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ASSESSMENT OF MICROPLASTICS POLLUTION IN MARINE WATER ALONG GULF OF SUEZ, EGYPT

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ABSTRACT

Concern about the presence of plastic debris in marine habitats with a diameter of less than 5 mm, or "microplastics", has grown in recent years on a local and international level. This study represents an investigation to evaluate the spatial fluctuations of microplastics pollution in Egypt, particularly in the Gulf of Suez. microplastics particles from nine different beach locations have been evaluated (east and west Gulf of Suez-Red Sea, Egypt). Various morphologies of microplastic have been identified under a microscope. 1982 microplastics debris in water samples with a mean and standard deviation of 220 ± 179 items/L were found. A one-way ANOVA test has been used to find the differences between morphological groups; line, fragment, and film. The line morphology was the most prevalent form of microplastic in water samples with a mean and standard deviation of 351 ± 26 items/L. According to the Coefficient of Microplastics Impact (CMPI) and the Environmental Status Index (ESI), Suez and Ras-Sadder areas are having the most microplastic pollution among all locations. That could be due to the various activities that these areas are facing. Further study is needed to assess risks to marine ecosystems, including FTIR analysis, SEM analysis, and chemical examination of microplastics and polymers, to understand potential pollution sources.

Keywords: Microplastics, Marine biota, Suez Gulf, Human impact**,** Plastic pollution.

INTRODUCTION

Over 50 years, plastic manufacturing has grown, reaching 300 million tons in 2013, reaching 311 million tons annually by 2014, with projections ranging from 850 to 1124 million tons by 2050. **(Pauna et al., 2019)**. For that, the widespread application of different plastic pollutants in the environment is a global concern **(Andrady, 2011; Sher et al., 2021)**. Their physical and chemical properties, such as durability and resistance, have now become a serious problem, triggering adverse environmental effects **(Hartmann et al., 2019; Montoto-Martínez et al., 2020).**

Plastic pollution threatens marine ecosystems, affecting water, wastewater, soil, air, and atmosphere, affecting marine biota and ecosystems at various levels. (**Thiel et al., 2018; Hartmann et al., 2019; Seeley et al., 2020**). It is estimated that plastics contribute approximately 80% of total sea litter (**Montoto-Martínez et al., 2020**). Plastic debris from urban areas, fishing, shipping discharge, and sewage and effluent release into the ocean via surface drainage systems and anthropogenic activities. **(Horsman, 1982; Galgani et al., 2000; Ng and Obbard, 2006; Andrady, 2011).**

Over time, large plastic debris breaks down through photolytic ultraviolet radiation, oxidation, hydrolysis, mechanical forces, thermal and biological degradation processes, resulting in the formation of microplastics. **(Browne et al., 2013; Andrady, 2011).** Microplastics (<5 mm in size) are the most abundant form of plastic debris and serve as a growing aquatic contaminant **(Thompson et al., 2004**).

Microplastics are considered a more serious threat to marine biota than larger plastic debris as they are often in the same size-range as natural food items, thus leading to their ingestion when mistaken as food **(Boerger et al., 2010; Lusher et al., 2013; Bond et al., 2013; Shabaka et al., 2020).** Microplastics ingestion disrupts the endocrine system, poses toxicological hazards, and contributes to the bioaccumulation of organic pollutants in the marine food chain. **(Teuten et al., 2007; Hirai et al., 2011; Gassel et al., 2013).**

(Dai et al., 2018) found that microplastics levels in Bohai Sea seawater increased at depths 5-15m, with fibers being the primary source accounting for
75%-96.4% of total microplastics.

microplastics pollution was investigated by **(Lenaker et al., 2019)** along a freshwater continuum from Milwaukee River estuary to Lake Michigan. The five categories of particle types (fragment, film, foam, pellet, and line) were the most common particle types in all water samples, making up 45% of all particles, regardless of density.

Microplastics pollution in seawater and marine organisms across the Tropical Eastern Pacific and Galápagos has been detected by **(Alfaro-Núñez, A. et al., 2021)**, who found that plastic pollution in oceans is linked to robust, durable materials, with microplastics fragments found in sedimentary habitats, shores, pelagic zones, deep seas, and living organisms, including humans.

Quantifying microplastics pollution in the Red Sea and Gulfs of Suez and Aqaba were studied by **(Ghani et al., 2023)**, according to the referred study, the majority of pollution originates from maritime activities, such as cargo ships and intensive recreational activities, with mean concentrations ranged from 23.3 ± 15.28 to 930.0 ± 181.9 MPs/kg DW. 12 of the 17 beaches that were investigated had mean concentrations of less than 200 items/kg.

Gulf of Suez is a strategic maritime region for Egypt, as it represents the vital eastern gate of Egypt to the world. It constitutes the left arm of the Red Sea that separates the mainland of Egypt (specifically the Eastern Desert) from the Sinai Peninsula of Egypt **(El-Sikaily et al., 2005).** The objectives of this study are (i) determine the level, spatial distribution, and variability of microplastics in marine water along the Gulf of Suez, (ii) understand the controlling factors for the transportation and distribution of microplastics, (iii) evaluate microplastics impacts using environmental indexes.

MATERIALS AND METHODS

Sampling location

In this study, nine different sampling locations were selected from the east and west of the Suez Gulf **(Fig. 1 and Table 1)** to study the spread of microplastics particles in water.

Table1: Surveyed areas from East and West of Suez Gulf.

	LOCATIONS	TYPE	CODE	LAT.	LONG.
West	Suez	Public seaside wake	A1	29.95102	32.550831
	El-Addabia	beside El-Addabia port	A2	29.893035	32.459223
	El-Sokhna	Open area	A3	29.5550538	32.3615696
	Zafrana	Open area	A4	29.259628	32.6158055
	Ras-Gharib	Public seaside wake	A5	28.3629366	33.0943545
East	Ras-Sadder	Public beach	A6	29.583547	32.713803
	Abu-Radis	Public seaside wake	A7	29.058104	33.09489
	Al-Tur	Public peach	A8	28.235204	33.602452
	Jubayl	Open area	A9	28.2232777	33.6238721

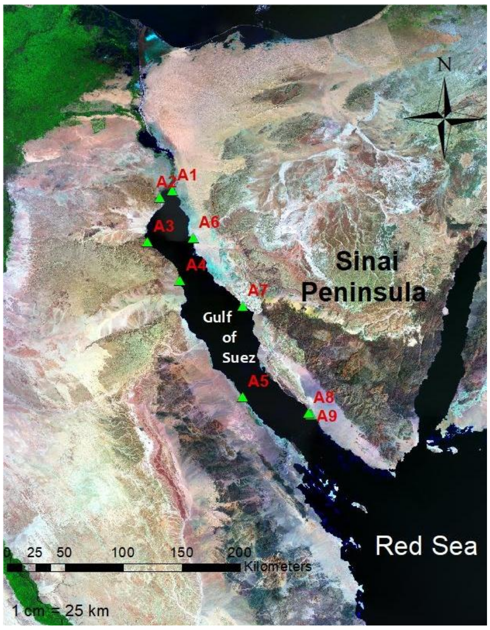

Fig.1: The Gulf of Suez, Egypt with the locations of surveyed areas.

Sample collection and preservation

To prevent external contamination, 2.5 L of water sample was directly collected from water surface in glass bottles five meters away from the shoreline during low tide when the water reached 1 meter in depth in the winter season for each location.

Sample preparation

To extract microplastics particles from the samples, a vacuum system was used to filter the samples using a 0.45 µm cellulose nitrate filter paper **(Fig. 2).**

To keep the samples from becoming contaminated by plastic fibers in the surrounding air, cotton coats were worn during the analysis, and the surfaces of the operating platforms were wiped permanently. Before being utilized, every glassware item was carefully cleaned with distilled water, and covered with glass stopper, and the prepared solutions were filtered through membranes **(Hidalgo-Ruz et al., 2012)**.

Fig.2: Filtration by 0.45µm cellulose nitrate filter paper with a vacuum system.

Microscopic examination:

A STEREO-MICROSCOPE has been used with **LEICA MC 190 HD lens and 25X magnification** to examine all water samples.

Particles are generally classified throughout this procedure based on their morphology (fragment, pellet, line, film, and foam) **(Kershaw et al., 2019).**

The differences in the study compatibility of microplastic morphology in the study area have been decided by a one-way ANOVA test. The data was considered statistically significant at $p \leq 0.05$.

Evaluating pollution by environmental indexes:

The Coefficient of Microplastics Impact (CMPI) was used as an indicator to evaluate the impact of all microplastics shapes. This coefficient is the existing relationship between the total amount of a specific MPs shape (fragment, pellets, fibers, foam) and the total amount of MPs found in a sampling unit. The CMPI of each beach was calculated using the formula:

$$\mathbf{CMPI} = \frac{\textbf{Specific MPs shape}}{\textbf{Total MPs}}$$

According to this methodology, different categories of microplastics impact can be obtained ranging from minimum at CMPI = 0.0001–0.1; average when CMPI = 0.11–0.5; maximum if CMPI = 0.51–0.8; and extreme CMPI = 0.81–1 **(Rangel-Buitrago et al., 2021).**

The second index calculated was **the Environmental Status Index (ESI).** The ESI is an indicator that rates the quality of beaches according to effects on the health of beach organisms produced by MPs with a scale ranging from 1 to 4 (where 1 = Good, 2 = Mediocre, 3 = Unsatisfactory, 4 = Bad) **(Table 2) (Schulz et al., 2013; Rangel-Buitrago et al., 2021)**.

Table 2: Microplastics different shapes and classification (xi) for each one.

SHAPE	**CLASSIFICATION (XI)**			
	Good	**Mediocre**	**Unsatisfactory**	**Bad**
Line	Less than 44	45 to 60	61 to 78	More than 79
Pellet	Less than 1	2 to 3	4 to 7	More than 8
Fragment	Less than 4	5 to 11	12 to 26	More than 27
Film	Less than 2	3 to 7	8 to 15	More than 16

The ESI implies the use of a weighted value for each MPs shape (i.e., fiber, pellets, etc.) found following two criteria:

- Weight: 1 if the microplastics typology causes indirect damage, but with no direct risk potential.
- Weight: 1.5 if the microplastics typology causes a direct impact.

The ESI of each beach was calculated using the formula:

$$\mathbf{ESI} = \frac{\sum_{i=1}^{n} wi * xi}{\sum_{i=1}^{n} wi}$$

Where ESI is the final score as the result of a weighted average of MP shapes found on a specific beach (wi) multiplied for the class (xi) assigned to the beach based on the presence and abundance of that specific shape.

RESULTS

Morphological analysis:

Microscopic examination has revealed the presence of suspected microplastics particles which have size range from more than 0.45 µm to less than 100 µm. The most common MP shapes found were opaque, clear, or colored line shapes, fragment shapes (irregular shape appearance of being broken down from a larger piece) were also noted **(Fig. 3)**.

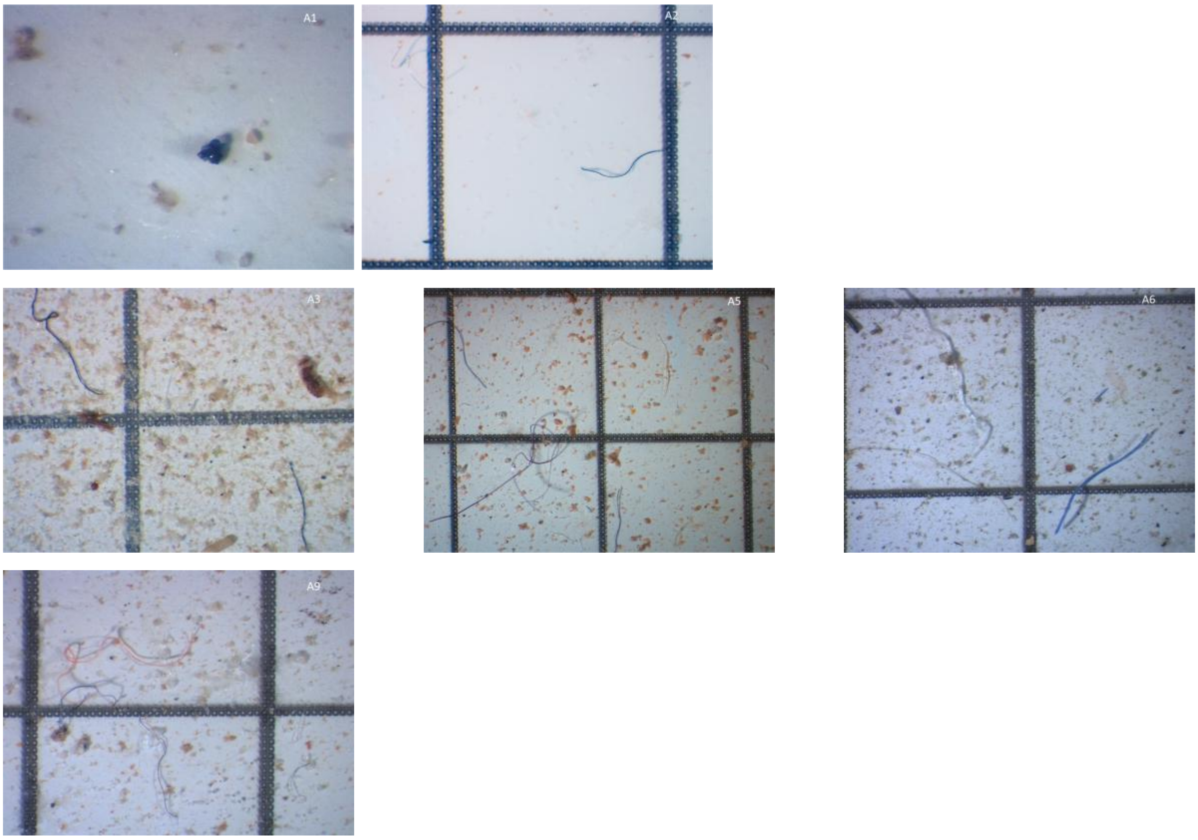

Fig.3: MP for water samples in various locations.

A1 was the most abundant area with MPs at 597 items; 515 items were fragment shapes, followed by the A6 area with 363 items; 319 items were line shapes. The least abundant area of MPs was A3 with 69 items; 68 items were line shapes **(Fig.4)**.

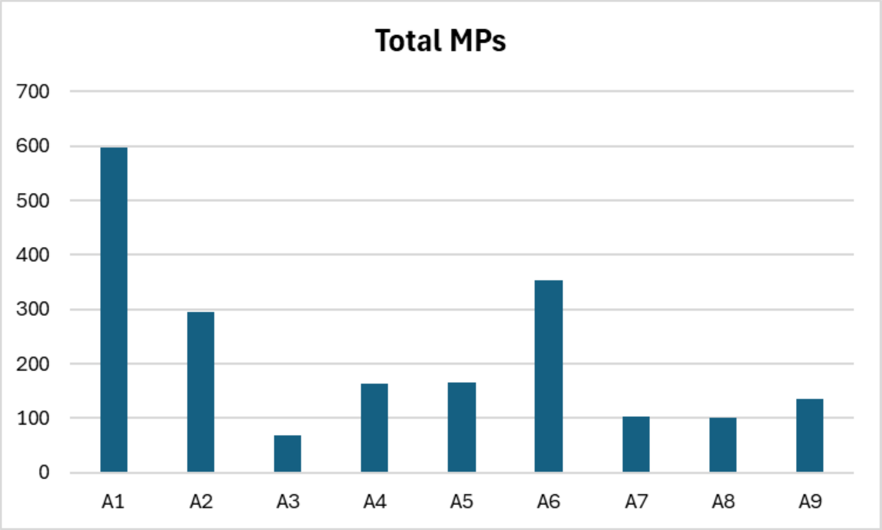

Fig.4: The abundance of total MP in all locations.

There are statistically significant differences in the study compatibility of microplastic morphologies in the study area. They were determined using the one-way ANOVA test **(Table 3 & Fig.5).**

Table 3: Results of the one-way ANOVA test according to the differences between the microplastic morphologies.

SHAPE	TOTAL	MEAN	STDEV.	SOURCE	DF	F VALUE	P VALUE	STATISTICALLY SIGNIFICANT
Line	1054	351.3	25.9	Between Groups	2.0	17.791	0.003	Yes
Fragment	916	305.3	11.15	Within Groups	6.0			
Film	12	4	3	Total	8.0			

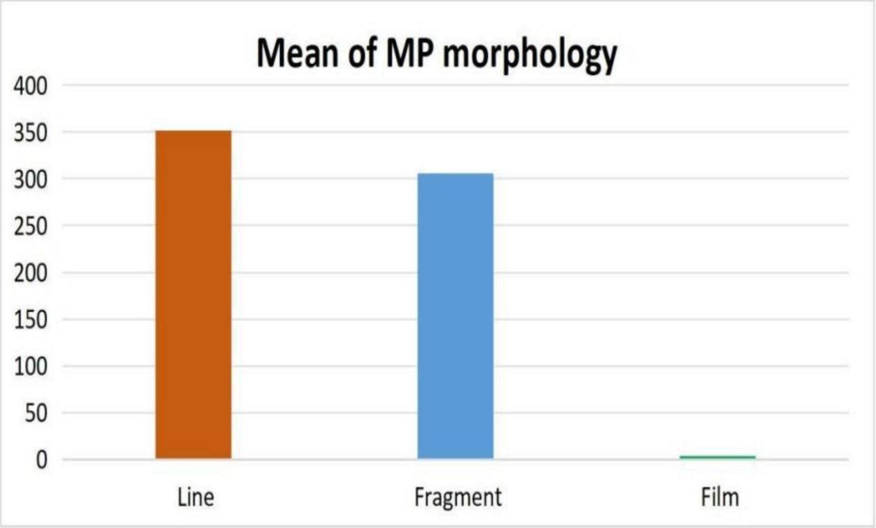

Fig.5: MP means according to various morphology.

Microplastics abundance and Impact

(Table 4 & Fig.6) Shows the shape-based microplastics abundance and the impact of microplastics contamination at each site.

According to CMPI, 44% of total microplastics shapes had extreme contamination impact, and 17% had average contamination impact of all surveyed areas; all were line shapes except A2 and A3, which had extreme fragment impact.

Table 4: The Coefficient of Microplastics Impact of water samples in surveyed region

ID	LINE		FRAGMENT		FILM	
	CMPI	**Impact**	**CMPI**	**Impact**	**CMPI**	**Impact**
A1	0.14	Average	0.86	Extreme	-	-
A2	0.11	Average	0.89	Extreme	-	-
A3	0.99	Extreme	-	-	0.01	Minimum
A4	0.37	Average	0.63	Maximum	-	-
A5	0.97	Extreme	0.03	Minimum	-	-
A6	0.90	Extreme	0.09	Minimum	0.01	Minimum
A7	1.00	Extreme	-	-	-	-
A8	0.98	Extreme	-	-	0.02	Minimum
A9	0.96	Extreme	-	-	0.04	Minimum

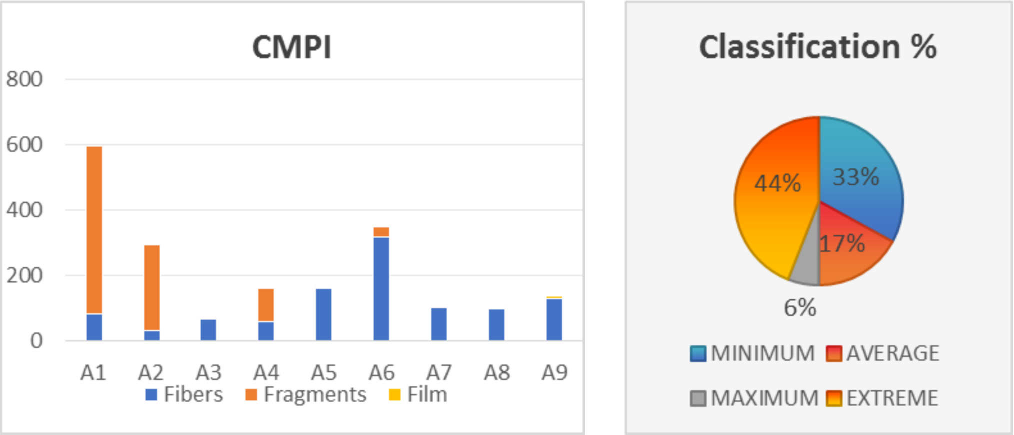

Fig. 6: The Coefficient of Microplastics Impact of water samples and percentage of each classification of surveyed regions.

The quality of the area was evaluated based on **the Environmental Status Index (ESI) (Table 5 and Fig.7).**

A6 show the unsatisfactory state of beach quality, while the other regions were mediocre in beach quality state.

Table 5: The Environmental Status Index of water samples in surveyed region

SHAPE	**A1**	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**	**A8**	**A9**
	Xi								
Line	6	1.5	4.5	4.5	6	6	6	6	6
Fragment	6	6	1.5	6	3	6	1.5	1.5	1.5
Pellet	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Film	1.5	1.5	1.5	1.5	1.5	3	1.5	1.5	3
Final	2	2	2	2	2	3	2	2	2
Status	Mediocre	Mediocre	Mediocre	Mediocre	Mediocre	Unsatisfactory	Mediocre	Mediocre	Mediocre

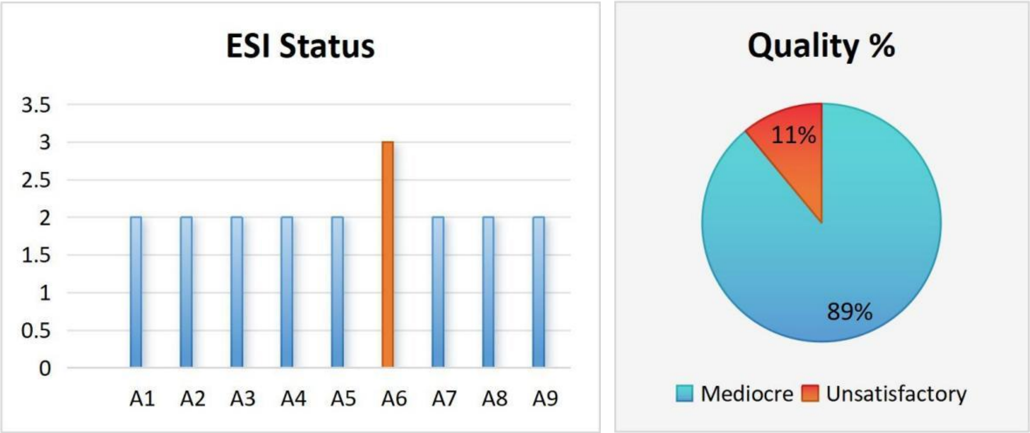

Fig. 7: The Environmental Status Index and Quality percentage of all locations.

DISCUSSION

Although there is a limitation to identify the polymer found in each sample due to the very tiny size of microplastic particles, the analysis study of water surface samples of nine different locations along the gulf of Suez, east and west, after filtering by a 0.45µm cellulose nitrate filter paper with a vacuum system, referred to the fact that all samples had positive MPs pollution results, with abundance average of 220 ± 179 items/L, that was close enough to the results that were obtained in the Yangtze River estuary in China, which had 170 items/L average abundance of microplastics in the water **(Ji.X et al., 2023)**, while in Milwaukee River estuary in the United States of America, mean depth-weighted sample concentrations for the water column varied from 420 to 5670 items/L were detected by **(Lenaker et al., 2019)**, this big difference was mainly due to the different sampling methods used in those studies.

Based on microscopic examination, A1 and A6 exhibited the greatest levels of microplastics contamination at 597 items/L and 353 items/L, respectively, with the most abundance shapes of fragment in A1 (515 items/L) and line in A6 (319 items/L). One-way ANOVA test shows that there are statistically significant differences between the microplastic morphology in the study area, where the value of F was 17.791 and the significance value P was 0.003 less than 0.05 statistically significant. The line shape came higher in the average than the other forms with a value of 351±26. Otherwise, the study results show the shape-based microplastics abundance and the impact of microplastics contamination of those two locations to be having the extreme impact of MP pollution on marine biota, with 44% of extreme impact and 17% of average impact for all locations based on The Coefficient of Microplastics Impact (CMPI). Environmental Status Index (ESI) showed that A6 had unsatisfactory beach quality; however, other locations had mediocre beach quality.

Depending on this result, Suez area (A1); west Gulf of Suez and Ras-Sadder area (A6); east Gulf of Suez are facing the highest contamination factors that allow those two locations to be the lowest area in quality with the highest pollution impact on marine biota, that could be due to most of local Egyptian tourists visit Suez seaside wake and beaches for vacations, enjoying cafes and restaurants. The area is safe for children and includes six beaches for guests and foreigners to visit. Likewise, the public beach of Ras-Sadder offers numerous summer resorts for visitors to enjoy the sandy Red Sea beaches during the summer season.
All of this might result in a high volume of plastic product waste in these locations, which, when combined with climatic conditions and other various factors, break down into microplastics, which exposes the marine biota to the risk of microplastics pollution as well as the marine ecosystem.

CONCLUSION AND RECOMMENDATION

This study aims to evaluate microplastics pollution in the marine water along the Gulf of Suez. The study found 1982 microplastics debris in water samples with a mean and standard deviation of 220 ± 179 items/L and a ratio between minimum and extreme microplastics impact to marine ecosystems. 89% of beaches quality were mediocre, while 11% were extreme represented in A6.

This requires further study to assess the risks to marine ecosystems, including chemical identification of excreted particles using FTIR analysis, investigating debris microstructures using the SEM technique, and chemical examination of pollutants adsorbent on microplastics and various types of polymers, those further study can help to understand the potential pollution source and how to control the microplastic contamination in environment.

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تقييم تلوث المياه البحرية بالميكروبلاستيك على طول خليج السويس، مصر

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المستخلص

قد تزايد القلق في السنوات الأخيرة على المستوى المحلي والدولي بشأن وجود الحطام البلاستيكي الذي يقل قطره عن 5 مم في الموائل البحرية "الميكروبلاستيك". هذه الدراسة تقدم تحقيق حول تقييم التقلبات المكانية لتلوث الميكروبلاستيك في مصر، وخاصة في خليج السويس. تم تقييم وجود جزيئات الميكروبلاستيك من تسعة مواقع شاطئية مختلفة (شرق وغرب خليج السويس – البحر الأحمر، مصر)، وقد تم تحديد أشكال مختلفة من الميكروبلاستيك من خلال التعريف المجهري (الميكروسكوب) والتي تبلغ في المجموع 1982 قطعة من الميكروبلاستيك في عينات المياه بمتوسط وانحراف معياري 220 ± 179 قطعة / لتر، وكشفت هذه الدراسة أن الشكل الخطى كان الشكل الأكثر انتشارًا لجسيمات الميكروبلاستيك في عينات المياه بمتوسط وانحراف معياري 351 ± 26 قطعة / لتر. أظهر معامل تأثير الميكروبلاستيك تأثيراً متوسطاً بنسبة 17 % إلى تأثير شديد بنسبة 44 % فى منطقة الدراسة وأظهر مؤشر الحالة البيئية أن جودة مناطق الدراسة كانت متوسطة بنسبة 89% وغير مرضية بنسبة 11% لجميع الشواطئ قيد الدراسة، والتي تمثلت في منطقتي السويس ورأس سدر والتي أظهرتا أكثر المناطق تعرضاً للتلوث بالبلاستيك الدقيق نتيجة لاختلاف أنشطة المنطقة.

الكلمات الدالة: الميكروبلاستيك، الأحياء البحرية، تأثير العامل البشرى، خليج السويس، التلوث بالبلاستيك.