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Water quality in Istanbul, Marmara Sea

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The Marmara coast in Istanbul, an intensely industrialized and overpopulated city, is a popular center for recreational activities, such as swimming, and fishing. The Kucuksu, Fenerbahce and Suadiye beaches on the Anatolian side of the Marmara coast are highly preferred for swimming and the Sea of Marmara is very important for the diversity of coast organisms. Therefore, this study was conducted to determine whether the seawater quality at the coast is suitable for marine life and human health through investigating the heavy metal concentrations in the seawater. To determine the concentrations of As, Cr, Ni, Pb and Zn in seawater samples were collected in Kucuksu, Fenerbahce and Suadiye beaches in Istanbul near Asia at weekly intervals in the period between 19 October 2016 and 4 June 2017, laboratory analysis was conducted using ICP-MS was conducted. In addition to measuring pH and temperature onsite at the same time interval, pH and temperature were measured with dissolved oxygen from 18 November 2018 to 31 January 2019. The results showed that heavy metal concentrations, pH, temperature and dissolved oxygen in the Sea of Marmara do not pose a serious threat to aquatic life or human health.

Keywords: Marmara Sea, seawater quality, beaches, pH, recreation.

Introduction

Marine ecosystems are susceptible to ambient conditions[1]. Therefore, high concentrations of heavy metals can cause environmental degradation in marine ecosystems[2]. Major sources of heavy metal pollution are emitting mining, industrial, agricultural and urban wastes into the environment[3] damaging coastal areas due to heavy metal contamination[4]. This type of pollution can affect both marine environment and human health when seawater is used for industrial and recreational activities or when marine resources are used as a source of nutrition[5]. In Turkey, millions of people (locals and tourists) use the beach to swim and sunbathe, especially during the hottest seasons of the year[6].

Inductively coupled plasma mass spectrometry (ICP-MS) can be used to measure heavy metal concentrations in seawater[7]. A number of studies investigating seawater pollution by heavy metals were conducted in different coastal regions[8–11]. In Istanbul, the situation is more critical because the region is vulnerable to natural disasters. For example, on 18 July 2017, heavy rainfall inundated the roads, underpasses and subway lines causing serious damage to the city[12]. In addition, some manmade disasters, such as the fuel leak at the Gulf of Izmit in the Sea of Marmara, which took place on 12 January 2017, also occur in the area[13]. Therefore, continuous monitoring of the coastal areas is necessary to facilitate immediate actions for mitigating disasters.

People who use water at very high and very low pH values for recreation have a direct negative effect on skin and eyes[14]. According to Hamzah and other's study, the average pH values of the Port Dickson beach in Negeri Sembilan, Malaysia between 24 October 2000 and 28 March 2001 were suitable for coliform growth and the average temperature values at four sampling stations, were also normal for tropical climates[15]. Negative effects of pH levels below 7.0 are problems of reproduction, morphology and metabolism in marine organisms[16].

The variation in water temperature is mainly a due to prevailing weather condition.

According to Rudolph and other's study, while oxygen in the water was increased in winter due to the dominant of the north-west wind, in the summer, it was reduced by the water input from outside the San Vicente Bay[17]. According to Karthik and other's study, high dissolved oxygen and low salinity at seawater of Port Blair, South Andaman Island during September and November was caused by rainfall – induced freshwater input and flooding from land[18]. Both abundance and diversity of finfish, lobster and squid was significantly decreased when dissolved oxygen was less than 2 mg/L in bottom of western Long Island Sound[19].

In this study, temperature, pH, and concentrations of arsenic (As), chromium (Cr), nickel (Ni), lead (Pb) and zinc (Zn) between 19 October 2016 and 4 June 2017 and temperature, pH, dissolved oxygen from 18 November 2018 to 31 January 2019 were investigated in seawater samples collected from Kucuksu, Fenerbace and Suadiye beaches in Istanbul on weekly. The objective of the study was to assess the possible effects of seawater on public health.

Experimental

100 ml-polyethylene bottles were soaked in a mixture of nitric acid and deionized water (Fig. 1a) for at least 24 h, were rinsed three times with deionized water and, then, were dried. Seawater samples were collected on a weekly basis at 50 cm below the sea-surface in these polyethylene bottles, which were attached to a 3–4 m long telescopic rod[20]. Before filling the bottles, they were being rinsed three times with seawater, and then they were filled completely. The temperature, dissolved oxygen and pH of seawater were determined onsite using a multiparameter (YSI) (Fig. 1b). Then, the samples were delivered refrigerated to the laboratory of Marmara University for analysis. In the laboratory, each sample was filtered through a 0.45 μm sieve syringe filter (Sartorius) using a sterile syringe. The samples were diluted using a dilution factor of 100 (Fig. 1c). To protect the metals and prevent sedimentation, the pH of the samples was adjusted to below 2 using a 2% nitric acid (HNO_3). Then, the samples were stored in a 4°C refrigerator until its analysis using ICP-MS (Agilent 7500A) (Fig. 1d) to determine the concentration of heavy metals.

Results and discussion

The temperature and pH values measured between 19 October 2016 and 26 March 2017 ranged from 11.8 to 19.2°C and from 7.1 to 9, respectively (Fig. 2a). The maximum pH value was the one measured on 26 October 2016 in the Suadiye beach and it was below the threshold values for Turkey[21,22] (6–9) and EPA[23] (5–9 for human health, and 6.5–8.5 for aquatic life). In addition, higher values of pH were observed in the direction of the south-east wind. On the other hand, due to snowing, the lowest sea temperature was observed in the middle of January.

In Fenerbahce, pH ranged from 7.55 to 7.89, with a higher range of 8.01 to 8.51 in Kucuksu, with a lower range of 8.01 to 8.32 in Suadiye from 18 November 2018 to 31 January 2019 (Fig. 2b). The weekly water temperatures from the three sites were from 6.3 to 15.4°C and the weekly dissolved oxygen was in the range of 80 to 95.4% from 18 November 2018 to 31 January 2019 (Fig. 3a). These dissolved oxygen values did not exceed the Turkish threshold values (in the range of 80 to 120%).

The highest pH was in Kucuksu as 8.51 on 25 November 2018, and the highest temperature was in Kucuksu as 15.4°C on 18 November 2018, and the highest dissolved oxygen was in Suadiye as 95.4% in 25 November 2018. While sea-



Fig. 1. (a) Elga Purelab Flex Deionized water, (b) YSI Professional plus multiparameter meter, (c) Sampling bottles and vials, (d) Autosampler (CETAC ASX-51) and ICP-MS (Agilent 7500a).

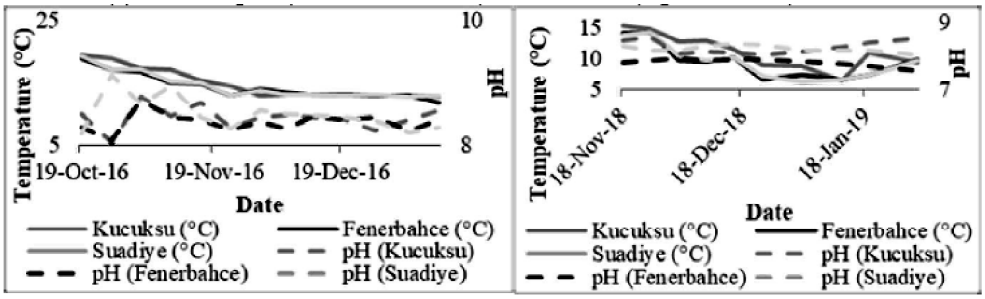


Fig. 2. Weekly temperature, pH values (a) between 19 October 2016 and 26 March 2017 and (b) between 18 November 2018 and 31 January 2019.

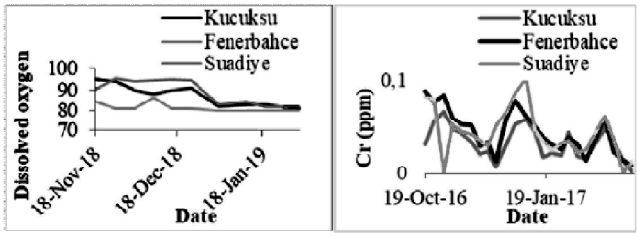


Fig. 3. (a) Weekly dissolved oxygen values and (b) Cr concentrations between 18 November 2018 and 31 January 2019.

water temperatures of Kucuksu, Fenerbahce, and Suadiye beaches were low in January 2019, they were high in November 2018.

Strength of association for Pearson correlation was investigated[24]. For Kucuksu and Fenerbahce (–0.67) and for Kucuksu and Suadiye (–0.58), pH had strong negative correlations but pH had strong positive correlation (0.70) between Fenerbahce and Suadiye. Therefore, when the pH value increased for Fenerbahce and Suadiye, pH value decreased for Kucuksu. Temperature correlations were greater than 0.87 and were strong for all beaches like dissolved oxygen correlations. Furthermore, for all beaches, seawater temperatures decreased until middle of January 2019 and later temperatures increased. The dissolved oxygen values synchronously decreased for all beaches.

pH and temperature correlation was 0.28 for Kucuksu, 0.10 for Fenerbahce, and 0.12 for Suadiye and these correlations were weak for all beaches. For Suadiye, pH and dissolved oxygen had strong positive correlation (0.68). There was a positive correlation between temperature and dissolved oxygen in the range from 0.40 to 0.78. This means that the dissolved oxygen was affected by water temperature like Hamzah and others study[15].

pH range in our study is wider than study in Malaysia (7.59–7.8) but pH ranges in both studies are suitable for human health and aquatic life because Turkish pH standard is 6–9 and Malaysia pH standard is 6.5–8.5. Minimum temperature in our study is less than studies in Malaysia (18.9°C), Chile (10.59°C), and India (25°C).

Minimum dissolved oxygen in our study (8.8 mg/L) is higher than minimum values in Malaysia (3.7 mg/L), and India (3.2 mg/L). So this vital parameter in marine life positively affects the Sea of Marmara in terms of aquatic creature's diversity and number.

The concentrations of As, Cr, Ni, Pb and Zn (Fig. 3b, 4a,b) were found to be lower than the threshold values[22] (0.1 mg/L for every element). In addition, the values were found to be lower in windy weather. For example, on October 26 and 12 December 2016, all element concentrations were found to be relatively low compared to the values measured during the previous week.

An assessment was conducted to estimate the correlations between the concentrations of each element with temperature. A negative correlation (–0.4) was found between arsenic and temperature. This indicates that the arsenic concentration increases as the temperature decreases. On the other hand, the positive correlation (0.5) between temperature and chromium shows that its concentration increases with temperature. The Pb concentrations in seawater of Fenerbace beach on 16 November 2016 and in Kucuksu beach on 1 April 2017 were high; however, they did not exceed the threshold value.

Zn concentrations were also lower than the threshold value, although they were relatively high at the end of Janu-

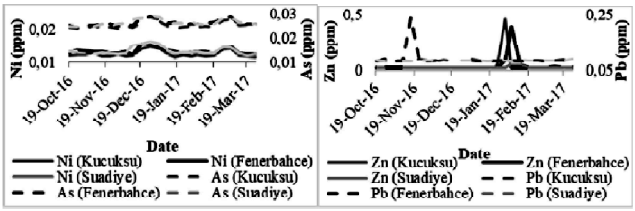


Fig. 4. Weekly heavy metal concentrations: (a) Ni and As and (b) Zn and Pb between 18 November 2018 and 31 January 2019.

to be lower than that of the studies held in Mexico[9] and Turkey[25] as well as the maximum allowable limit in Mexico. Similarly, the maximum Pb value (0.1 ppm) was found to be lower than the maximum allowable limits and the maximum values measured in studies carried out in Mexico[9], Indonesia[7] and Turkey[25]. Finally, the maximum zinc value was found to be close to the values measured in the studies carried out in Mexico and Indonesia and below the maximum allowable

Table 1. Comparing with references about heavy metals

Element	Concentration (ppm)				Country for limit value	Coast	Year
	Sampling point A	Sampling point B	Sampling point C	Limit			
Zn[7]	0.155	0.126	0.109	0.01	Indonesia	Mamboro District of North Palu	2015
Zn (max)[9]	0.167	0.153	0.175	20	Mexica	Mexican Pasific Ocean coastline	2013
Zn (max)[25]	5.45			0.1	Turkey	Black Sea	2010
Pb[7]	0.35	0.391	0.433	0.025	Indonesia	Mamboro District of North Palu	2015
Pb (max)[25]	0.808			0.1	Turkey	Black Sea	2010
As (max)[9]	0.001	0.001	0.001	0.1	Mexica	Mexican Pasific Ocean coastline	2013
Cd (max)[9]	0.093	0.093	0.091	0.1	Mexica	Mexican Pasific Ocean coastline	2013
Cd (max)[25]	0.169			0.01	Turkey	Black Sea	2010
Cu (max)[9]	0.044	0.044	0.044	1	Mexica	Mexican Pasific Ocean coastline	2013
Cu (max)[25]	0.775			0.01	Turkey	Black Sea	2010
Cr (max)[9]	0.146	0.097	0.097	0.5	Mexica	Mexican Pasific Ocean coastline	2013
Cr (max)[25]	0.582			0.1	Turkey	Black Sea	2010
Ni (max)[9]	0.325	0.399	0.381	2	Mexica	Mexican Pasific Ocean coastline	2013
Ni (max)[25]	0.833			0.1	Turkey	Black Sea	2010
Pb (max)[9]	0.373	0.356	0.349	0.5	Mexica	Mexican Pasific Ocean coastline	2013

ary and the beginning of February; especially, during the first week of February, because of the fuel oil leakage at the Gulf of İzmit in the Sea of Marmara that occurred on 12 January 2017[13].

The maximum arsenic value (0.03 ppm) was compared to the value measured in a study held in Mexico[9] (0.001 ppm) and was found to be higher (Table 1). However, it was still lower than the maximum allowable limit in Mexico. The maximum Cr value (0.102 ppm) measured in the present study was found to be close to that measured in the same Mexican study, which is lower than the maximum allowable limit in Mexico[12], and it was also lower than the Cr value (0.58 ppm) measured in a similar study in Turkey[25]. On the other hand, the maximum nickel value (0.02 ppm) in this study was found limits in Mexico, Indonesia and Turkey.

Briefly, compared to previous studies carried out in Mexico and the Black Sea, Turkey, the concentrations of Cr, Ni, Pb and Zn in the present study were lower. On the other hand, Pb and Zn concentrations in a study carried out in Indonesia were higher than the values measured in the present study. Finally, the results showed that the concentrations of all the elements measured in this study were below the maximum allowable limits in Mexico and Indonesia.

Conclusions

The results of the analysis showed that the level of pH and dissolved oxygen and the heavy metal (As, Cr, Ni, Pb and Zn) concentrations in the Sea of Marmara did not repre-

sent a serious threat to the aquatic life and human health, because they were all below the threshold values. It was observed that the concentrations of all elements decreased in October 26th and December 20th, when the wind was excessive.

The lowest sea temperature between 19 October 2016 and 26 March 2017 was observed in the middle of January due to snow. In addition, the temperature was found to be positively correlated with the arsenic concentration and was negatively correlated with the chromium concentration. The maximum Pb concentrations were observed at the Fenerbace beach on 16 November 2016 and at the Kucuksu beach on 1 April 2017. There was an increase in the zinc concentrations in the Sea of Marmara, where the fuel leak occurred in the Gulf of İzmit on 12 January 2017.

At all three beaches from 18 November 2018 to 31 January 2019, seawater was warmer on the January, 2019 while the seawater was colder in November, 2018 than other months. The range of seawater temperatures recorded in this study was the normal for humid subtropical climate. Correlation values indicated that the dissolved oxygen was affected by water temperature.

The concentrations of all the tested elements except As were found to be low compared to studies carried out in Mexico and the Black Sea, Turkey. In addition, the concentrations of all tested elements were found to be below the Mexican limits. Furthermore, the Pb and Zn concentrations in the current study were lower than those measured in the study conducted in Indonesia.

These results show that, to enable immediate actions for the mitigation of accidents and natural disasters, beaches should be monitored periodically.

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