^3 (0, 57$). For domestic use, the increase is about 40% (22, 2–31 DA/m^3) (see Table 8). It should be noted, however, that water subsidies that turned around 60–67% and before 2005 decreased to 44–54% [28–31].

17. Capacity building

The main objective of capacity building in water management is to improve the quality of decision-making, sector efficiency, and managerial performance in the planning and implementation of sector programs, water policies, and projects. This can be achieved by:

- Improving the capabilities of assessing water resources.
- Planning improved sustainable water resources management in the context of national planning.
- Arriving at financially and environmentally sustainable more efficient and more effective delivery of water services, particularly for cities and agriculture.
- In capacity building three elements can be identified:
  - The creation of an enabling environment with appropriate policy and legal frameworks.
  - Institutional development, including community participation.
  - Human resources development and strengthening of managerial systems.

Capacity building in water management should be considered within the context of IWRM. IWRM is a process that promotes the coordinated development and management of water, land, and related resources in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems [32].

Two issues are at the core of IWRM:

- Acknowledging that ecologically sound water systems are essential for the sustainable use of water resources by humans, animals, and plants.
- Acknowledging that management requires a careful process of balancing the interests of all users and uses, as well as a regulatory framework to guarantee the sustainable use of water resources.

A major development in IWRM is the realization that ecologically sound water systems are essential for the survival of the resource itself. Without them there will soon be no water to satisfy the demands of any of the other users. Within the agricultural context, another environmental aspect to consider in integrated water management is the sustainability of the land resource. From this perspective, over-irrigation may not only represent an inefficient use of water, it may also lead to water logging and thereby destruction of the productive potential of the land resource. From the same perspective, under-irrigation is not a desirable response to water scarcity where it leads to accumulation of salts in the root zone.

Algeria needs support in capacity building to expand its nonconventional water resources through desalination and wastewater reuse.

18. Conclusions

Algeria, like many other countries through MENA region, is facing the challenging goal of achieving sustainable water resources development and management as part of a more comprehensive national plan for sustainable development. This commitment of achieving sustainable water development and management is subject to issues of integration, often conflicting targets between economic growth and development, environmental conservation, and climate change.

In the last decade, Algerian Government has established a national water plan with the aim to achieve integrated water resource management and secure water supply in major cities of the country.

In this setting, Algeria strives to develop in the short and medium terms to develop its activities in the following important areas:

- Reduction of water losses thanks to maximum operating of existing potentialities.
- A sustained effort in resource mobilization in surface water by building of new dams.
- The rationalization of the aquifer exploitation in the north and the improvement of the knowledge on resources in underground waters in arid areas (steppe) and in the Sahara.
- The development of capacities of purified wastewater reuse to improve availabilities in water for the industry and agriculture.
- The development of capacities of demineralization of the brackish waters and seawater desalination in the coastal zones in order to have more resources to satisfy the demand in drinking and agricultural water for the other zones.

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