Water transfer versus desalination in North Africa: sustainability and cost comparison

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Abstract
The North African region is experiencing water scarcity that is getting more severe with time. The regional annual average per capita water availability has been reduced from 2285 cubic meters in 1955 to 958 cubic meters in 1990 and is expected to reach 602 cubic meters by the year 2025. To meet the present and future water demands of the region the available options are limited to either long distance water transfers from the southern aquifers to the coastal areas or to investing in large scale seawater desalination technology. Economic analysis revealed that the cost of long distance water transfer can escalate to more than 0.83 US Dollars per cubic meter. When sustainability considerations are taken into account this figure may reach up to 2.35 US Dollars per cubic meter. While these figures were competitive with the cost of seawater desalination twenty years ago, the situation has been recently shifted in favor of seawater desalination which dropped from 5.5 US Dollars in 1979 to less than 0.55 US Dollars in 1999. It is concluded that sustainable development of North Africa will depend in the future on large scale desalination as a last resort. Presently planned water transfer projects should be substituted by this fast growing technology as the best option.

Introduction

The relation between man and his environment in North Africa had been stabilized throughout the past centuries by the establishment of production systems and socio-political structures based on subsistence economics and a simple way of life. The introduction of misguided modern technologies and mutilated production systems imported from the highly developed economies of the humid western countries has shattered the intricate balance between the subsistence economies and the meager natural resources of the region, including water. Conventionally available water supplies on renewable basis are simply insufficient to meet the insatiable water demands of the present modes of economic activities and resource exploitation. Non-conventional water resources have not received the serious consideration they deserve for their full potential development. Thus the whole region is becoming increasingly dependent on the non-sustainable mining of local groundwater aquifers that are presently threatened by pollution and depletion. The search is on for alternative water supplies that are economically viable, environmentally sound and socially equitable. This article endeavours to evaluate the available options in view of the present level of technology and the information gained from real world practices.

The Present Water Resources Situation

The population of North Africa increased from 49.5 million in 1955 to 118.1 million in 1990 and it is expected to exceed 188 million by the year 2025 [1]. The total annual renewable fresh water supplies available in the region has been estimated at the fixed rate of 113.1 Km^3/yr. [2]. According to these figures, the regional annual average per capita water availability has been reduced from 2285 m^3 in 1955 to 958 m^3 in 1990 and is expected to reach 602 m^3 by the year 2025. Thus the whole region is already experiencing water scarcity that is getting more severe with time. As indicated in Tables 1 and 2 however, these regional averages mask the spatial variability of the severity of water scarcity on a country by country basis. Even within the same country water availability varies widely from one location to another.

Table 1. Total renewable available water supplies and population distribution in the North African Countries

Country	Water supply (Km^3/year)	Population (millions)		
		1955	1990	2025
Egypt	58.9	24.7	56.3	87.1
Morocco	28.0	10.1	24.3	36.3
Algeria	17.2	9.7	24.9	40.4
Tunisia	4.4	3.9	8.1	11.8
Libya	4.6	1.1	4.5	12.4
Total	113.1	49.5	118.1	188.0

Source: UNDP [1]

Table 2. Per capita renewable water availability in the North African countries

Country	Per capita water availability (m^3/year)		
	1955	1990	2025
Egypt	2385	1046	676
Morocco	2764	1151	770
Algeria	1770	690	426
Tunisia	1130	540	369
Libya	4103	1017	332
Regional Average	2285	958	602

Source: PAI [2]

The Available Options

Escalating water demands during the past 20 years led to severe pumping and overdraft of the local groundwater aquifers of limited extent and annual recharge. These aquifers have been exposed in several locations to unacceptable levels of piezometric declines and seawater intrusions with disastrous environmental and socioeconomic impacts. However, since almost all surface water supplies have already been developed to their full potential, to remedy the resulting deteriorating situation the available options are limited to either expanding groundwater exploitation in newly developed, previously untapped, aquifers or investing in large scale seawater desalination technology. These two options are discussed in the remaining parts of this article.

Increased Groundwater Exploitation

Most of the significant groundwater resources of North Africa are located in the southern Saharan and Sub-Saharan regions far away from dense population centers and important socioeconomic activities. This situation posed the question of whether to move people and their socioeconomic activities to where groundwater can be explored and economically exploited or to pump water and mass transfer it to where it is most urgently needed. The countries of the region are responding to both alternatives in varying degrees with more emphasis on one alternative than the other. Egypt, for example, is contemplating large scale agricultural settlement projects and industrial centers in the western and southwestern desert with the objective of reducing population pressure in the Nile Valley and exploiting the waters of the Nubian sandstone aquifer system [3]. On the other hand, Libya has emphasized huge mass water transfer schemes through its Great Man-made River project [4]. The other countries may start similar projects when they feel the need and get the means. But since the Saharan and Sub-Saharan aquifers are non-renewable, or their rate of renewal is much less than the planned abstractions of these projects, several issues concerning their sustainability and role in the future development of the region must be raised and satisfactorily settled before heating up the race for their exploitation. These issues include the basis for sharing a most likely non-renewable common pool resource, the need for its cooperative regional study and management, conflict avoidance and risk aversion and socioeconomic integration among the countries sharing the resource.

The question as to whether exploitation in situ, or long distance mass water transfer is more viable, cannot be settled by economic analysis alone, since several strategic and sociopolitical factors are involved. However, as will be explained later, economics does and can be safely used to compare the viability of mass groundwater transfer vis a vis desalination, since both are intended to provide the already established socioeconomic activities and population centers with their escalating water demand.

Large Scale Seawater Desalination

No reliable data is available concerning the total actual capacities concerning desalination units presently operating in the region. It is generally agreed that the annual production of these units is relatively insignificant in proportion to total water demand, and quite modest compared to the production of similar installations in Saudi Arabia and the other Gulf states. But in spite of their limited capacities, their small production volume does satisfy part of the municipal and industrial water requirements of several communities in water shortage areas along the southern Mediterranean coast. Several factors, including poor management and lack of spare parts and local skills for maintenance and repair, have contributed to the low operating capacities of these units in comparison to their full installed potential. These facts clearly indicate that desalination has not been taken seriously in the past. Most of the installed units came about almost through the commercial efforts of sales companies as accessory components to steam power generation plants. Some of them were installed under the expediency of short term drinking water shortages in certain locations. All of them, however, lack a long term rational plan to integrate them with the overall national water supply system.

Desalination technology in the region has been clouded with several misconceptions and lack of understanding its multifarious aspects. Top level decision makers usually associate desalination with international companies of imperialist tendencies that monopolize this technology to extract the highest possible price for its products. As a result only very rich nations that are willing to squander their national wealth can afford the high cost of desalinated water. These misconceptions should be immediately corrected since all available facts and information, as will be demonstrated later, clearly indicate that desalinated water is no longer so expensive as it has been thought and desalination technology is not monopolistic.

Sustainability and Cost Comparison

The only available example of mass water transfers that has been implemented in the region is the Libyan Great Man-made River project. After its completion the project will transfer and redistribute a total of more than 2 billion cubic meters per year. Whenever large-scale mass water transfers are considered, the financial resources available for investment in these projects and the expected cost of the transferred water are of prime concern. It is essential to compare the average unit cost of transferred water with the other potentially available alternate supplies.

The economic analysis performed during project conception estimated the average unit cost of transferred water at about 0.25 US Dollars per cubic meter, which was highly competitive with other alternatives such as seawater desalination estimated at 2.5 – 3.0 US Dollars per cubic meter at that time. Actual economic studies performed after the completion of stage one [5] revealed that the average unit cost of water to the user's gate, with the cost of capital set at 7 percent interest, is 0.83 US Dollars per cubic meter at 1991 prices. It is generally believed that this figure has been dramatically exceeded for the remaining stages of the project since that time.

While there is a clear trend of increasing costs of transferred water with time, the cost of desalinated seawater has witnessed during the last two decades a dramatic revolutionary trend in the opposite direction. The average price of desalinated seawater is today only one-tenth of what it was twenty years ago. It dropped from 5.5 US Dollars per cubic meter in 1979 to less than 0.55 US Dollars in 1999, including interest, capital recovery and operation and management [6]. A Tampa Bay seawater desalination plant in Florida, USA, was contracted in 1999 at a cost of 0.45 – 0.49 US Dollars per cubic meter in the first year of operation. This low cost of desalinated seawater takes on an international significance when compared with a proposed desalination plant in Singapore for which the first year cost of water has been estimated to be 1.5 US Dollars per cubic meter at its worst case. It seems that mass water transfer projects in North Africa, at least as represented by the Libyan Man-made River project, have lost their economic advantages over the fastly developing and expanding desalination technology. When the questions related to sustainability considerations are raised, the advantages of the desalination option become even clearer. For example, the above mentioned cost of transferred water in the first stage of the Great Man-made River project was based on the costs of development, operation and maintenance of well fields and conveyance systems only. But since the exploited aquifers are nonrenewable, and thus nonsustainable, the scarcity value, or for a better term, a "depletion cost" of the mined groundwater resources should be taken into account when calculating the actual cost of the transferred water. A rough estimate of depletion cost can be derived according to the willingness to pay of the would be users, or as the equivalent of the cost of developing the least expensive alternative water supply that can be used to sustain the socioeconomic activities based on transferred water after its pumping and conveyance become uneconomical, or its feeding aquifers are completely exhausted.

In the absence of any sufficient amounts of surface water for development, the only available alternatives to the North African countries, including Libya, are limited to cross-boundary water importation or seawater desalination. Potential sources for cross-boundary water importation are limited to water diversions from Equatorial Africa or southern Europe. There are speculations at the present time concerning the technical, financial and political feasibilities of rerouting the Congo river towards the Northern Sahara, or at least diverting part of the water of its Ubangi tributary towards the river Shari that discharges into lake Chad. But these speculations are in the realm of future dreams and devoid of any practical importance at the present level of socioeconomic planning strategies.

As to the south European source, a new emerging technology promises to provide most of the southern Mediterranean region with good quality water at a reasonable price through water importation by mega-sized plastic bags [8]. These so called "Medusa Bags", having a capacity of 1.75 million cubic meters each can be loaded with water at specially constructed terminals at any southern European water source and tugged across the Mediterranean sea to unload there contents at any water receiving terminals in the southern Mediterranean coasts. The Canadian firm "Medusa Corporation" that develops this technology claims that it can supply the cities of Tunis and Tripoli at a cost of 0.17 US Dollars per cubic meter. Libya is currently involved in assessing this technology and its feasibility for future use in augmenting local water supplies.

But even if the Medusa bags or any other cross-boundary water importing technology proves its competitiveness with desalination, most of the North African countries will exclude the alternative of cross-boundary water importation simply on the mere grounds of national sovereignty and geopolitical considerations. Thus the only remaining alternative is seawater desalination. If we accept the cost of desalinated seawater at the conservative figure of 1.5 US Dollars per cubic meter, then the actual cost of transferred water through stage one of the great Man-made River project may reach up to 2.35 US Dollars per cubic meter inclusive of depletion cost. This is more than four times the cost of desalinated seawater. To achieve long-term sustainability of the transferred groundwater, it should be priced for utilization in production models that can generate the financial and economic resources to be needed in the future for the development of large scale desalination after the fossil groundwater aquifers are depleted. At the above actual price inclusive or exclusive of a depletion cost, it is unlikely to sustain this transferred water unless it is continuously subsidized throughout the project life. When the national treasury becomes unable to provide the required subsidies for any reason, the project either fails to achieve its objectives or will be put out of operation altogether.

Conclusions and Recommendations

Unlike what it used to be during the late 1970's and early 1980's, seawater desalination is becoming more than four times cheaper than transferred groundwater for the Saharan and Sub-Saharan aquifers, at least in the case of the Libyan Great Man-made River project. In view of these radical shift in water costs, the Libyan authorities must reconsider their position on whether to go ahead with completing the remaining stages of the Great Man-made River project and implement the other proposed water transfer projects from the Kufra, Ghadames and Jagbub areas, or stop any further expansion in water transfer projects and substitute them with large scale seawater desalination industry. They should also consider the development of large scale seawater desalination for mixing with the transferred water, especially in stage two of the great Man-made River project where the average nitrate concentration exceeds 60 parts per million. Mixing this transferred water with desalinated seawater at the proper ratio can both eliminate the negative health and environmental impacts of high nitrate concentration and augment the present water supply to meet the ever increasing future water demand. In addition to improving the overall water quality the added desalinated water will significantly reduce the average unit cost of the mixture. Simple economics and the new paradigm of development sustainability clearly indicate that even though water transfers my seem cheaper in the short run, project implementation and real life practical experience have shown that long-term sustainability of growth and development in North Africa will depend on large scale desalination as a last resort for meeting its future water demands. Recent awareness of developments in desalination technology and its strategic importance to the future of the region, especially to Libya, requires more concerted effort on the planning and installation level to put this industry on a firmer and permanent footing. The need for applied research and training in this fast developing field is quite apparent. Programs and plans for action to rehabilitate the present installations and construct new ones should be immediately considered at the present time.

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Comments by The Center of Data, Studies and Researches of the Great Man-Made River Authority, 2004, Libya.

1. The Author of this paper (1) Dr. Saad A. Alghariani endeavors to compare the cost of mass groundwater transfer via the Great Man-Made River Project (GMRP) versus desalination using economic as the sole criterion for comparison neglecting other factors like environmental impact and water use.

2. The cost price cannot be compared for the two alternatives since the cost price of one cubic meter of produced water in the GMRP as reported by Brown and Root overseas in 1990 (2) includes additional cost components associated with transmission and distribution network system up to the user's gate. On the other hand, the quoted cost price for desalination presently amount to $0.82 refers solely to production of desalinated seawater in situ (i.e., exclusive of any additional costs related to transmission and distribution network).

3. The Author claims that there is an additional cost component that should be added to the cost of one cubic meter of GMRP referred to as "depletion cost, The Author explained that the depletion cost price is equivalent to the cost of providing an alternative water resource (desalinated water) when the ground water resource fails to provide. When this additional cost is added to the cost price of 1990, the cost price is boosted to $2.35 (i.e. the addition cost is $1.52 per cubic meter). This contradicts the established fact that the cost price of desalinated water is presently estimated at less than $(0.55) per cubic meter as the Author mentioned in his paper.

4. The projected price of one cubic meter of desalinated water of the Tampa Bay seawater desalination plant which is adopted as an example in the paper (a projected average for 30 years) is quoted as $0.659 per cubic meter. The price of $(0.45-0.49) per cubic meter given in the paper should be referred to as a co-funding price.

5. The Author agrees with the fact that the cost price per cubic meter of groundwater derived from the GMRP for phases 1 and 2 was competitive with desalination alternative at the time of inception of the GMRP. He claims that the situation recently shifted in favor of seawater desalination. Recent survey of groundwater development in Libya and Jordan indicates clearly that the option of groundwater development is still cheaper and competitive with the desalination alterative as shown below:

- Al Jaghboub-Tobruk System $0.296 per cubic meter.
- Ajdabiya-Tobruk system $0.274 per cubic meter. (3)
- Ghadames-Zwara–Zawia System $0.330 per cubic meter.
- Al Kufra-Tazerbo System $0.171 per cubic meter.
- Disi-Amman system $0.33 per cubic meter. (4)

6. The higher productivity of groundwater irrigation is veracious and should be brought as a factor in the comparison. The results of studies in Spain (5) emphasize that groundwater irrigation is several times more productive in terms of money and jobs. Groundwater is the cheapest and fastest way to achieve outstanding socio-economic benefits. In order for desalinated water to be used in agricultural purposes additional costs are needed for distribution and blending with low quality groundwater.

7. Even though some of the environmental effects have been satisfactorily addressed other environmental and ecological consequences of disposing large volumes of desalination brines, thermal discharges and air pollution should be taken into account when planning a massive desalination plant. Thus, it makes no sense to encourage economic growth through desalination only to destroy the environment that sustains the people in the region. There is no assurance that desalination plants can be compatible with the environment. On the other hand, environmental impact study on the GMRP does not indicate serious negative impacts on the environment.

8. The paper envisages the beneficial use of large scale seawater desalination when blending it with GMRP transferred water especially in case of (phase 2) where the average nitrate concentration exceeds 60 PPM. It should be noted that the problem has been affectively dealt with either by abandonment of water wells with high nitrate concentration or by blending with the waters of other wells. The over-all nitrate concentration of the conveyed water to the end users ranges between (20 to 40) PPM which is below the permissible WHO guideline and limits.

9. The Author claims a possible occurrence of full depletion in GMRP aquifer system (in his response to the GMRA comments, the Author has withdrawn his claims about depletion re-explaining the concept of depletion in a vague way). The results of the hydrogelogical modeling and wellfield optimization performed on the existing GMRP wellfields do not indicate a full depletion status of the aquifers throughout the 50 years project period and water level drawdowns will not exceed the economic pumping lift. According to the recent modeling 2001 study performed by (CEDARE)*(7) the recoverable reserve groundwater volume for the Kufra Basin is estimated at 245.51 cubic km. Assuming a maximum allowable water level drawdown of 100 meter, and a planned future abstractions of 1090 MCM per year, the available resource would sustain this supply for the next 225 years. The maximum draw down at the center of GMRP well field ranges from 30 to 40 meter at the end of 60 years of continuous abstraction amounting to 1.68 MCM per day. Thus, the added costs of depletion introduced in the paper are based on conjecture rather on sound hydrogelogical calculations. No interruption is anticipated for the water supply of the Great Man-Made River Project wellfields.

10. The Author agrees with the fact that Libyan experience with seawater desalination is not encouraging due to the low operating capacities in comparison with their full operating potential. He attributes these shortcomings to the fact that “desalination plants in Libya have not been taken seriously in the past”. The Tampa Bay desalination plant in Florida, (USA) was adopted in the paper as a recent example of large scale desalination feasibility (95,000 cubic meter per day and planned expansion of 37,000 cubic meter per day) also

run through numerous technical and operating difficulties. The performance tests run at different dates have revealed many deficiencies in the plant including excessive membrane silting compounded by Asian green mussels clogging the filters (6). In addition, three of the (BOT) companies involved in the project have filed for bankruptcy. First 20,000 cubic meter of water was produced in March 2003 (the date of issuing the paper) subsequently the plant has run sporadically, producing far short of its intended output. This clearly shows that the large scale desalination option somehow is unreliable and lacks the required sustainability.

11. If the environmental impacts of desalination plants are satisfactorily addressed, planning of desalination plants in Libya would introduce a level of diversity of sources of water which is necessary to prevent over-reliance on a single source (groundwater). In this manner, sustainability of the resource is assured and in addition keeping water supply affordable.

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