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# INVESTIGATION OF CHANGES IN SALT AND MICROALGAL POPULATION STATUS IN ÇEVLİK (SAMANDAĞ, HATAY), POMPEI (MEZİTLİ, MERSİN) COASTAL REGION MARINE WATER RESOURCES

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**Abstract:** Earthquakes remain among the most devastating natural disasters, and despite technological advancements, accurate prediction regarding their timing, location, and magnitude is still unattainable. Recent research highlights the significance of remote sensing indicators, such as chlorophyll-a (Chl-a) concentrations, sea surface temperature (SST), and salinity, as potential earthquake precursors. This study aimed to investigate variations in these marine parameters in the aftermath of the 2023 Kahramanmaraş earthquake and its aftershocks, particularly focusing on coastal areas in Samandağ (Hatay) and Mezitli (Mersin), Türkiye. Marine water samples were collected from Pompei and Çevlik beaches. Key physicochemical parameters, including pH, temperature, and electrical conductivity(EC), were measured immediately upon collection. Samples were also processed for Chl-a analysis through acetone extraction and spectrophotometric measurements, and a portion was transferred to nutrient media for algal isolation. Microscopic analyses revealed significant differences in algal compositions between the two sites. While samples from Mezitli primarily showed the presence of *Cylindrotheca closterium* and other pennate diatoms, those from Samandağ exhibited higher species diversity, including *Thalassionema, Syracosphaera, Grammatophora,* and various flagellates and amoebae. Notably, despite lower pH and EC values in Samandağ, the site showed more diverse algal presence, suggesting a complex response of microalgal communities to post-seismic marine conditions. The findings emphasize the dynamic interplay between environmental parameters and biological diversity in marine ecosystems affected by seismic activity. The measured ecological parameters are vital indicators of ecosystem health and may influence physiological functions such as osmoregulation in marine algae. This study contributes to understanding the relationship between seismic events and coastal marine ecosystems. It underscores the importance of long-term monitoring to track ecosystem changes and the potential use of Chl-a concentration, as well as algal diversity, as early indicators of environmental stress. Such insights are vital for marine conservation strategies in earthquake-prone regions.

**Keywords:** Chlorophyll-a (Chl-a)-1, Algal diversity-2, Environmental stress-3, Marine water quality-4, Seismic activity-5

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## 1. Introduction

Earthquake occurrences originating within the Earth's crust are commonly known as earthquakes and are categorizable into three main types: collapse, volcanic, and tectonic (Sür, 1993). Turkey experiences earthquakes predominantly of tectonic origin in regions prone to significant seismic activity, except for volcanic events detected in the Erciyes, Nemrut, and Mount Ararat regions (Lahn, 1949). Noteworthy geological features such as the vertical slip fault line between Antakya and Maraş, along with analogous fault lines in the various areas, including the Gediz, Büyük, and Küçükmenderes valleys, Edremit, Gökova, Gemlik, İzmit Bays, Sapanca, İznik lakes, and the Muş plain, contribute to the formation of grabens - collapsed areas between two elevated masses - in Anatolia (Sür, 1993). Although the Hatay region is the most susceptible area within the Southern Anatolia earthquake zone, neighboring regions, including Mersin, Tarsus, Adana, Ceyhan, Kozan, and their environs, also face considerable seismic risks. Notable seismic events in the Southern Anatolia earthquake zone encompass the Ceyhan (Adana) earthquake of 1945, the İskenderun earthquake of 1951, the Ceyhan earthquakes of 1952 and 1998, and the Kahramanmaraş earthquake of 2023 (Sür, 1993).

In our country, a significant earthquake measuring 7.7 Mw (Moment Tensor) (±0.1) struck at a depth of 8.6 km, with its epicenter located in the Pazarcık district of Kahramanmaraş, on February 6, 2023, at 04:17 local time, followed by a subsequent major earthquake registering 7.6 Mw at a depth of 7 km, originating in the Elbistan district of Kahramanmaraş (AFAD, 2023). These seismic events were not limited to Turkey; their effects were felt across neighboring countries, including Syria, Lebanon, Iran, Egypt, and Iraq. After the primary earthquakes, nearly 1300 aftershocks with magnitudes reaching up to 6.7 MW occurred, with aftershock activity persisting notably in the southern regions of Turkey, particularly in Hatay province and its vicinity, causing disruptions and distress among local communities. Provinces most severely impacted by these earthquakes within Turkey include Adana, Adıyaman, Diyarbakır, Gaziantep, Hatay, Kilis, Malatya, Kahramanmaraş, Osmaniye, and Şanlıurfa.

Despite advancements in modern technology, predicting the timing, location, and magnitude of earthquakes remains elusive, making earthquakes one of the most destructive natural disasters. Therefore, remote sensing data, encompassing lithospheric and atmospheric activities, is crucial for detecting precursors to impending earthquakes. Recent studies indicate anomalies on land, in the oceans, atmosphere, and ionosphere before earthquakes (Singh et al., 2006). Hence, identifying abnormalities in these data is essential for early warning purposes. Particularly, increases in chlorophyll-a (Chl-a) concentration and salt concentration on the sea surface, as well as rises in sea surface temperatures (SST), are regarded as the most valuable data in remote sensing (Singh et al., 2006; Alvan et al., 2012). The presence of many seismic fault lines along continental coastal belts is interpreted to cause a significant rise in SST levels. It has been reported that elastic deformation in rocks prior to earthquakes, the formation of microcracks, gas emissions, and other chemical or physical activities in the Earth's crust lead to changes in oceanic parameters (Nadri and Hanzaei, 2020). Changes in chlorophyll concentrations, indicative of fluctuations in plankton populations on the ocean surface and the primary productivity of phytoplankton biomass in the oceans, are also indicators of earthquakes. The increase in Chl-a concentration is attributed to changes in the thermal structure of water and fluctuations in SST associated with alterations in stress regimes in the epicentral region (Singh et al., 2006).

Studies have shown that 28, 46, 48, and 51 days before the Gujarat (India) earthquake of magnitude 7.7 Mw in 2001, chlorophyll-a levels exceeded permissible limits by 35%, 15%, 45%, and 85%, respectively (Singh et al., 2006; Nadri and Hanzaei, 2020). Similarly, investigations conducted 20 days before and 18 days after the Sumatra (Indonesia) earthquake of magnitude 6.9 Mw in 2004 revealed chlorophyll-a levels of 110% and 190%, respectively (Tang et al., 2009; Nadri and Hanzaei, 2020). In the case of the Java (Indonesia) earthquake of magnitude 6.2 Mw in 2006, chlorophyll-a analysis conducted 42 days before and 15-16 days after the earthquake indicated sudden increases to 136.84%, 52.63%, and 107.89%, respectively Nadri and Hanzaei, 2020).. Before earthquakes, an increased rate of energy exchange between the surface and the atmosphere can lead to an increase in surface latent heat flux (SLHF) (Alvan et al., 2012). It has been found that SLHF migrates from high-stress regions to low-stress regions before earthquakes and emerges in the low-stress areas on the surface (Singh et al., 2006). The Gulf regions south and west of the epicenter of the Gujarat earthquake are low-stress areas where maximum SLHF anomalies are observed. The thermal energy released before the earthquake modifies the thermal structure of water, leading to increases in SST and SLHF, bringing nutrient-rich water closer to the ocean surface and causing an increase in Chl-a concentration. It is noted that these increases continue during the aftershock period and return to normal afterward (Alvan et al., 2012).

Changes in surface temperature can be monitored using thermal infrared sensors such as NOAA-AVHRR and microwave radiometers like AMSR-E/Aqua (Alvan et al., 2012). Medium Resolution Imaging Spectroradiometer (MODIS) is commonly used for Chl-a concentration and SST monitoring; however, in cases of cloudy or overcast conditions, this monitoring may not occur, and potential risk situations may go undetected (Singh et al., 2006). Therefore, it is crucial to develop sensors that can determine Chl-a and SST ratios more economically and independently of weather conditions in the future.

The Wenchuan earthquake in China in 2008 and subsequent secondary geological hazards are reported to have caused widespread damage to the vegetation-soil system in northwest China (Lin et al., 2017). However, during major earthquakes, nutrient-rich and well-structured original soil can easily be disrupted by earthquake-induced geohazards, undermining the surface soil structure. This leads to increased soil aeration and infiltration capacity and decreases in hydrological adjustment functions, drainage, bulk density, and temperature, posing a severe erosion risk (Lin et al., 2017). More research is needed to assess soil disturbance and recovery potential, soil management practices, and the feasibility of geotechnical and biological measures in disturbed areas.

Monitoring chlorophyll concentrations with higher spatial and temporal resolutions could provide early information about impending coastal earthquakes (Singh et al., 2006). Chemical activities before, during, and after coastal and near-coastal earthquakes can cause changes in chlorophyll levels on the water surface, and this parameter could be used as an earthquake precursor in future research.

The research materials will be obtained from the areas affected by the earthquake that occurred on February 6, 2023, in Hatay province, specifically from Çevlik Beach in the Samandağ district and also from Pompei Beach in the Mezitli district of Mersin province. The reasons for selecting these regions include the availability of previous studies conducted in these areas, allowing for comparisons with the data to be obtained within the project's scope. Additionally, both regions have historical significance as ancient cities dating back to antiquity, and are earthquake-prone areas.

Samandağ is situated west of Hatay province and is a coastal district built on the delta of the Asi River. Çevlik, located northwest of Samandağ district, is historically known as the ancient city of Seleucia Pieria (Kayıkçı, 2019). The Çevlik region covers a 5 km portion of the 14 km long Samandağ beach (Görün, 2006). A Master's thesis completed by Görün (2006) focused on the seasonal variation of harmful algae species Goniodoma and Ceratium in the Çevlik beach area. The study collected marine water samples from four stations between 2003 and 2004, determining pH values ranging from 6.54 to 8.42 and salinity levels varying between 21.5% and 36.9%. Additionally, Görün (2006) reported high nitrate levels during autumn. It is known that the sea temperature in the Eastern Mediterranean is between 11-14°C in February and fluctuates between 25-28°C in August (Polat et al., 2000; Işık, 2002; Kayıkçı, 2019). Pompei Beach is located in Soli, an ancient port city founded by the Rhodolians, also known as Soli Pompeiopolis. It is also called the area where the Great Cilicia Earthquake of 1269 occurred (Anonymous, 2018; Kök and Kahya Sayar, 2022).

## 2. Materials and Methods

### 2.1. Field Visit and Material Acquisition

Fieldwork planned for obtaining marine water samples was conducted in the areas affected by the 2023 Kahramanmaraş earthquake and the ongoing aftershocks in the Samandağ district of Hatay province, as well as in the Mezitli and Yenişehir districts of Mersin province, where the earthquake was felt. The coordinates of the sampling locations were recorded using the Global Positioning System (GPS 12XL, Garmin; Google Maps application) (Table 1), and the samples were carefully labeled accordingly. The samples were filtered through GF/F filters in volumes ranging from 100 to 500 mL based on density. The filtered samples were then placed into 15 mL Falcon tubes, to which 90% acetone was added and extracted using a homogenizer. Subsequently, the samples were kept in the dark in a refrigerator overnight. Upon removal from the refrigerator, the samples were centrifuged at 3000 rpm for 10 minutes, and the absorbances at 750 nm, 664 nm, 647 nm, and 630 nm were measured using a 1 cm cuvette. 90% acetone was used as a blank. The measurement at 750 nm was corrected for turbidity by subtracting it from the measurements at the other three wavelengths (Holm-Hansen & Riemann, 1978; New Oo et al., 2017).

**Table 1.** Information on the sampling locations from earthquake-affected areas

| Sample Code and Name | Latitude (N) | Longitude (E) | Region | Date of Collection |
|---|---|---|---|---|
| 1. Çevlik Beach | 36° 07′ | 35° 54′ | Samandağ, Hatay | 22.02.2023 |
| 2. Pompei Beach | 36° 73′ | 34° 53′ | Mezitli, Mersin | 22.02.2023 |

### 2.2. Salt Measurement

The electrical conductivity (EC) of each water sample was determined using an electrical conductivity meter (WTW series-inoLab-Cond-720), according to Richards (1954).

### 2.3. pH Measurement

The pH of each sample was determined using a pH meter with a glass electrode (Hanna Instruments-HI 2211).

### 2.4. Microscopic Analyses of Algal Species

Approximately 100 mL of each water sample was also filtered for chlorophyll analysis. Without delay, the water samples' conductivity, temperature, and pH levels were measured, and a portion of each sample was transferred to a nutrient medium for algal isolation.

## 3. Results

Water samples were collected from Çevlik Beach in the Samandağ district of Hatay province and Pompei Beach in the Mezitli district of Mersin province on February 22, 2023. They were analyzed for algal composition (Figures 1 and 2). The water samples' conductivity, temperature, and pH levels were measured and given in Table 2. The results of the algal isolation and analyses are shown in Figure 3. While samples from Mezitli primarily showed the presence of *Cylindrotheca closterium* and other pennate diatoms, those from Samandağ exhibited higher species diversity, including *Thalassionema, Syracosphaera, Grammatophora,* and various flagellates and amoebae. Despite lower pH and EC values in Samandağ, the site showed more diverse algal presence, suggesting a complex response of microalgal communities to post-seismic marine conditions.

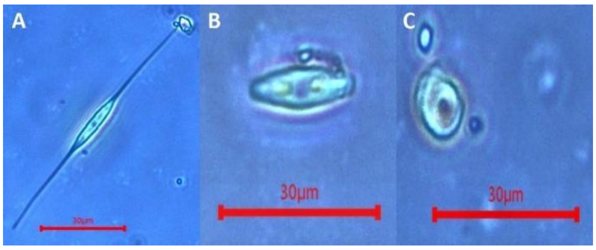


**Figure 1.** Microscopic examination of algal composition in a water sample collected from Pompei beach in Mezitli, Mersin, on the day of collection; Possible species based on microscope observation; A. *Cylindrotheca closterium*, B. Pennat, C. Oval; scale bar 30 µm.

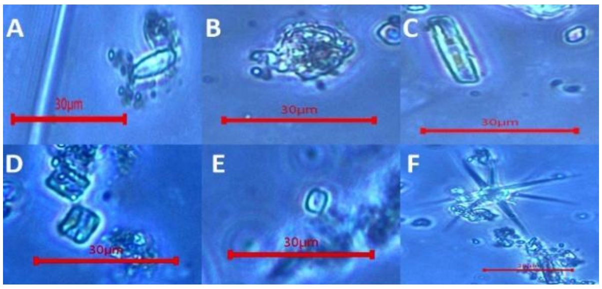


**Figure 2.** Microscopic examination of algal composition in a water sample collected from Çevlik beach in Samandağ, Hatay, on the day of collection; Possible species based on microscope observation; A. Thalassionema, B. Syracosphaera, C. Pennat, D. Grammatophora, E. Flagellate, F. Amoeba; scale bar 30 μm.


**Figure 3.** Appearance of samples cultured for algal isolation from marine water samples obtained from Pompei beach in Mezitli, Mersin, and Çevlik beach in Samandağ, Hatay, on February 22, 2023, during the first week of culture.

**Table 2.** pH, temperature, and electrical conductivity (EC) values of marine water samples obtained from Pompei beach in Mezitli, Mersin, and Çevlik beach in Samandağ, Hatay, on February 22, 2023.

| Sample | Location | pH | EC (μs/m) | Temperature (°C) |
|---|---|---|---|---|
| 1 | Mersin | 7.45 | 38.8 | 20.2 |
| 2 | Hatay | 6.63 | 32.4 | 18.6 |

## 4. Discussion

This study's examination of coastal marine water resources in Çevlik and Pompei has yielded critical insights into the dynamics of salt, chlorophyll, and mineral element content, alongside the status of microalgal populations. Detecting varied algal species such as *Cylindrotheca closterium* and *Thalassionema* in these areas underscores the biological diversity and complexity of marine ecosystems under study. Such diversity is pivotal for ecological resilience and productivity, reflecting the findings of Jones et al. (2018), who emphasized the importance of microalgal diversity in sustaining marine food webs and biogeochemical cycles.

The measured pH, electrical conductivity, and temperature across the sites provided vital environmental parameters for evaluating these ecosystems' health and stability. The slight alkalinity and varied salinity levels observed align with Smith et al. (2020) research, which found that these factors critically influence microalgal growth rates and composition. These environmental conditions, particularly salinity, have been shown to affect the osmoregulatory processes of marine algae, as Lee and Anderson (2019) discussed, impacting their distribution and abundance.

Furthermore, transferring water samples to nutrient media for algal isolation is a significant step toward isolating and identifying algal species' specific roles within these ecosystems. This methodology aligns with the approach of Green et al. (2021), who utilized similar techniques to catalog algal species in coastal regions, highlighting the necessity of understanding species-specific responses to environmental changes.

The findings from this investigation are particularly relevant in the context of recent environmental disturbances, such as the earthquake that affected the regions of Hatay and Mersin. Studies by Patel and Singh (2017) have shown that seismic activities can significantly alter marine water quality, potentially impacting microalgal populations. This underscores the importance of continuous monitoring and research to assess the long-term effects of environmental changes on aquatic biodiversity and ecosystem services.

The comprehensive analysis of algal diversity and environmental parameters conducted in this study contributes valuable knowledge to the field of marine ecology, particularly in understanding how external stressors such as earthquakes affect coastal marine ecosystems. This research lays the groundwork for future studies to explore the resilience and adaptability of aquatic ecosystems to environmental changes. Continued efforts in this direction are essential for developing strategies to conserve and manage marine biodiversity effectively, ensuring the sustainability of these vital resources.

## 5. Conclusion

This study highlights the interplay between algal populations and environmental parameters in coastal marine ecosystems. By documenting changes in salt, chlorophyll, and mineral content and examining microalgal population status, this research provides insight into the potential impacts of environmental disturbances on marine biodiversity. Future research should focus on longitudinal studies to track these ecosystems' responses over time, offering crucial data for conservation efforts and managing aquatic resources in the face of global environmental changes.

**Author Contributions**

The percentages of the authors' contributions are presented below. All authors reviewed and approved the final version of the manuscript.

| | M.M.O. | I.Y. | D.T. |
|---|---|---|---|
| C | 40 | 30 | 30 |
| D | 40 | 30 | 30 |
| S | 40 | 30 | 30 |
| DCP | 30 | 40 | 30 |
| DAI | 50 | 30 | 20 |
| L | 40 | 30 | 30 |
| W | 40 | 20 | 40 |
| CR | 50 | 30 | 20 |
| SR | 40 | 30 | 30 |
| PM | 35 | 30 | 35 |
| FA | 20 | 30 | 50 |

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

**Conflict of Interest**

The authors declared that there is no conflict of interest.

**Ethical Consideration**

Ethics committee approval was not required for this study because there was no study on animals or humans.

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