A study on assessing the domestic water resources, demands and its quality in holiday region of Bodrum Peninsula, Turkey

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HIGHLIGHTS
- Domestic water supply, demand, and its quality of Tourism regions.
- Population diversity and projection of Bodrum peninsula, tourism region in Turkey.
- Water needs of tourism regions according to population diversity and water resources.
- Domestic water project needs for tourism region.
- Importance of water for Bodrum peninsula.

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ABSTRACT

The Bodrum peninsula is one of the more important tourist locations in Turkey. Due to an increasing population and tourism demand, water shortages have emerged as a significant problem during the summer months in recent years. It has now reached the point where the peninsula no longer has a sufficient, safe and continuous water supply to meet its needs. In this study, population projections of the peninsula until the year 2060 are provided along with estimates of the water needs of the population, the amount of water resources available and the resources that need to be developed to supply water of the required quality. It is concluded that, given population growth and tourist demands, in each of 2020, 2030, 2040, 2050 and 2060 water needs will be 23.47; 32.46; 45.52; 60.76 and 83.18 hm³/year.

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1. Introduction

In tourist areas, resident populations can show seasonal variation in numbers as they respond to tourist visitation patterns. Such population variations may also be exacerbated by holiday home ownership when owners not only reside there but may also rent out the accommodation. In the regions where there is mountain tourism, there is a definite increase of population in the winter months, while in the areas where coastal tourism exists there is a peak increase in the summer months. The summer population in these regions can be multiple times of the winter population.

Given these variations in population, there will be a corresponding increase in the summer need for water as compared to the low seasons. Thus the management of water resources becomes more important in regions that experience such changes in their population. The water consumed in the Spanish Balearic Islands in July of 1990 was equivalent to 20% of the total water consumed by the local population in one year (EEA, 2003, p. 341). Due to the development of tourism in that part of Spain, the demand for water increased by 15 times from 1980 to 1995. Another example is that of Noirmoutier, an island off the Atlantic coast of France. The local population of the island is about 9000 people. In the summer...
months, the population can increase to between 90,000 and 130,000 people. Correspondingly, water consumption also increases in the summer months. Daily water consumption is 11,000 m³/day in August and 1800 m³/day in the winter months (Xu, Valetta, Brissaud, Fazio, & Lazarova, 2001). While the share of water use for tourism in Rhodes is unknown, it reaches about 4.8% of domestic water use in nearby Cyprus (Gössling et al., 2012), or 10% of indirect water use (Hadjikakou, 2014). A lack of studies on tourism and the demand for water relation has made it difficult for the tourism sector to engage in the political debate about these concerns (Crase, O’Keefe, & Horwitz, 2010). Most research on the direct consumption use of water for tourism has been in the dry areas of Australia (Crase et al., 2010; Pigram, 2001; Lehman, 2009) and in relation to the Mediterranean countries (Kent, Newnham, & Essex, 2002; García & Servera, 2003; De Stefano, 2004; Essex, Kent, & Newnham, 2004; Rico-Amoros, Olcina-Cantos, & Sauri, 2009; Tortella & Tirado, 2011; Gössling, 2015; Stefano, 2004; Tekken & Kropp, 2015).

The trend for tourism development, which started in the Western Mediterranean, has shown a rapid growth in Turkey and more generally the Aegean in the last 30 years, and the Mediterranean coasts have quickly become home to tourist facilities and second homes. However, uncontrolled population growth, and failure to keep pace with planning, technical infrastructure, legal systems and business systems, along with administrative and political failings, have increased pressure on drinking water resources and led to the emergence of extensive negative impacts on the environment.

While freshwater availability is increasingly under pressure (WWAP, 2012), water use in the tourism sector has received growing attention by organizations such as UNEP (2011), UNWTO (2013), and OECD (2013, p. 24). Water demand from tourism tends to be exceptionally concentrated in space and time (Essex et al., 2004; Hadjikakou et al., 2013; Kasim, Gursoy, Okumus, & Wong, 2014; Sun & Pratt, 2014) and non-academic circles (Becken, Rajan, Moore, Watt, & McLennan, 2013; Tourism Concern, 2012; UNEP-UNWTO, 2012). This study aims to examine the drinking water and potable needs of the Bodrum peninsula, which is one of the more important tourism centers found in the Mediterranean Region. The study provides an analysis until the year 2060 along with expected population growth, the amount of present and the future water resources, their location and development, along with the quality of water being utilized.

2. Material and methods

2.1. Material

The Bodrum peninsula is located at the southern tip of Turkey and has a rich history due to its geographical location in the Mediterranean basin. It has the Gulf of Gülük to its north, Gulf of Gökova to its south and the Aegean Sea to its west. The Bodrum peninsula covers an area of 680 km². The coastline of the peninsula is 174 km. The peninsula consists of the central town of Bodrum and its 55 districts (Fig. 1).

The geological structure comprises Palaeozoic aged schists and limestone. Limestone is a carbonated rock with a permeable structure (usually located in the area closest to the sea) and is common in the peninsula. Carbonated limestones transport the water they absorb directly to the sea. Therefore, limestone regions close to the sea tend to be poor in terms of surface water, and lack the springs and groundwater that are more abundant in interior regions and areas with impermeable beds. Karava and groundwater reserves in Milas illustrate this situation (MM, 1996, 1998; Bakış, 2001). There are no rivers with a steady flow in the Bodrum peninsula; therefore it is not possible to construct any dams (DSI, 2010). The peninsula has a Mediterranean climate. Summers are hot and dry, winters are mild and rainy (Arı, 2010). The average annual rainfall is 681.9 mm. Average highest and lowest temperatures are respectively between 23.8 °C and 18.9 °C. The average sea temperature is 19.4 °C, and the highest values can be seen in the months of August and September (23.5 °C). The total evaporation in the study area is 1862.8 mm and the average monthly relative humidity is 63.66%.

The most important settlements in the Bodrum Peninsula comprise the center of Bodrum along with Turgutreis, Orakent (Yalikavak), Turgutkızı and Karavası. The data obtained on the Bodrum peninsula (for this study) includes information obtained from the Forestry and Water Affairs Ministry, Tourism Ministry, General Directorate of State Hydraulic Works, Municipalities, General Directorate of Environment and Forestry and also earlier
reports and plans. In addition, it is based on the “Bodrum Peninsula Emergency Water Supply Project” which was put into service in 2011 and the report published in 2009 (DSI, 2009). The construction of Bodrum Peninsula Drinking Water Project started in the year 2006. The constructions of Bodrum Peninsula Drinking Water Facilities and Water Transmission Lines and the Drinking Water Treatment Facility were completed in 2009. The project was realised in three phases, namely:

Phase I: The transmission lines which cover the whole peninsula after the construction of Güvercinlik Treatment Plant.
Phase II: The construction of Güvercinlik Treatment Plant and the rehabilitation of present Mumcular Treatment Plant.
Phase III: The construction of transmission lines to Güvercinlik Treatment Plant and to Çamköy groundwater wells, which are raw water resources along with Geyik Dam (Fig. 2).

This project, which will solve the potable and drinking water problem of Bodrum Peninsula until the year 2040, was put into service in 2011.

2.2. Methods

The winter population of Bodrum peninsula can be easily obtained from the official recorded data of Turkey Statistical Institute (TSI). In order to determine the summer population, it is essential to know the population for second homes, tourist inflows and the day-visitor population. However, there is no recorded data related to the population for second homes, and the day-visitor populations. Nonetheless summer population who come to Bodrum is more important in terms of plan and projects related to requirements of drinking and potable water and water management. Therefore, data related to tourism facilities and their bed capacities, total number of residences and occupancy rates in the year have been obtained with this field study. The population and total number of second homes and occupancy rates in the year, and tourism population, tourist facility capacities and occupancy rates and the change in the year were determined by discussion with Municipalities and Tourism Bureau in the region. However, net figures cannot be given for the day-visitors of Bodrum peninsula. Therefore, taking into account past experiences, observation, field studies, and mutual consultations, in this study, day-visitor population is determined as 10% of the tourist population.

In this study, the population projection for Bodrum Peninsula until the year 2060 has been calculated for the winter residents, second home, tourism, and for day-visitor population numbers using the method of Turkish Iller Bank (IB, 1996). This method is derived according to an assumption of geometric growth rate in population estimates. The equations of method used are given below.

\[ C = \left( \sqrt[\frac{P_2}{P_1}] - 1 \right) \times 100 \]  

If \( C < 1 \) then \( C = 1 \); If \( 1 \leq C \leq 3 \) then \( C = C_i \); If \( C > 3 \) then \( C = 3 \)

\[ P_{\text{future}} = P_{\text{past}} \left( 1 + \frac{C}{100} \right)^n \]  

In this equation, \( P_2 \) = new census result, \( P_1 \) = former census result, \( a = t_2-t_1 \) (difference between the two census year), \( C \) = coefficient of variation, \( n = t_{\text{future}}-t_{\text{past}}, P_{\text{future}} \) = future population \( t_{\text{future}}, P_{\text{past}} \) = last census \( t_{\text{past}} \). C coefficient is determined by considering the previous population growth rate, development of areas envisaged in the environmental order and zoning plans. To reveal the population projections of the Bodrum peninsula until the
In this study, depending on the residential unit, coefficient of variation (C) is estimated at 3 for the winter population, between 0 and 3 or the second home population, between 1 and 3 for the tourist population, and 2 for the day-visitor population.

As previously noted, the Bodrum Peninsula is poor in terms of water resources. The primary factors that come into play include the fact that there is an arid and semi-arid climate for approximately six months in the region and that the transitional calcareous formations take up a large amount of space (Güner, 1998). When the drought reaches maximum levels in the summer season, the demand for water increases as there is a large population flow to the coasts. As a result, the lack of supply of water reaches very serious levels in the high season. The water needs of the Bodrum peninsula have been supplied from five water sources since 2011; the total amount of water supplied is 22.52 hm³ per annum (see Table 1).

The drinking water needs of the future population of the Bodrum peninsula have been determined based on daily water consumption per person, population diversity on the value of the network and its leakage losses. The amount of drinking water consumed per person in the cities in Turkey in the 1990’s was 200 l/day, while in 2000 it was 270 l/day (DSI, 2010). The summer and winter population of Bodrum peninsula and the amount of water consumed per person per day in the area of tourism vary according to the seasons and population. In addition, the amount of water that can be consumed by a tourist exceeds 3 times the normal consumption. The amount of water consumed by tourists is estimated as being 300 L per day. This figure can go up to 880 L with luxury tourism. However, the average rural resident uses an average of 150–200 L of water (EEA, 2000). As a comparison, in a study of Majorcan residents, the average water consumption in the countryside is 140 l/day/person, the average water consumption in the countryside is 250 l/day/person, the average tourist consumption is 440 l/day/person and luxury tourist consumption is calculated as 880 l/day/person (Bono & Pietro, 2004). While many water utility companies perform water demand forecasting, they use simple techniques such as estimation by multiplying the projected population per capita water consumption. These methods include the ability to determine the daily water consumption per capita and analysis also depends on the prediction of population by other institutions (Billings, Bruce, & Clive, 2008).

In this study, the amounts of drinking and potable water for the winter population and for the second home population are given in Table 2 for the Bodrum Peninsula. The daily water need for the tourism population has been taken as 350 l/day/person, for day-visitors 72 l/day/person and for important water needs (military facilities, yacht port, sea port) it has been taken as 37 l/day. The amount of water needed over the years has been calculated taking into account winter, second homes, and tourism population types.

In order to determine the quality of the drinking water supply

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**Table 1**


<table>
<thead>
<tr>
<th>Water resources</th>
<th>Capacity (hm³/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peninsular GW</td>
<td>5.00</td>
</tr>
<tr>
<td>Mumcular Dam</td>
<td>5.00</td>
</tr>
<tr>
<td>Karaova GW</td>
<td>2.80</td>
</tr>
<tr>
<td>Geyik Dam</td>
<td>5.00</td>
</tr>
<tr>
<td>Çamköy GW</td>
<td>4.72</td>
</tr>
<tr>
<td>Total</td>
<td>22.52</td>
</tr>
</tbody>
</table>
for Bodrum, since 1995 water samples have been analyzed by the DSI XXI Regional Directorate for Mumcular for the Geyik dams and Çamköy groundwater wells, and these samples have been taken to the Quality and Control Department for laboratory analysis. The raw water supplied to the treatment facilities comes from Çamköy groundwater wells and from Mumcular and Geyik dams. Çamköy wells, Mumcular and Geyik raw water analysis has been compared with Geyik and Çamköy water, and results were evaluated together. The samples taken have been classified according to raw water quality criteria of the “Water Pollution Control Regulation”. According to this regulation, there are four classes of raw water depending on the category of water resources and degree of treatment they require. These classes are:

- **Class I**: high quality water requiring only filtration and disinfection.
- **Class II**: slightly polluted water requiring a normal treatment process.
- **Class III**: polluted water requiring intensive physical and chemical treatment.
- **Class IV**: highly polluted water requiring intensive physical and chemical treatment and advanced biological treatment (Official Gazette, 2004).

### 3. Results and discussions

#### 3.1. Population increase and population projection

The acceleration of the construction of urban complexes used as second homes started after 1980 in Bodrum and caused acceleration in the seasonal population. While Bodrum looks like a coastal town during winter, it can look like a metropolitan city in the summer. Projections of the total population including winter and day-visitor population as well as tourism and second home owners are shown in Fig. 3. Accordingly, the peninsula’s 2020, 2030, 2040, 2050 and 2060 populations will be respectively 447,734, 577,145, 750,027, 922,110 and 1,205,227 people. In the years under review, the total of second home and tourist population is approximately 3 times that of the winter population. The winter population of Bodrum peninsula was 66,677 and the summer population was 216,783 in 2000. The estimated winter population for the year 2060 is 378,464, while the summer population is 868,808. The ratio of the summer population to the winter population varies between 2.30 and 3.25 times in the years examined. It is estimated that the winter population will increase by 5.68 times and the summer population by 4.0 times from 2000 to 2060.

Nowadays, the Bodrum peninsula has predominantly become a center of attraction for tourism. Therefore, it has been a residential
area where many people prefer to become a landlord as second home owners. The distribution by months of population diversity determined based on the projection of the peninsula by 2040 is given in Fig. 4. In particular, tourism and second home population shows significant increases in June, July, August and September. Total population is reaching peak levels in July and August. The expected total population of the Peninsula in July and August of 2040 is respectively 1,413,012 and 1,473,803. Although the total population is 198,439 in the winter months; in the months of June, July and August it exceeds 1 million, which is about 7.43 times the normal population.

The total population of the peninsula for the studied years of 2000-2060, has ranged between 3.18 and 4.15 times the populations of winter. Total population was approximately 3 times that of the tourism and second home population. Tourists from outside the Bodrum peninsula and second home domestic tourist populations are approximately 2.18-2.75 times of the winter population.

### 3.2. Water resources and water demand

In the region, the high temperature and relative humidity also cause an increase in water consumption. Furthermore, since the freshwater resources are limited in the peninsula, this causes a competition between residential, agricultural, urban and industrial uses of water. The high amount of water consumption due to tourist activities increases the pressure on the freshwater resources. The daily peak water need, flow rate, peak factor and the future expected water needs for the peninsula are given in Table 3. Between the years of 2000-2060, the daily peak water need of the Bodrum peninsula changes between 65,972 m³/day and 403,315 m³/day. Within this period, the daily water need has increased by 6 times. In the Bodrum peninsula, in the year of 2000, water demand and daily peak water requirement of winter population was 3.06 hm³ and 15,838 m³/day, of summer population, 9.68 hm³ and 50,134 m³/day. For the years 2025 and 2040, the water demand expected of the winter population is 6.96 and 12.54 hm³, the daily peak water requirement is 104,028 and 163,574 m³/day, respectively. In this case, it is expected that the water demand of summer population will be about twice of water demand of the winter population.

The amount of water that will be needed in the future, according to future population numbers, is shown in Fig. 5. If the population of the peninsula continues in this manner, then the populations in the years of 2025, 2040, 2050 and 2060 are estimated to be 507,824, 750,027, 922,110 and 1,207,227 people respectively. The water needs of the population respectively will be 27.60; 45.52; 60.76 and 83.18 hm³/year. It is expected that the water demand of the tourism and second home population will be 2.8 times the winter population and 2.53 times in 2040.

The drinking water needs for Bodrum peninsula to 2010 have been met from current available groundwater wells (5 hm³/year) in Bodrum center, from Mumcular dam (5 hm³/year) and Karaova groundwater wells (2.80 hm³/year). In order to meet the water needs in the years from 2040, the Bodrum Peninsula Emergency Drinking Water Project was commissioned and completed in 2011 by DSI. The water needs up to 2025 are under the project in Phase I of the peninsula, and Phase II is intended to meet the water needs until 2040. The water resources considered until 2025 in the project

**Table 3**

<table>
<thead>
<tr>
<th>Year</th>
<th>Peak water needs (hm³/day)</th>
<th>Peak factor (→)</th>
<th>Total water need (hm³/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>65.972</td>
<td>1,89</td>
<td>12.74</td>
</tr>
<tr>
<td>2005</td>
<td>76.332</td>
<td>1,88</td>
<td>14.82</td>
</tr>
<tr>
<td>2010</td>
<td>88.447</td>
<td>1,87</td>
<td>17.26</td>
</tr>
<tr>
<td>2015</td>
<td>101.810</td>
<td>1,86</td>
<td>19.98</td>
</tr>
<tr>
<td>2020</td>
<td>118.977</td>
<td>1,85</td>
<td>23.47</td>
</tr>
<tr>
<td>2025</td>
<td>139.114</td>
<td>1,84</td>
<td>27.60</td>
</tr>
<tr>
<td>2030</td>
<td>162.766</td>
<td>1,83</td>
<td>32.46</td>
</tr>
<tr>
<td>2035</td>
<td>190.577</td>
<td>1,82</td>
<td>38.22</td>
</tr>
<tr>
<td>2040</td>
<td>225.740</td>
<td>1,81</td>
<td>45.52</td>
</tr>
<tr>
<td>2045</td>
<td>256.931</td>
<td>1,80</td>
<td>52.10</td>
</tr>
<tr>
<td>2050</td>
<td>297.907</td>
<td>1,79</td>
<td>60.76</td>
</tr>
<tr>
<td>2055</td>
<td>346.637</td>
<td>1,78</td>
<td>71.09</td>
</tr>
<tr>
<td>2060</td>
<td>403.315</td>
<td>1,77</td>
<td>83.18</td>
</tr>
</tbody>
</table>

Fig. 4. Expected peak values by months of the population diversity for 2040.
are; Mumcular dams (5 hm³/year), Geyik dam (5 hm³/year), Karaova groundwater wells (2.80 hm³/year), Çamköy groundwater wells (4.72 hm³/year), and the available groundwater wells (5 hm³/year) of total water resources reaching a value of 22.52 hm³/year. This water need of the population can be met with existing re-wells (4.72 hm³/year), and the available groundwater wells (5 hm³/year). As it can be seen, the current project water resources and 2060 are 27.60; 45.52 and 83.18 hm³/year, then additional water resources need to be allocated by DSI; otherwise it will not be possible to meet the future water needs of the peninsula.

The water resources and the amount of water to be acquired through DSI for the Bodrum Peninsula Drinking Water Project are seen in Table 4. Water needs have been compared with taking into account that the total amount of water to be supplied from the planned sources will be 22.52 hm³/year until 2025, and water shortages have noted. According to the Table 4, if no additional water supply is allocated in the near and medium future, then the lack of the required amount of water in the years 2020, 2025, 2030 and 2040 is estimated respectively to be 0.95, 5.08, 9.94 and 23 hm³/year. As it can be seen, the current project water resources put into service in year 2011 will be sufficient to meet the water needs of the peninsula until 2025. Therefore, in 2025 the Bozalan dam, the Gökçeler dam in the year 2045, and Namnam dam in 2055 will need to be built in order to supply the required sources of water.

In the medium term, water should be allocated to the Bodrum peninsula from Bozalan dam which is on the outskirts of the village Bozalan at Milas district. A total of 23 hm³/year of water should be planned annually from the dam. If the dam is constructed, then the problem of water supply will be solved until 2040. When Gökçeler and Namnam dams are assumed to be in service until 2045, in the years of 2045, 2050, 2055 and 2060, respectively 7, 16, 16 and 17 hm³/year of water will be withdrawn from Gökçeler dam. In the Namnam dam, 10 hm³/year of water in 2055 and 21 hm³/year will be withdrawn in 2060. In this case, the future water needs of the Bodrum peninsula will be met with the existing and planned infrastructure. The current dams and the dams to be constructed are shown in Fig. 6 along with the transmission lines.

It is essential to determine the start up and the end dates for the planning, project creation and construction of dams planned to meet for the water consumption of Bodrum Peninsula by the years to 2060. This is due to the fact that it takes a certain amount of time for the water storage facilities to become operational. Furthermore, important groundwater resources at Karaova, Çamköy and Bodrum are becoming salinized due to heavy withdrawal and their quality has been adversely prejudiced as a result. It has also been determined that every year, water hardness has been increasing due to

![Fig. 5. Total population and water needs of Bodrum peninsula between 2000 and 2060.](image)

<table>
<thead>
<tr>
<th>Year</th>
<th>Total water need</th>
<th>Mumcular Dam*</th>
<th>Geyik Dam*</th>
<th>Karaova groundwater well*</th>
<th>Çamköy groundwater well*</th>
<th>Peninsula existing groundwater well*</th>
<th>Bozalan Dam**</th>
<th>Gökçeler Dam**</th>
<th>Namnam Dam**</th>
<th>Total water supply</th>
<th>Total Water Deficit</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>12.74</td>
<td>5.00</td>
<td>0.00</td>
<td>2.80</td>
<td>0.00</td>
<td>5.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>12.80</td>
<td>0.06</td>
</tr>
<tr>
<td>2005</td>
<td>14.82</td>
<td>5.00</td>
<td>0.00</td>
<td>2.80</td>
<td>0.00</td>
<td>5.00</td>
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<td>0.00</td>
<td>0.00</td>
<td>12.80</td>
<td>-2.02</td>
</tr>
<tr>
<td>2010</td>
<td>17.26</td>
<td>5.00</td>
<td>0.00</td>
<td>2.80</td>
<td>4.72</td>
<td>5.00</td>
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<td>5.26</td>
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<tr>
<td>2015</td>
<td>19.98</td>
<td>5.00</td>
<td>0.00</td>
<td>2.80</td>
<td>4.72</td>
<td>5.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
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<td>2.54</td>
</tr>
<tr>
<td>2020</td>
<td>23.47</td>
<td>5.00</td>
<td>0.00</td>
<td>2.80</td>
<td>4.72</td>
<td>5.00</td>
<td>5.00</td>
<td>0.00</td>
<td>0.00</td>
<td>27.60</td>
<td>0.00</td>
</tr>
<tr>
<td>2025</td>
<td>27.60</td>
<td>5.00</td>
<td>0.00</td>
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<td>4.72</td>
<td>5.00</td>
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<td>0.00</td>
<td>37.20</td>
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</tr>
<tr>
<td>2030</td>
<td>32.46</td>
<td>5.00</td>
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<td>2.80</td>
<td>4.72</td>
<td>5.00</td>
<td>16.00</td>
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<tr>
<td>2035</td>
<td>38.22</td>
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<td>2045</td>
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<td>5.00</td>
<td>23.00</td>
<td>16.00</td>
<td>10.00</td>
<td>95.72</td>
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significant withdrawal of water (MM, 1996, 1998). The pressure on the underground waters has increased due to the climb in demand for water and the heavy consumption of underground waters that have caused both temporary and continuous intakes of sea water at the coastal areas. The excessive consumption of groundwater is observed in many tourism centers and mainly at Mediterranean countries. For example, as per the 2003 EEA, the groundwater has reduced to below seawater levels in Greece, Italy, Turkey, Southern Cyprus, Libya and in the coastal areas of Spain (De Stefano, 2004).

In Bodrum the drinking water project built and restored mains pipelines and storage tanks to the existing water distribution network. However, since the water distribution network is old and decrepit, at present, the water losses in the distribution scheme cannot be handled because of the high cost of repairs, leading to a further loss of large volumes of water. In a study of the water distribution system in the center of Bodrum (Url-3, 2010), it was determined that the water loss rate is 70%. Preemptive maintenance and network renovation are the most important factors influencing the reduction of network losses. Also, speed and quality of the repair of existing damage and regular monitoring of the scheme are important in the management of water network losses. In addition, the leakage flow rate is proportional to the system pressure and it can be overcome to a large extent by the management of correct pressure. Prevention of loss and leakage in the network and to encourage people to save water depend primarily on the correct measurement of the amount of water and incorporation of all water users into the system.

One of the historic water structures in the cultural history of the Bodrum Peninsula is the cisterns which collect rainwater. Just as it has been done in the past civilizations, these cisterns can be constructed at topographically and visually suitable locations in the peninsula by protecting the historical architectural structure. The water stored in the cisterns can be first passed through a filter and then they can be used in bathroom closets and in watering of gardened areas. In the study by Dworak, Berglund, and Laaser (2007), it is observed that the rainwater collection systems should be supported in France and in other Mediterranean countries facing drought climate.

3.3. Quality of water resources

The water needs of the settlement areas in the Bodrum peninsula are met from the present groundwater wells in center of Bodrum, from Karaova groundwater wells, from the waters transported to Mumcular Treatment Facility from Mumcular dam and from the waters transported to Güvercinlik Treatment Facility from water supplied jointly from Geyik dam and Çamköy groundwater wells. The capacity of Mumcular treatment plant is 28,080 m³/day. Phase I of Güvercinlik Treatment Plant is 40,000 m³/day, and Phase II of Güvercinlik Treatment Plant is 40,000 m³/day for a total of 80,000 m³/day. When the deep water 90% probability values for Geyik dam is analyzed, the water quality grade for COD (Chemical Oxygen Demand) and BOD (Biological Oxygen Demand) have been found to be Class IV and for fecal coliform and for total nitrogen it has been found as Class III. Hence, as a result, it is seen that the treatment made with classical treatment techniques will not be
sufficient. Çamköy ground water is very clean. The hardness of Karaova groundwater increases every year due to intensive water withdrawal. As per the analysis conducted between the years 1996–2006 at Mumcular and Geyik dams as well as at Çamköy groundwater, the water quality of these sources has been examined and the concentration limits of organic parameters are per the Water Pollution Control Regulations are given in Table 5 (DSL, 2009).

Both the Mumcular dam water and specially Geyik dam water are in the polluted water classification especially as per COD and BOD. Particularly, the maximum value of Geyik dam is within the classification of heavily polluted waters. The reason for this is due to the uncontrolled discharge of both domestic and industrial waste water at the drainage area of Geyik and Mumcular dams. The combined raw water analysis of Geyik dam and Çamköy ground water along with Karaova groundwater and at well waters in the peninsula shows high Calcium (Ca) values according to the European Union Drinking Water Standards. However, by applying coagulation, the calcium value can be brought to more suitable levels. The combined raw water analysis of Geyik dam and Çamköy groundwater along with water from Mumcular dam also has higher measurements of iron as compared to required standards. The water quality of Geyik dam is Class III as per Water Pollution Control Regulations for Continental Water Resources. These waters which will be used as drinking water and potable water have to be treated, continuously controlled and maintained under observation. The water quality of Mumcular dam is Class II as per the same regulations. This water which is suitable as a drinking water since it has very low pollution, has to be treated. Çamköy ground water is very clean waters. Since due to the project, the Class III water of Geyik dam and Çamköy underground water are combined at the same treatment facility, and as a result this reduces the quality of Çamköy waters, which are classified as clean waters.

Güvercinlik Water Treatment Plant, which treats waters that are combined from Çamköy groundwater and from the Geyik dam, has equipment to control parameters such as turbidity, Ammonia Nitrogen, Calcium, Organic Materials, Iron, Manganese, Total Coliforms and Biological and Chemical Oxygen Demand parameters. Hence, the operations which are selected for processing accordingly comprise of aeration, coagulation, flocculation, sedimentation, filtration and disinfection. The disinfection process is carried out in the facilities with both chlorine and ozone. Furthermore, filtration is performed by both sand and granular carbon filters.

4. Conclusion and recommendations

The importance of the continuous availability of high quality potable and drinking water for the local population as well as for the development of domestic and international tourism is very important in the Bodrum Peninsula. The Bodrum Peninsula Drinking Water Project, which is being constructed by DSL, will meet the water needs of the Bodrum Peninsula until the year 2025. In order to meet the water needs of the Bodrum Peninsula until the year 2060, the Bozalan, Gökçefer and Namnam Dams must be built and put into operation. If the Namnam dam is not constructed, then the water transportation alternative from Dalaman-Akköprü dam must be utilized. It would be impossible to think of leaving such an important and developed region without water.

It is becoming increasingly essential to understand the demand for water and to predict future demand as water resources become scarcer, and water scarcity is experienced more at larger settlements. As a result, prediction of water demand by central and local water agencies and implementing the necessary measures will have a great role in preventing the problems. Furthermore, prediction of water demand and the analysis of population, social-economic and seasonal factors which comprise water demand will cause an important increase in the precision of predictions.

Water management should be taken as a whole in the peninsula and integrated basin management philosophy based upon the “balance of protection and utilization” should be engaged which can minimally effect the present ecological structure and allow for daily and economical activities at the same time.

The growth the peninsula’s population and the increase in the construction of second homes and tourist facilities utilize land that could otherwise be used for the construction of water storage structures (dams) and they also cause changes in surface flow conditions and the hydrology of the peninsula. This in turn leads to negative selection criteria when it comes to choosing the location of water storage structures for obtaining water from nearby resources.

It is observed, based upon the calculations, that current policies based on finding and developing new water resources will not be sufficient for the solution of the water problem in the Bodrum Peninsula. In this regard, it is essential to create demand management policies. In order for this to happen, first the losses in the water distribution system should be identified and the necessary rehabilitation and/or renewal work must be carried out. Furthermore, transmission and piping which allows for water conservation should be encouraged in homes and in tourist facilities.

References
