Salinity Problems in Northern Cyprus and Desalination Applications

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Abstract

Northern Cyprus (NC) lives water scarcity problems and it is expected to increase in future due to the reduction in rainfall owing to the climate change.

In Northern Cyprus, the annual water consumption is about 100 MCM, in which the share of the agricultural water is 70 %, whereas domestic water consumption is 30 %. The small industry in the country is supplying water from the municipal networks. Despite the water limitation in the country, the water consumption is 250 l/day/capita, and the share of the householders, industry and water trade is 80%, 12% and 8% respectively. The water in the country is mainly supplied from the groundwater resources (95 %), dams, ephemeral springs, desalination plants and transported water.

Poor water management has impacts on aquifers of the region, which end up with salinization problems due to the seawater intrusion. In this study, salinity problems in NC and desalination applications have been mentioned.

Key words: desalination, water scarcity, NC, groundwater salinization

Introduction

Population growth, pollution and climate change, all accelerating, are likely to combine to produce a drastic decline in water supply in the coming decades, according to the World Water Development Report. At present 1.1 billion people lack access to clean water and 2.4 billion lack accesses to proper sanitation, nearly all of them in the developing countries. Yet the fact that these figures are likely to worsen remorselessly has not been properly grasped by the world community, the report says. "Despite widely available evidence of the crisis, political commitment to reverse these trends has been lacking" (Independent 2003).

Although in general water scarcity is met many countries in the world, Cyprus lives this problem more heavily owing to being a remote island in Mediterranean Sea.

1. Water Resources in Cyprus

Northern Cyprus (NC) has very limited water resources owing to being a part of a small island with a surface area of 3355 km^2. The main water resource is groundwater with a safe yield of 74.1 MCM, contributing not only to the domestic but to the agricultural sector as well. Mainly, there are three big aquifers, Magosa, Guzelyurt, Girne aquifers in NC with a variable capacity (Elkiran and Ergil 2002).

Magosa aquifer is located in the East of the country with an area of 45 km^2 of which 20 km^2 is located in the North, which was one of the main aquifer supplying water to the country in 1960s. However it is completely salinated by sea water due to over-pumping beyond its safe yield. The aquifer is completely damaged and cannot be used for any purpose nowadays (Ergil 1999).

Guzelyurt aquifer is situated along the west of NC near Guzelyurt bay. It is the most important water reservoir and has the highest agricultural potential of NC. The aquifer rests on an impervious layer of 100-120 meters below sea level. The aquifer area is 180 km^2 in the North and 100 km^2 in the South. The annual average rainfall between 1993 and 1998 is about 300 mm. The capacity of the resource is 37 MCM, however this can be hardly met in wet seasons, inasmuch, the recharge capacity has reduced to 15 MCM in drought seasons due to lack of intensive rainfall. The total storage capacity of the aquifer is about 920 MCM (Elkiran 2006; Alkaravli 2002).

Girne Aquifer consists of two aquifers, Girne Coastal and Girne Mountains aquifers. Girne Mountain aquifers consist of one single craggy crest with an elevation of 750 meters and with a total area of 62 km^2. The limestone and dolomite stones located in the centre of the region are heavily fractured and allow water to flow directly to the sea, hence the storage capacity is about 10 MCM, however the recharge capacity in the dry seasons is about 5 MCM. The water table between the compartments is varying from 250 m to 100 m above mean sea level (UNDP 1970; Mollaoglu 1985).

Former experiences indicated that, about 74.1 MCM of water could be safely withdrawn from the aquifers annually. However, because of the water requirement 28.9 MCM of water is over extracted annually from the aquifers of the North Cyprus (Table 1) (Gokcekus 1999, Bozer 1999).

The temperature in the overall Cyprus is very high and hence the evaporation effect reduces the contribution of the rainfall to the ground. From the researches, it is found that, the temperature increase in Southern Cyprus based on a hundred years of data is 0.01 ^oC/year (Tsiourtis 2002),

whereas in NC between 1980 and 2004, the temperature increase is found to be 0.45 ^{o}C/year (Sharifi 2006). Annual averages of regional evaporation of NC are, 4.2 mm/day in Girne, 6 mm/day in Guzelyurt, 6.1 mm/day in Lefkosa, and 4.7 mm/day in Gazimagusa (Goymen 2003).

Table 1: Aquifer capacities and their consequent conditions after the annual extractions in NC (DSI 2003)

Aquifers	**Recharge (10^6 m^3)**	**Safe Yield (10^6 m^3)**	**Withdrawals (10^6 m^3)**	**Situation (10^6 m^3)**
Guzelyurt	37	37	57	-20 (deficit)
Akdeniz	1.5	1.5	1.5	-
Lefke-G.Konagi-Y. dalga	15.5	6	6	-
Yesilirmak	7	1.5	1.5	-
Girne Mountains	11.5	11.5	11.5	
Gazimagusa	2	2	8.5	-6.5 (deficit)
Beyarmudu	0.5	0.5	0.5	-
Cayonu-Guvercinlik-Turkmenkoy	2	2	2	-
Lefkosa-Serdarli	0.5	0.5	0.5	-
Yesilkoy	1.6	1.6	3	-1.4 (deficit))
Girne Coast	5	5	5	-
Yedikonuk-Buyukkonuk	0.3	0.3	0.3	-
Dipkarpaz	1.5	1.5	1.5	-
Korucam	1.2	1.2	1.2	-
Others	2	2	2	-
Total	**89.1**	**74.1**	**103**	**-28.9** (deficit)

There are 41 dams constructed in the country in order to contribute to the agricultural sector and allowing recharge to the aquifers in the regions. Only 18 of the dams are contributing to the agricultural sector with a total capacity of about 20 MCM, in which two of them are suffering from sediment accumulation transported by ephemeral rivers in the country (Mavioglu 2004).

The water deficiency experienced in NC enforced the governments to search the other water resources to be alternative in order to reduce the immense pressure on the aquifers. Hence in 1998, bringing waters in large water bags towed by tugboats or tankers of varying capacity from 10000 to 30000 m^3 from Turkey were found feasible, in order to supply municipal water needs and hence, to reduce the water extractions from the available aquifers. These bags were filled with water in Aydincik, Turkey, and brought to Kumkoy reservoir, which is a place near Guzelyurt. The first ship arrived in September 1998 and during the whole year. Unfortunately, only 65374 m^3 of water were carried in five trips. This was highly below the expectations of the feasibility studies. In the following two years from 1999 to 2000, the water transported by bags from Turkey had reached up to 217988 m^3 (14 trips) and 579339 m^3 (49 trips), respectively. These values were followed by 1719010 m^3 (77 trips) in 2001 (Mavioglu 2004). The total quantity of water imported from Turkey during five years (1998-2002) was only 4.1 MCM, however the transfer of 5 MCM of water per year was planned. As it is noticed, the total value could not be achieved during these five years of time interval. The technical problems

experienced during the transportation made the project inefficient for water transfer. Thus, the contract between the company and the General Directorate of State Hydraulic Works (DSI) was abolished and the project stopped in 2002 (Sidal 2006).

Recently, a new project is being carried out for the construction of an undersea pipeline between Turkey and NC. The feasibility study on the transportation of water by tankers from Manavgat-Turkey to Kumkoy-NC, with a capacity of 40000 m^3 indicates that 0.46 USD/m^3 of cost, considering only the transportation charges. However, when port-handling charges were also included, this value rises up to 0.79 USD/m^3 (Bicak and Jenkins 2000).

There are three central wastewater treatment plants in the country, in which the biggest one is constructed in Lefkosa region allowing the treatment of the waste water coming from the North and South. The quantity is about 3.5 MCM which is diverted to the channel bed to flow to the sea. The reuse of this effluent water is out of the concept due to traditional belief among stakeholders (Mavioglu 2004). However, it is strongly evident that the reuse of recycled water is essential in the coming decades. There is also few local treatment plants established by the institutions in order to be used in the irrigation of green gardens at the environment, which is enforced by the department of Tourism Department. The total wastewater treated in locals is about 0.4 MCM (Muslu 2003).

There is no perennial stream in NC. Ten of the streams originated from Trodos Mountains of Southern Cyprus are carrying 43 MCM of water per year. However, most of them are controlled by the South Cyprus owing to the dam constructions at the upper reaches (Elkran and Ergil 2004). Approximately 27 MCM of water is carried by 28 of the streams located in Northern Cyprus annually (Ozturk 1995).

Today, out of 110 ephemeral streams, 59 of them are worth for recording with a total discharge capacity of 1.4 MCM per year, as for the remaining of the streams were dried up completely. Domestically, 34 streams are in use for municipal water (0.8 MCM per year) and 28 for irrigation purposes (0.6 MCM per year) (Ozturk 1995; Mavioglu 2004).

2. Salinity Problems

The water scarcity in Cyprus has started in 1960s and soon after, several researches identifying the situation are carried out by United Nations Development Program (UNDP 1970). Unfortunately, the continuous over extraction of water from the underground resources in the recent years caused some of the coastal aquifers to be salinated up to 5000 ppm NaCl and some others even depleted locally at the inner parts of the country (Elkiran and Ergil 2002).

Unrestricted water extractions, increase in the population, contamination of the water resources and salinization of the coastal aquifers, reduced the safe yield of the water that can be supplied to the householders (Mollaoglu 1985).

In 1960s the main aquifer supplying water to the whole country was Magosa aquifer which is situated in the East of NC. However, the over-abstraction from this resource cause complete salinization of the aquifer and nowadays it is out of use (Ozturk, 1995). Soon after; all the pressure was given to Guzelyurt aquifer which is located in the West of the country. However, the over extractions from this aquifer was also continued and the aquifer water quality was reduced to 5000 ppm in salinity in some local regions. Hence, the tab water cannot be used as a drinking water and bottled water is preferred (Bozer 1999; Ergil 1999).

In NC, agriculture contributes a lot to the economy. Citrus fruit occupies the greatest part of the production in agriculture and the revenue of the export is also high (Elkiran and Ergil 2004).
The distribution of cultivated area and production yield of citrus fruit for the three main regions in Northern Cyprus are, 5475 ha for Lefkosa (16 tons/ha), 53 ha for Gazimagusa (12 tons/ha) and 361 ha for Girne (4.5 tons/ha). Approximately, 39.4 % of the citrus fruits are exported to the other countries and nearly 6 % is consumed within the country and 54.6 % is used for the industrial sector. Owing to limited water resources and degradation of water quality only 10 % of the total agricultural land can be cultivated (ASP 1996-2004).
In NC, the water consumption within the aquifers is far beyond their safe yields and the fruit yields of the crops are far below the expectations. As an example, the average yield of orange trees is 15 t/ha, in 2001, whereas the expectation was 35 t/ha. The decrease in the yield can be seen in all the crops and orchards (ASP 2001, Markou and Mavrogenis 2002). In addition, the decrease in the yield is aggravating every year (ASP, 1996-2004).
Owing to the limitations in water resources and decrease in water quality, agricultural income in 2001 was found to be 41 million US Dollars, however it would be 72 Million US Dollars if water quality and land reclamation were considered (Elkiran and Turkman 2007).

3. Desalination Applications

The number of people living in water scarce countries is 430 million, which is about 8% of world population. This ratio is expected to increase to 25% by 2050 (http://www.sci.sdsu.edu/salton/).
Desalination is getting more and more popular in the world due to the increase in water scarcity and reduction in cost of membrane processes. At present, there are 4000 desalination plants in 120 countries in the world. Total capacity of these plants is 13 250 000 m^3/day and more than 60 percent of this capacity is in Middle East. In USA the total capacity of 800 desalination plants is 850 000 m^3/day and most of these plants serve industries (www.ncseonline.org).

Israel decided to address water scarcity problem by launching a desalination project which plans the construction of several seawater treatment sites along its Mediterranean coastline. The Ashkelon unit is the first of the series. Its production represents 25 percent of Israel's initial goal of 400 million cubic meters if drinking water a year. By 2020, the country aims to produce 750 million cubic meters. The drinking water that is produced in Ashkelon costs around 52.7 cents per cubic meter, which has been evaluated as the lowest price in the world for this kind of operation (http://www.water-technology.net/projects/israel).

Membrane process applications in Turkey were started in 1990. Over the last 16 years these processes have shown considerable development. The capacities of membrane process systems in Turkey vary between 1 m^3/day to 2000 m^3/day. In general, the influent quality varies between 200-2000 μs/cm, but there are application examples reaching to 10 000 μs/cm in groundwater and 60 000 μs/cm in seawater.
According to the data collected from the companies operational expenses are in the order of 0.3-0.4 USD/m^3 of product water in groundwater and 0.9 USD/m^3 of product water in seawater applications.

For the industrial systems, the construction cost varies between 3000-150 000 USD. The data collected from the companies indicate that at the end of year 2000 the total capacity of systems was 44 634 m^3/day. The maximum application was observed in 1998 (7585 m^3/day). Due to the economical crisis in 2001 and 2002 membrane process applications were less than expected (Gemici et al, 2006).

Table 2 gives comparative costs of reverse osmosis (RO) desalination for several Latin American and Caribbean countries

Table 2: Comparative Costs of RO Desalination for Several Latin American and Caribbean Developing Countries (http://www.oas.org/dsd/publications/Unit/oea59e/)

Country	**Capital Cost ($/$m^3$/day)**	**Operation and Maintenance ($/$m^3$)**	**Production Cost* ($/$m^3$)[a]**
Antigua	264 - 528	0.79 - 1.59	
Argentina		3.25	
Bahamas			4.60 - 5.10
Brazil	1454 - 4483		0.12 - 0.37
Chile	1300		1.00

[a] Includes amortization of capital, operation and maintenance, and membrane replacement.

Desalination plants have already been implemented in Cyprus in 1990s, in Southern Cyprus and 2000s in Northern Cyprus. The number of desalination plants is increasing every year (Elkiran 2006).
The use of desalinated water in NC is very limited. Two institutions located at the coastline have experienced it with about 0.4 MCM per year with a cost of 0.7 Euro/m^3 (Elkiran 2006). However, the moderate scale of desalination plant is constructed at the Karpaz region in order to serve the new hotels constructed in the region and the stakeholders in the region as a domestic use, based on Built-Own-Operate-Transfer system, in which the cost is about 0.97 USD/m^3 and the quantity of water treatment is expected to be 2000 m^3/day (Kibris 2007).
Seawater desalination has some advantages as indicated below:

- It is a reliable and independent water source
- Cost is getting lower owing to the research and developments

Especially in Cyprus, where the water resources are limited and transportation is difficult, the desalination plants have a big potential in future.

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