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Water loss through evaporation from water surfaces of lakes and reservoirs in Turkey

ABSTRACT

The objective of this study[2] was to estimate the amount of evaporative loss from fresh water lake and reservoir surfaces in Turkey and to compare it with supplied water in Turkey. In this study 129 lakes and 223 reservoirs were subjected to evaporation estimates. The total surface area was 3213.97 km^2 and 4026.16 km^2 for the lakes and the reservoirs, respectively. Results showed that total evaporation loss from reservoir and lake surfaces is about 6.8 x 10^9 m^3 per year, 2.7 x 10^9 m^3 from lakes and 4.1 x 10^9 m^3 from reservoirs. This amount exceeds the total annual water consumption of Turkey that is met from ground water and the amount of domestic use (5.7 x 10^9 m^3) and industrial use (4 x 10^9 m^3) in 1999.

KEYWORDS: Evaporation; Water reservoirs; Fresh water; Surface area; Water consumption; Evaporation control

INTRODUCTION

All living things depend on water. It is essential for many aspects of human existence, from life itself to agricultural to production of energy. However, the distribution of water is not homogeneous around the world, even though more than two-thirds of the world is covered with water. In some places, a majority of the populace does not have access to adequate amounts of fresh water. In addition population growth, industrial developments, increases in energy demand, tendency toward irrigation in agriculture, and rising quality of life standards have resulted in an increase in importance for water resources that are already short in supply. These limited water resources cause conflicts among cities and towns in the same country, and also among neighbouring countries. Problems with water scarcity are found across the globe [1, 2], including in Turkey. For instance, water issues are the basis for serious conflict in the Middle East. Therefore, Turkey needs to develop and use its resources effectively so that the wasting of water is minimized. In Turkey, for decades much effort has been made and money invested in the developing of water resources. These efforts and investments, in addition to creation and maintenance of water distribution systems, include construction of manmade resevoirs, such as ponds, and dams constructed on the rivers.

One of the most effective water loss processes is the evaporation from natural water bodies, such as lakes, or artificial water bodies, such as dams. Although much effort, time and money is invested in storing water in these reservoirs, evaporation occurs often in large quantities.

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For example, in late 1950s total evaporation from water surfaces in the United States was greater than the total amount of water withdrawn for domestinc purposes by cities and towns [3].

The main purpose of this study was to estimate the amount of evaporative loss from water surfaces and to compare it with supplied water in Turkey.

In order to determine the amount of usable water in Turkey, the water suppy of the country must be examined. According to data from the State Hydraulic Works, the average annual precipitation is 642.6 mm. This is the equivalent of 501 x 10^9 m^3 water, of which 186.05 x 10^9 m^3 (approximately 37 percent) runs into rivers, lakes, and seas as runoff [4]. Using all the available water resources is not technically possible. Because certain amounts of water must remain in rivers to meet the legal demands of neighbouring countries, to prevent sea water from moving inland, to maintain the viability of wetland ecosystems, to prevent water pollution, and to provide opportunities for transportation on the rivers. In addition, in some cases the topographic and geologic structures of the land make it impossible to built reservoirs or dams for water storage. For these reasons, in Turkey the amount of usable water from the rivers is estimated to be 95 billion m^3. On the other hand, the amount of potential usable ground water is approximately 12.3 x 10^9 m^3. Thus, total usable water potential of Turkey is 107.3 x 10^9 m^3 [4].

Turkey certainly is not a water-rich country from the perspective of annual water consumption per person. In order to be accepted as a water-rich country, annual usable water must be much more than 10^4 m^3 per person [5]. If the total amount of 107.3 x 10^9 m^3 of usable water is divided by the population of the country acorrding to 2000 census (67 803 927 people), annual consumable water is approximately 1582 m^3 per person, which is much less than 10^4 m^3. In other words, it is particularly necessary to conserve the amount of usable water and control evaporative losses, especially from lake and reservoir surfaces.

MATERIAL AND METHODS

To estimate evaporative loss on Turkish water bodies, the names and surface areas of the lakes were obtained from “Turkish Waters” [6], and the names and surface areas of the reservoirs were obtained from “Dams and Hydroelectric Power Plants in Turkey” [4, 7]. The names and surface areas of the reservoirs built during Ottoman Empire in Istanbul were derived from annual activity report of Istanbul Water and Sewage Works [8], as well as from other publications [9]. Based on these references, evaporative losses estimated in this study included 223 reservoirs in operation and 129 lakes (Table 1).

In order to estimate evaporation from water bodies, the most commonly used method is to multiply pan evaporation by a coefficient [10]. This value, called “pan coefficient,” varies between 0.5 and 0.8 and it is between 0.70 and 0.75 for evaporation estimates from lake surfaces. This coefficient was chosen to be 0.70 in this study, as recomended by Pereira [11], Bayazıt [12], and Schwab et al. [13].. Evaporation records of meteorological stations were obtained from the State Meteorological Service [14, 15].

Evaporation cannot be measured throughout the year due to frost events during the winter months at most meteorological stations. This is the reason that some evaporation measurements could not be recorded. Therefore, available monthly evaporation values were added up to estimate total annual evaporative loss of each meteorological station. Thus, estimated evaporation values should be accepted as the lowest evaporative loss, because these estimates included only frost-free months for each meteorological station.

To calculate water loss from the surface of each lake and reservoir, the nearest meteorological stations were selected to determine an applicable evaporation pan value. The surface area of each lake or dam was multiplied by the pan evaporation value of the nearest meteorological station and pan coefficient. In this way the variance of evaporative losses among different regions due to different climatic conditions was taken into account.

RESULTS AND DISCUSSIONS

If surface areas of the tiny lakes and manmade reservoirs are ignored, total surface areas were found to be 3213.97 km^2 for the 129 lakes and 4026.16 km^2 for 223 reservoirs/dams which currently are in operation (Table 1). Thus, the total surface area of fresh water lakes and reservoirs dams was 7240.13 km^2 (Table 1).

Table 1: Surface areas and evaporative losses of lakes and dams in Turkey.

	Number	Surface area (km^2)	Evaporation (10^9 $m^3.year^{-1}$)[1]
Lakes	129	3213.97	2.7
Reservoirs/Dams	223[2]	4026.16	4.1
Total	352	7240.13	6.8

[1]estimated according to maximum area of the water surface
[2]including 202 dams, 7 reservoirs built during Ottoman Empire, and 14 dams constructed in the lakes.

Total evaporative loss from fresh water surfaces averages 6.8 x 10^9 m^3 per year, of which 2.7 x 10^9 m^3 is from lakes and 4.1 x 10^9 m^3 from reservoirs (Table 1). This amount of water loss through evaporation is greater than the 6 x 10^9 m^3 of water that is the annual water consumption met from ground water [16]. In another words, evaporation from the surfaces of lakes and dams in Turkey is greater than the amount of water that is withdrawn from ground water. Also, it is greater than the amount of domestic use (5.7 x 10^9 m^3) and industrial use (4 x 10^9 m^3) in 1999 [16]. Moreover, evaporative loss was more than one-fifth of the 29.2 x 10^9 m^3 of water used for irrigation in 1999 [16].

Situation in Istanbul

Even though the evaporative loss mentioned above included water loss from surfaces of lakes and reservoirs that meet the water needs of Istanbul, it is important to discuss evaporative loss from municipal reservoirs and lakes in Istanbul. Because population increase and industrial developments have increased water demand and made it necessary to have intensive

investments for new water storage and distribution facilities in Istanbul. This fact has increased the cost of water per unit volume in the city. From this point of view, Istanbul is in the first order in Turkey, and for this reason, each unit volume of water stored should be kept with minimum loss as much as possible at reservoirs and during the water distribution. As seen in Table 2, the surface area of the lakes and reservoirs that provide fresh water to Istanbul City is 112.75 km^2 and the average annual evaporative loss from that area is 65.488 x 10^6 m^3 (Table 2).

The annual water demand of Istanbul City was 939 x 10^6 m^3 in 2000 [17]. This means that daily water consumption of Istanbul was 2.57 x 10^6 m^3. If the daily water need of the city is compared with annual evaporative loss, then it can be seen that the amount of evaporation from lake and reservoir surfaces in Istanbul can meet that city's water demand for 25.5 days.

Table 2: Lakes and reservoirs in Istanbul, and their surface areas and evaporative losses.

Name	Surface area (km^2)	Evaporation (10^6 $m^3.year^{-1}$)[1]
Topuzlu Reservoir	0.03	0.015
Valide Sultan Reservoir	0.05	0.027
Sultan Mahmut Reservoir	0.05	0.028
Kirazlı Reservoir	0.02	0.013
Ayvad Reservoir	0.05	0.029
Karanlık Reservoir	0.03	0.016
Büyük Reservoir	0.26	0.153
Terkos Lake	25.00	14.521
Ömerli Reservoir	23.45	13.621
Elmalı-2 Reservoir	0.83	0.482
Alibey Reservoir	4.42	2.567
Büyük Çekmece Lake	43.00	24.977
Darlık Reservoir	5.56	3.230
Sazlı Dere Reservoir	10.00	5.809
Total	112.75	65.488

[1]estimated according to maximum area of the water surface

CONCLUSION

Available water in Turkey is 107.3 x 10^9 m^3 and the annual evaporative loss from the surfaces of lakes and reservoirs is around 6.8 x 10^9 m^3. Since Turkey is not a rich country in terms of water resources, necessary measures should be taken to consider future water requirements of the country and to keep water losses as low as possible.

These measures include: selection of deep valleys for building dams and reservoirs to store a greater amount of water with a correspondingly smaller surface area; phreatophyte control; minimization of water losses in water distribution systems by using better and more reliable facilities; and use of underground reservoirs if physical and geological conditions permit [13]. In addition to these measures, some chemical substances (e.g., Hexadecanol) and very thin wrapper materials can be used to cover especially small water surfaces, and other measures such as mechanical wind fences could also be established to prevent water loss due to evaporation [3, 18, 11, 13]. Among the measures mentioned above, the most feasible and applicable methods are selection of deep and narrow valleys to construct dams and reservoirs to minimize water surface area with higher storage capacity, phreatophyte control, and decreasing water losses taking place in the water distribution systems.

REFERENCES

[1] [1] Frey, F. W. (1993) Power, conflict, and cooperation, Research & Exploration, Water Issue, pp.18-37.

[2] Kolars, J. (1993) The Middle East's growing water crisis. Research & Exploration, Water Issue, pp. 38-49.

[3] Eaton, E. D. (1958) Control of evaporation losses, United States Government Printing Office, Washington, USA.

[4] State Hydraulic Works. (1999) Dams and hydroelectric power plants in Turkey, DSI Teknoloji Dairesi Başkanlığı Basım ve Foto-Film Şube Müdürlüğü, Ankara, Turkey.

[5] Avcı, I. (1996) Middle east and water problem (Ortadoğu ve Su Sorunu), Cumhuriyet Gazetesi, 11-17 Ocak, Istanbul, Turkey.

[6] Munsuz, N., Ünver, İ. & Çaycı, G. (1999) Turkish waters (Türkiye Suları), Ankara Üniversitesi Ziraat Fakültesi Yayınları No: 1505, Turkey.

[7] State Hydraulic Works. (2002) http://www.state hydraulic works.gov.tr

[8] ISKI. (1985) Activity report and budget (Faaliyet Raporu ve Bütçesi), Istanbul Su ve Kanalizasyon idaresi, İstanbul, Turkey.

[9] Çeçen, C. (1957) Water facilities of Taksim (Taksim Suyu Tesisleri, in Turkish), İstanbul; Belediyesi Sular İdaresi. Sayı:3, İstanbul, Turkey.

[10] Brooks K.N., Ftolliot, P.F., Gregersen, H.M. & Thames, J. L. (1996) Hydrology and the management of watersheds, Iowa State University Press, Ames, Iowa 50010, USA.

[11] Pereira, H. C. (1973) Land use and water resources in temperate and tropical climates, Cambridge University Press, Bentley House, London.

[12] Bayazıt, M. (1991) Hydrology (Hidroloji, in Turkish), Istanbul Technical University, İnşaat Fakültesi, Matbaası, Istanbul, Turkey.

[13] Schwab, G. O., Fangmeier, D.D., Elliot, W.J. & Frevert, R.K. (1993) Soil and water conservation engineering, Fourth Edition, John Wiley & Sons, Inc. New York, USA.

[14] DMI. (1974) Mean and extreme meteorological bulletin, Ministry of Food, Agriculture and Animal Husbandry, State Meteorological Service, Ankara, Turkey.

[15] DMI. (2002) Evaporation data for meteorological stations, Ministry of Food, Agriculture and Animal Husbandry, State Meteorological Service, Ankara, Turkey.

[16] State Hydraulic Works. (2001) 1999 Statistical bulletin (1999 Haritalı İstatistik Bülteni), DSİ Genel Müdürlüğü, G. Yayın No: 991, Grup No: VIII. Özel No: 177, Ankara, Turkey.

[17] Eroğlu, V., Sarıkaya, H. Z. & Saatçı, A. M. (2001) Water supply and quality in Istanbul, Pages 71-78 in Proceedings of international symposium on water resources and environmental impact assessment, July 11-13, 2001. Istanbul-Turkey.

[18] Cluff, B. (1966) Research on evaporation reduction relating to small reservoirs. 1963-65, The Institue of Water Utilization Agricultural Experiment Station, The University of Arizona, Tucson, Arizona.