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Research Article

Environmental statistical analysis on the impacts of marine mucilage on some seawater quality parameters

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Abstract

Marine mucilage creates significant pollution in seawater due to high amount of nitrogen and phosphorus discharges. The water quality of Sea of Marmara has been damaged due to this environmental problem with the rising sea water temperature since 2020. This study aims to investigate the statistical differences in the impact of marine mucilage in the Sea of Marmara between 2020 and 2021, taking into account dissolved oxygen, pH, seawater, and ambient temperature. Ten sampling locations were established for this purpose on the Anatolian part of the Sea of Marmara. The statistical analysis revealed there is a statistically significant difference with a percent of 99 confidence levels at all sampling points. The variables pH and dissolved oxygen revealed a difference between 2020 and 2021, however, no statistically significant results were determined for the seawater temperature.

Keywords: Mucilage, Ecology, Environmental pollution, Dissolved oxygen, Seawater quality

Introduction

The Marine mucilage (sea snot), (Proboscia alata) occurs from the eutrophication (algal bloom) (Lancelot, 1995) and eutrophication is a pollution process that occurs when a lake or stream becomes overly nutrient-rich in plants. Algae and other water plants overgrow the area as a result. Plants decay and die, and their residues decompose in the water, depriving the lake, river, or stream of oxygen and turning it lifeless. Nitrate fertilizers that flow off the fields, nutrients from animal waste, and human sewage all contribute to eutrophication (EU, 2022). The excessive growth of these harmful phytoplankton species is known as harmful algae growth and as a result, a considerable amount of extracellular polymeric organic matter is secreted from a large number of newly produced living cells. Consequently, mucilage is an extracellular organic material formed mostly by diatoms and dinoflagellates (Eren, 2021). According to Savun-Hekimoglu and Gazioglu (2021), mucilage is a global phenomenon that occurs once in a while or on a regular basis in overall incidents took place in the Mediterranean Sea, West Japan Sea, New Zealand’s Tasman Bay, and near the Pacific coast of the United States. The first incident noticed in the North Adriatic Sea, according to the authors, was recorded in the scientific literature in 1729. Azam et al., (1990) stated that mucilage is largely produced as a consequence of bacteria-organic matter interactions and bacterial capsular polysaccharide synthesis and the environmental impacts of mucilage have still been unknown. Moreover, debate can be detrimental for invertebrates and fishes since it blocks the gills, over feeding and protection area in coastal aquatic ecosystem. Additionally, it has negative effects on tourism activities and industrial activities such as blocking filtering systems of boats and nets’ mesh (Yentur et al., 2013). Mucilage has been investigated by a number of researchers. For instance, Haque et al., (1983) investigated the alleviation of mucilage problem for the isolation of jute species, and the authors conducted the experimental study in-vitro conditions to present the consequences of mucilage. Lancelot (1995) investigated the effects of the mucilage problem in seawaters, stating that the foam accumulation seen every spring at the sea surface and on beaches during windy conditions is caused by a food chain disruption caused by the proliferation of a single phytoplanktonic species, the colony-forming Phaeocystis. Rinaldi et al., (1995) studied the mucilage problem in the Adriatic and Tyrrhenian Seas from 1988 to 1991, and they concluded that more research was needed to fully comprehend the phenomenological and dynamic components of this environmental issue. Fukao et al., (2009) conducted a study about mucilage, which is the product of Coscinodiscus granii in Ariake Sound of Japan. The researchers exhibited that the polysaccharide composition of the transparent exopolymer particles (TEPs) produced by Coscinodiscus granii may determine the viscosity of the ne mucilage. By examining prokaryotes within the mucilage and in the surrounding seawater, Danovaro et al., (2009) investigated the potential of mucilage to host new microbial diversity and/or spread marine diseases employing genetic methods. The researchers revealed that marine mucilage had an unusually high microbial diversity and supported pathogenic species not found in the surrounding seawater. According to Mecozzi et al., (2012), infrared spectroscopy and independent component analysis to be used to monitor the effects of marine mucilage in Italian sea waters. As a result, besides eutrophication, the creation of marine mucilage is also based on refractory organic matter mechanisms and production, which gives some infrared spectroscopy-based devices an edge in monitoring this environmental pollution. Acar et al., 2021) published a study about determining the coverage area of mucilage by employing remote sensing technology. They applied different satellite band visualing techniques to detect the borders of spilled area of the mucilage in the Sea of Marmara. Similarly, Özsoy (2021) highlighted the importance of employ the remote sensing methods to monitor the mucilage impacted area on the Sea of Marmara, Tuzcu Kokal et al., (2022) employed the same remote sensing technique with multi-scale satellite data. In the beginning, the purpose of this article was to monitor seawater quality levels of Kurbağalıdere Creek, which is of one the sours of a drastic sea pollution (Öze, 2001); Unlu and Alper (2015); The Union of Chambers of Turkish Engineers and Architects (UCTEA) (2016) in the Sea of Marmara. Therefore, the sampling locations were determined due to that purpose in 2020.

However, after the serious marine mucilage incident took place in the Sea of Marmara in the spring of 2021, the aim has been changed, respectively. Therefore, the purpose of this research is to see how mucilage impacts sea water quality between 2020 and 2021 on the Anatolian side of the Sea of Marmara. The most unique novelty of this article is that sea samples were collected and seawater quality was determined one year before the mucilage occurrence in 2021. Until now, no year-by-year comparison of seawater quality has been revealed, particularly in studies on mucilage in the Sea of Marmara. This enables a scientific comparison and evaluation of the impacts of mucilage incidents from the environmental aspect.

The study is structured as follows: Section 2 presents the materials and methods, which cover the sampling procedures and provide information about the study area and the measured onsite seawater quality parameters, Section 3 emphasizes the results and discussion, which presents the measurements' results and compare them to previous literature findings, and Section 4 concludes the study.

Materials and Methods

The materials and methods utilized to conduct the research are displayed in this section. The statistical analyses were carried out using the SPSS package software 19.00 version. Due to its widespread use by other researchers (Cottrell and Graefe, 1997; Giles-Corti and Donovan, 2003; Huijuan *et al.*, 2021) in various environmental science and engineering studies, this program is preferred. First, descriptive statistics for all seawater quality parameters such as pH, dissolved oxygen, and sea and ambient temperature were calculated in this study. Following that, an independent sample t-test was conducted to see if there was statistical evidence that the linked population means differed significantly between 2020 and 2021.

Study area

The study is conducted at the Sea of Marmara, between the coastline of Kadıkoy and Bostanci line, located on the Anatolian side of the Province of İstanbul (Figure 1). This study location is chosen due to the intensive layer of mucilage formations on the sea level (Savun-Hekimoğlu and Gazioğlu, 2021, Kavzoğlu et al., 2021-2023; Savun et al., 2021, Kömüşcü et al., 2022).

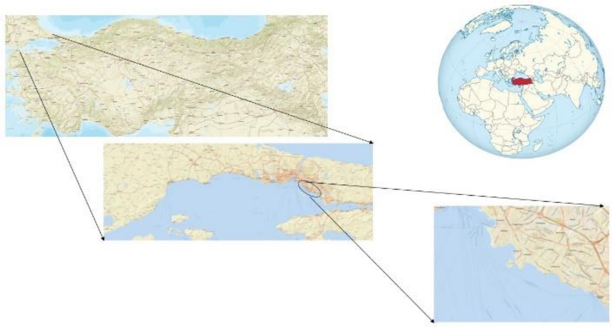

Fig. 1 . Location Map (Sources: modified from ArcGIS (2021) and Wikipedia (2022))

Sampling points are marked with an indoor tracking system based on Bluetooth technology GPS (Opoku, 2012) from 0-5 m depth (Tüfekci *et al.*, 2010) from the sea surface. The Bluetooth GPS technology has emerged in the last 10 years and is most widely used by some researchers (Fu et al 2008, Liu et al 2014, Namaki-Araghi *et al.*, 2015). Figure 2 represents the sampling points within the study area.

Fig. 2: Sampling Points

Sampling periods

The goal of this study, as previously stated, was to look into the seawater quality values of a creek known as Kurbagalidere, which was once one of the major pollution sources for the Istanbul Anatolian side of the Sea of Marmara until recently. As a result, samples' were collected in 2020 from measurement locations established during the first 15 days of June, July, and August (Hansson and Berg, 2009; Guitterrez *et al.*, 2016), when air and sea temperatures are at their peak. At a depth of 1 to 10 cm below the water surface, samples were obtained from 200 mL glass sample containers and measurements were taken on-site in bye standards outlined in Table 1 (Fong *et al.*, 1975).

Table 1. On-site measured parameters from seawater

Parameters	Unit	Standard/Method	Sampling Depth
Seawater pH		Standard Methods: 4500-H+B	0 – 10 cm
Dissolved Oxygen (DO)	mg/l	Standard Methods: 4500-O G	0 – 10 cm
Seawater temperature	ºC	Standard Method: 2550 B	0 – 10 cm
Ambient temperature	ºC		

Data Analysis

This section presents the descriptive analysis results of the pH, dissolved oxygen, sea, and ambient temperature. Descriptive statistics are a set of short descriptive coefficients that summarize a data set, which could be a sample of the population or a representation of the entire population. Descriptive statistics include measurements of central tendency and measures of variability (spread). Central tendency measures include the mean, median, and mode, whereas variability measures include standard deviation, variance, minimum and maximum variables, kurtosis, and skewness. (Hayes, 2021). The obtained descriptive statistics for pH values are shown in Table 2 below. The descriptive statistics for DO, sea and ambient temperature levels are also shown in further tables.

Table 2 below shows that deviation values range from 0.36 to 0.66, and the mean values of each sampling unit declined from 2020 to 2021. The reason for the decrease in pH values may be due to many reasons, especially marine pollution.

Table 2: Descriptive Statistics of pH Values

	Date	**N**	**Mean**	**Std. Deviation**
Sampling Point 1	2020	30	8.17	0.41
	2021	30	6.81	0,48
Sampling Point 2	2020	30	7.98	0,41
	2021	30	6.87	0,49
Sampling Point 3	2020	30	8.11	0,36
	2021	30	6.92	0,48
Sampling Point 4	2020	30	8.07	0,50
	2021	30	7.04	0,57
Sampling Point 5	2020	30	8.06	0,41
	2021	30	7.00	0,47
Sampling Point 6	2020	30	8.15	0,49
	2021	30	7.01	0,56
Sampling Point 7	2020	30	8.19	0,54
	2021	30	7.01	0,57
Sampling Point 8	2020	30	8.04	0,63
	2021	30	7.04	0,54
Sampling Point 9	2020	30	8.03	0,60
	2021	30	7.08	0,66
Sampling Point 10	2020	30	7.98	0,59
	2021	30	6.75	0,56

Table 3 presents that the mean DO levels for each observation unit was decreasing at a rapid rate. This decline was observed at all sample points between 2020 and 2021, which is significant. As a result, it is possible to conclude that pollution is affecting marine water quality as a result of this reduction. DO is a crucial means of determining the contamination state of water resources.

Table 3: Descriptive Statistics of DO Values

	Date	N	Mean	Std. Deviation	Min	Max
Sampling Point 1	2020	30	8.85	1,66	9,3	7,2
	2021	30	5.42	0,71	6,7	4
Sampling Point 2	2020	30	8.86	1,65	9,5	7,6
	2021	30	5.42	0,64	6,4	4,1
Sampling Point 3	2020	30	8.78	1,64	9,4	7,6
	2021	30	5.32	0,78	7,1	3,9
Sampling Point 4	2020	30	8.88	1,67	9,3	7,1
	2021	30	5.64	0,91	9,2	4
Sampling Point 5	2020	30	8.78	1,64	9,4	7,4
	2021	30	5.41	0,78	6,8	4
Sampling Point 6	2020	30	8.79	1,64	9,4	7,9
	2021	30	5.43	0,69	6,6	4,2
Sampling Point 7	2020	30	8.71	1,61	9,5	7,9
	2021	30	5.41	0,7	6,9	4,1
Sampling Point 8	2020	30	8.66	1,61	9,5	7,9
	2021	30	5.21	0,77	6,8	3,9
Sampling Point 9	2020	30	8,70	1,61	9,3	8
	2021	30	5,15	0,82	7,2	3,6
Sampling Point 10	2020	30	8,64	1,61	9,4	7,9
	2021	30	5,06	0,88	7,8	3,5

Table 4: Descriptive Statistics of Sea Temperature

	Date	N	Mean	Std. Deviation
Sampling Point 1	2020	30	22,69	2,61
	2021	30	23,23	4,20
Sampling Point 2	2020	30	22,95	2,72
	2021	30	23,13	4,17
Sampling Point 3	2020	30	23,10	2,60
	2021	30	22,90	4,43
Sampling Point 4	2020	30	22,50	2,15
	2021	30	22,73	3,98
Sampling Point 5	2020	30	22,80	3,06
	2021	30	23,53	3,95
Sampling Point 6	2020	30	22,90	2,64
	2021	30	23,47	3,98
Sampling Point 7	2020	30	23,00	2,83
	2021	30	22,80	3,99
Sampling Point 8	2020	30	22,93	2,55
	2021	30	22,60	4,22
Sampling Point 9	2020	30	23,50	2,81
	2021	30	23,50	4,27
Sampling Point 10	2020	30	23,80	2,68
	2021	30	23,40	4,02

It was difficult to ascertain whether there was a noteworthy reduction or increase in terms of mean sea temperature between the years 2020 and 2021 for each sampling unit (Table 4). Following the interpretation of descriptive statistics, an independent sample t-test was used to examine the differences between 2020 and 2021, when the intensive mucilage attack initially occurred in the Sea of Marmara. According to Tables 5 and 6 below, the dissolved oxygen levels and pH values for each sampling point differ from those for the years 2020-2021. We were surprised to find that the results obtained for each sampling unit and with such sensitive confidence levels varied.

Finally, it can be stated that the sea temperature for each sampling point in Table 7 does not differ. This result is also expected in this case since, depending on geographical and climatic conditions, seawater temperature is closely related to various parameters other than pollution. Differences and variations in seawater temperatures can be detected even between two distinct sampling points.

Table 5: Independent sample t-test on pH Levels

Levene's Test for Equality of Variances				t-test for Equality of Means		
		F	Sig.	t	df	Sig. (2-tailed)
Sampling Point 1	E.V.A	0,663	0,419	11,758	58	0
Sampling Point 2	E.V.A	1,497	0,226	9,52	58	0
Sampling Point 3	E.V.A	2,254	0,139	10,811	58	0
Sampling Point 4	E.V.A	0,508	0,479	7,465	58	0
Sampling Point 5	E.V.A	0,579	0,45	9,261	58	0
Sampling Point 6	E.V.A	0,425	0,517	8,374	58	0
Sampling Point 7	E.V.A	0,019	0,892	8,196	58	0
Sampling Point 8	E.V.A	1,428	0,237	6,613	58	0
Sampling Point 9	E.V.A	0,15	0,7	5,879	58	0
Sampling Point 10	E.V.A	0,007	0,933	8,278	58	0

Table 6 Independent sample t-test on Dissolved Oxygen Levels

Levene's Test for Equality of Variances				t-test for Equality of Means		
		F	Sig.	t	df	Sig. (2-tailed)
Sampling Point 1	E.V.A	4,093	0,048	21,683	58	0
Sampling Point 2	E.V.A	3,496	0,067	23,958	58	0
Sampling Point 3	E.V.A	7,845	0,007	21,146	58	0
Sampling Point 4	E.V.A	3,159	0,081	17,101	58	0
Sampling Point 5	E.V.A	12,194	0,001	20,639	58	0
Sampling Point 6	E.V.A	5,653	0,021	22,451	58	0
Sampling Point 7	E.V.A	7,621	0,008	22,816	58	0
Sampling Point 8	E.V.A	10,035	0,002	21,712	58	0
Sampling Point 9	E.V.A	11,669	0,001	21,477	58	0
Sampling Point 10	E.V.A	7,538	0,008	19,915	58	0

Table 7 Independent sample t-test on Sea Water Temperature

Levene's Test for Equality of Variances				t-test for Equality of Means		
		F	Sig.	t	df	Sig. (2-tailed)
Sampling Point 1	E.V.A	3,837	0,055	-0,602	58	0,55
Sampling Point 2	E.V.A	3,832	0,055	-0,201	58	0,841
Sampling Point 3	E.V.A	5,36	0,064	0,213	58	0,832
Sampling Point 4	E.V.A	4,347	0,041	-0,283	58	0,779
Sampling Point 5	E.V.A	0,89	0,349	-0,805	58	0,424
Sampling Point 6	E.V.A	2,887	0,095	-0,65	58	0,519
Sampling Point 7	E.V.A	2,818	0,099	0,224	58	0,823
Sampling Point 8	E.V.A	3,685	0,06	0,371	58	0,712
Sampling Point 9	E.V.A	2,499	0,119	0	58	1
Sampling Point 10	E.V.A	4,838	0,062	0,453	58	0,652

Results

There were significant changes in DO, pH, and seawater temperature at each sampling site, according to the findings of the descriptive statistical analyses (Tables 2, 3, and 4) for this study. The DO indicated a statistical difference at each sampling site, at the 1% threshold, with a margin of error and absolute 99% confidence level. Sample Point 3, 5, and 7 values for DO, for example, fluctuate considerably between 2020 and 2021. There is a statistically low amount of DO in a year, even at points with a low pollution load. The pH levels also follow a similar pattern like DO. Lower-temperature water should have more DO per litre and a higher percent DO, whereas warmer, polluted waters should have less DO per litre and a lower percent DO.

Moreover, DO concentrations in healthy water should be above 6.5-8 mg/L and between 80 and 120 % (DO,2020).

Discussion and Conclusion

The statistical results obtained in this study are also similar to the results obtained in the DO (2017) technical report. The DO value at sample point E was notably low between 2020 and 2021 (Table 5), depending on the amount of mucilage in the water, and this low level was confirmed statistically significant in the tests conducted (p 0.05). Likewise, the seawater temperature of this point showed a similar result ($p \leq 0.05$). In their study, Balkis et al. (2011) revealed that the Sea of Marmara's marine mucilage explains a similar link between DO and temperature. It was discovered that identical conclusions may be made based on the DO measurement findings seen in Sample Points C and G. There is a statistically significant difference between 2020 and 2021 at all sampling points between pH values. ($p \leq 0.05$). The pH value of seawater accepted by EPA is stated as 8.1 (U.S. EPA, 1986). According to the standards used in Turkey for the Sea of Marmara (General Quality Criteria of Sea Water in Turkey, 2004; Turkey Recreational Standards, 2006), it was stated that this value should be between 6 and 9. In order to pinpoint the marine mucilage problem in the Sea of Marmara, the outcomes of on-site tests conducted on samples obtained from the sampling locations established throughout this research are crucial. Even though seawater temperature is an important indication of marine pollution (Fingas, 2019; O'Carroll, A et al., 2019; Fouiza et al., 2019), there was no statistically significant variation between sample points in this study between 2020 and 2021. However, analyses based on remote sensing-based high-resolution satellite images are necessary to expose this relationship extremely clearly and concretely (Fingas, 2019, Androulakis *et al.*, 2021). Adding to that, at the micro-level, the relationship between seawater temperature and marine pollution is influenced by geographical regions and other climatic factors (Maclahan et al., 2007; Vorkamp et al., 2022)

This study examined the effect of marine mucilage on several water quality parameters in a specified area on the Anatolian Continent of the Sea of Marmara. According to the study's findings, mucilage reduced the most essential water quality parameter values, particularly DO and pH. In comparison, no significant change or gradual decline in seawater temperature was observed, except for minor variances that can be statistically ignored between only a few sampling points. When this article was written in April 2022, mucilage started to reappear at a few locations in the Sea of Marmara. The probability that this environmental event occurred grows stronger with the increase in seasonal mean temperature in April.

To overcome the mucilage problem, advanced wastewater treatment units must be promptly developed and put into operation not only within Istanbul's provincial limits but also in other settlements along the Sea of Marmara's shore. Every country that borders the Aegean and Mediterranean Seas, especially Greece, faces the risk of being impacted by this environmental disaster.

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