**Aquifer Thermal Energy Storage in Mersin Coastal Aquifer: A Pre-Feasibility Study**

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**Abstract**

With the increasing awareness on environmental issues regarding the increasing greenhouse gas emissions, global warming and exploitation of earth’s resources due to the fossil fuel consumption, techniques on the utilization of renewable sources such as geothermal, solar and wind energy gained importance in recent years. Especially in the European Countries, there is an increasing amount of research on the utilization of heat potential available in shallow soils and aquifers in the recent decade. In this direction, Aquifer Thermal Energy Storage Systems (ATES), one of the accepted underground thermal energy storage techniques, was considered as an alternative for sustainable energy supply. Application and use of ATES technique may lead to reduction in fossil fuel consumption by providing sustainable air conditioning in our buildings in association with seasonal underground heat storage. Within the scope of this study, the potential application of ATES technique in Mersin Coastal Aquifer located in the Mersin Province towards fulfilling air conditioning needs of the buildings around the region was investigated. For this purpose, results of previous numerical modeling and thermal performance studies on ATES technique were considered to evaluate the application potential of the mentioned technique.

**Keywords:**

Aquifer Thermal Energy Storage, Mersin Coastal Aquifer, Thermal Performance.

**Mersin Kıyı Akiferinde Termal Enerji Depolama: Ön Değerlendirme Çalışması**

**Özet**

Fosil yakıtların tüketimine bağlı olarak artan sera gazları salınımı, küresel ısınma ve yerkürenin kaynaklarının aşırı tüketimi gibi çevresel konularda bilinçlenmenin artmasıyla birlikte son yıllarda jeotermal enerji, güneş enerjisi ve rüzgâr enerjisi gibi yenilenebilir enerji kaynaklarının kullanıma alınabilmesi amacıyla geliştirilen teknikler giderek daha fazla önem kazanmıştır. Sığ zemin ve akiferlerin ısı potansiyelinden faydalanmaya yönelik olarak başta Avrupa ülkelerinde olmak üzere son on yılda artan düzeyde araştırmalar yapılmaktadır. Bu doğrultuda, yeraltında termal enerji depolama yöntemlerinden biri olarak kabul edilen Akifer Termal Enerji Depolama Sistemleri (ATES), yenilenebilir enerji tedarikinde sürdürülebilir bir alternatif oluşturmaktadır. ATES tekniğinin uygulama ve kullanımı, mevsimsel ısı depolaması ile binalarımızda sürdürülebilir bir iklimlendirme sağlayarak fosil enerji tüketimini azaltmaya katkıda bulunabilmektedir. Bu çalışma kapsamında Mersin ili sınırları içindeki Mersin Kıyı akiferinde, ATES tekniği kullanımının bölgedeki binalarda iklimlendirme ihtiyaçlarını karşılamak üzere uygulanabilirliği araştırılmaktadır. Bu amaçla, ATES tekniği ile ilgili daha önce yapılan sayısal modelleme ve termal performans çalışmaları değerlendirilerek bahsedilen tekniğin kullanım potansiyeli irdelenmiştir.

**Anahtar Sözcükler:**

Akifer Termal Enerji Depolama, Mersin Kıyı Akiferi, Termal Performans.

**INTRODUCTION**

Seasonal storage of low-temperature thermal energy in aquifers, also known as aquifer thermal energy storage (ATES), has proven to be an economical and commercially viable, energy-efficient technology [1-6]. Numerous successful ATES projects are currently in operation in Europe, Asia, and North America, primarily for larger applications such as institutional or commercial buildings [7-12].

ATES, in its simplest form, involves heating or cooling groundwater using low-grade thermal energy, such as solar heat or cold outside air temperatures, and injecting it into a suitable aquifer for storage during periods of low energy demand. During periods of high energy demand, this water is extracted through warm wells, used for heating and then injected back through cold wells. In summer, cold water is extracted from an aquifer through cold wells, heated and injected back into the same or another aquifer through warm wells. In winter, the process is reversed and warm water is extracted through warm wells, used for heating and then injected back through cold wells. A schematic representation of an ATES doublet working principle is illustrated in Fig. 1.



Figure 1. ATES doublet working principle [13].

Currently, ATES systems are mostly constructed and utilised in Netherland, Sweden, France, Canada, Germany, the US and so on with Netherland as the technological leader [14-16]. It is expected that between 3500 and 18000 systems will be in operation by 2020 in Netherlands [17, 18]. ATES systems have been used for heating and cooling of offices, hospitals, universities, greenhouses, factories and so on [19-21]. Some projects related to ATES technique were summarized by Hesaraki et al. and Xu et al. [22, 20].

**1. THERMAL PERFORMANCE OF ATES SYSTEM**

Any ATES desing is a quite complex procedure and has to follow a certain pattern to be efficient. Andersson [23] provided a general design and construction procedure for an ATES system. Though the technical issues are general, in most countries the use of ground water for energy purposes will be restricted and will be an issue for application according to different kind of actions. Typical design steps are listed as follows:

1. feasibility study to specify the technical and economical feasibility and environmental impact compared to more than one reference system,
2. the first permit applications to local authorities,
3. definition of hydrogeological conditions by site investigations and measurements of loads and temperatures, etc on the user side,
4. evaluation of results and modeling for technical, legal, and environmental purposes,
5. final design for tender documents,
6. final permit application for court procedures.

Thermal performance of the underground aquifer decides the efficiency of ATES systems. Many studies on ATES systems are focused on the underground part which is the medium for the thermal energy storage and some indicators to determine the system performance are proposed. The most commonly used thermal performance indicators in literatures include thermal recovery ratio, exergy efficiency, energy balance ratio, etc. which are summarized in Table 1. Thermal recovery ratio (thermal efficiency, η) makes clear performance of underground part of the ATES system from the view of energy and is a primary indicator previously [14, 24, 25]. It can be classified as thermal recovery ratio of heat and thermal recovery ratio of cold. However, the thermal recovery ratio indicator may be misleading due to just taking energy quantity as the base. Therefore, exergy efficiency (ε) assessment using the second-law of thermodynamics is taken into account [27, 28]. If thermal recovery ratio is less than 1, the left heat or cold will be accumulated in the aquifer with the increasing of operation time. When the ATES system is used both for heating and cooling, the cold accumulation may reduce the efficiency and suitability of the system. Thermal balance should be reached in both heating and cooling system of an ATES project to make sure that the system has an acceptable long term effiency [29]. The closer to zero the thermal balance ratio, the more efficient the system is.

Table 1. Indicators for ATES system thermal performance indicator definition and equations [33].

|  |  |  |  |
| --- | --- | --- | --- |
| Indicator | Definition  | Equation or representative parameter  | Reference  |
| Thermal recovery ratio/thermal efficiency  | The ratio of energy extracted from the subsurface to energy injected into the subsurface. Usually the natural aquifer temperature is taken as the calculation base.  | = | [14, 24-26, 30-32]  |
| Exergy efficiency  | The ratio between exergy that is extracted from the subsurface and that is stored within the subsurface.  |  | [26, 32]  |
| Energy balance ratio  | The ratio of the difference between the energy that are extracted in cooling and heating mode to the total extracted energy over a certain period of time.  |  | [25, 31]  |

**2. THE APPLICATION POTENTIAL OF ATES TECHNIQUE IN MERSIN COASTAL AQUIFER**

In the region between Mersin and Tarsus cities, located along the Mediterranean Sea coast in southern Turkey, a hydrogeological study has been performed by Hatipoğlu et al. (2009) [34] to characterize the existing groundwater system. For this purpose, hydrochemical and environmental isotopic data were integrated with available geological and hydrogeological

information to develop a conceptual model of the system. In the study it is revealed that the aquifer system is supplied by the deep flow of karstic groundwater fed from the Taurus Mountains. In addition, it is concluded as a result of the numerical modeling of the study area that the direction of the groundwater flow is observed to be from the Taurus mountain to the sea level as illustrated in Figure 2. The calibrated model revealed the hydraulic conductivity as 45 m/day for coastal aquifer.



Figure 2. The conceptual model of regional groundwater flow system for hillside and coastal aquifer of Mersin [34].

In a research study [35], data on the location, permitted yearly storage volume, pump capacity and screen length of 331 ATES systems in The Netherlands (15% of total number of systems) were obtained from provincial databases that keep combined records for ATES characteristics (Provinces of Gelderland, Noord-Brabant, Noord-Holland, Utrecht and Drenthe). For a geographically representative subset of 204 ATES systems it was possible to extract available aquifer thickness and derive estimates on the ambient groundwater flow as listed in Table 2. When the hydrogeological parameters of Mersin Coastal Aquifer is compared with Table 2, it can be deduced that hydraulic conductivity parameter remain in the acceptable limits. In another study related with Mersin Coastal Aquifer [36], variable values of aquifer thickness remain in the range of the Table 2 indicating that the aforementioned aquifer is convenient for the application of ATES technique.

Table 2. Ranges in geohydrological characteristics of the 204 ATES systems [35]

|  |  |  |
| --- | --- | --- |
| Available aquifer thickness range (m) | Hydraulic conductivity range (m/day) | Groundwater flow range (m/y) |
| 30-180 | 5-45 | 3-100 |

**CONCLUSION**

Aquifer thermal energy storage (ATES) systems use natural water in a saturated and permeable underground layer as the storage medium. The transfer of thermal energy is carried out by extracting groundwater from the aquifer and by reinjecting it at a modified temperature into a separate well nearby. In this study a brief summary of the efficiency and thermal performance of ATES systems and an evaluation of ATES characteristics from practice were used to assess the pre-feasibility of an ATES system in Mersin Coastal Aquifer. Storage in aquifers has a quite long history and has achieved broad acceptance for heating and cooling in the energy market in many countries, though the application of ATES is quite different among the various countries. Any ATES project involves a quite complex procedure and has to follow a general procedure for design and construction of ATES system. The potential application of ATES technique in Mersin Coastal Aquifer located in the Mersin Province is evaluated to be acceptable towards fulfilling air conditioning needs of the buildings around the region.

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