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Characterization of Microplastic Pollution Along the Red Sea Coast of Jeddah, Saudi Arabia

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Abstract**: *This study presents a structured characterization of microplastic pollution along the Red Sea coast of Jeddah, Saudi Arabia. Utilizing advanced analytical techniques including Scanning Electron Microscopy (SEM), Energy-Dispersive X-ray Spectroscopy (EDX), X-Ray Diffraction (XRD), Raman Spectroscopy, Fourier-Transform Infrared Spectroscopy (FTIS), and Atomic Force Microscopy (AFM), we examined the physical, chemical, and morphological properties of microplastic samples. The research revealed significant weathering and degradation of particles, predominantly composed of polyethylene terephthalate (PET). Water analysis provided context for understanding degradation processes. Potential pollution sources were identified, including urban runoff, coastal activities, and industrial discharge. This work contributes to the understanding of microplastic pollution in the unique Red Sea ecosystem and informs targeted mitigation strategies.***

Keywords**: *Microplastics; Red Sea; Coastal Pollution; Polymer Characterization; Marine Ecosystems; Plastic Degradation; Urban Pollution.***

Abbreviations:
SEM: Scanning Electron Microscopy
XRD: X-Ray Diffraction
AFM: Atomic Force Microscopy
FTIS: Fourier-Transform Infrared Spectroscopy
EDX: Energy-Dispersive X-ray Spectroscopy
ESEM: Environmental Scanning Electron Microscope
RMS: Root Mean Square

I. INTRODUCTION

The proliferation of microplastic pollution in marine environments has emerged as one of the most pressing environmental challenges of the 21st century, with far-reaching implications for ecosystem health, biodiversity, and human well-being [1]. Microplastics, defined as plastic particles less than 5 mm in size, have been detected in virtually every marine habitat [2], from polar ice caps to deep-sea trenches, reflecting the pervasive nature of this contaminant [3].

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The Red Sea, a unique marine ecosystem known for its rich biodiversity and economic importance, is increasingly facing the threat of microplastic pollution [4], driven by rapid coastal development, urbanization, and industrial activities along its shores [5]. This study focuses on the coastal waters of Jeddah, Saudi Arabia, a major urban center along the Red Sea coast, for characterizing microplastic pollution and identify potential pollution sources. Jeddah with its population of over 4 million and its status as a key commercial and industrial hub, presents an ideal case study for examining the interplay between urban development and marine plastic pollution in the Red Sea region [6]. The city's rapid growth, coupled with increasing plastic consumption and waste generation, raises critical questions about the fate of plastic debris in the marine environment and its potential impacts on local ecosystems.

Previous research has highlighted the presence of microplastics in various components of the Red Sea ecosystem [7]. reported significant concentrations of microplastics in coastal sediments along the Egyptian Red Sea coast [8]. documented microplastic ingestion by commercial fish species in the region. These studies underscore the urgency of addressing microplastic pollution in the Red Sea and the need for characterization of microplastic particles to understand their sources, fate, and potential ecological impacts.

The unique environmental conditions of the Red Sea, including its high salinity, elevated temperatures, and intense solar radiation, may influence the degradation and transformation of microplastics in ways that differ from other marine environments [9]. Understanding these processes is crucial for assessing the long-term fate of microplastics in this ecosystem and their potential to act as vectors for other pollutants or pathogens [10].

This research builds upon these previous findings, employing a multi-analytical approach to examine the physical, chemical, and morphological properties of microplastic particles found in the coastal waters of Jeddah [11]. By integrating advanced analytical techniques such as Scanning Electron Microscopy (SEM), Energy-Dispersive X-ray Spectroscopy (EDX), X-Ray Diffraction (XRD), Raman Spectroscopy, Fourier-Transform Infrared Spectroscopy (FTIR), and Atomic Force Microscopy (AFM), we aim to provide a informative characterization of microplastic pollution in this area [12].

The use of these complementary techniques allows for a multifaceted analysis of microplastic particles. SEM provides high-resolution imaging of surface morphology, revealing weathering patterns and potential microbial colonization [13]. EDX offers insights into the elemental composition of particles, which can indicate the presence of additives or adsorbed contaminants [14]. XRD and Raman spectroscopy enable the identification of crystalline structures and molecular bonds, respectively [15], aiding in polymer identification and the assessment of degradation processes [16]. FTIR spectroscopy further confirms polymer types and can detect functional group changes associated with weathering [17]. AFM provides nanoscale topographical information, offering quantitative data on surface roughness and mechanical properties [18].

In addition to particle characterization, this study incorporates water quality analysis to provide environmental context for microplastic pollution. Parameters such as temperature, pH, salinity, dissolved oxygen, and turbidity can influence the distribution, degradation, and ecological interactions of microplastics [19]. By correlating water quality data with microplastic characteristics, we aim to elucidate the complex interplay between these pollutants and their aquatic environment.

Furthermore, this research considers the broader geographical and socio-economic context of the Jeddah coastal area to identify potential sources of microplastic pollution. Urban runoff, wastewater discharge, industrial activities, coastal tourism, and maritime operations are all potential contributors to microplastic pollution in this region [20]. By analyzing the types, sizes, and weathering patterns of microplastics in relation to local activities and land use, we seek to trace these pollutants back to their likely origins.

The significance of this study extends beyond the immediate geographical area of Jeddah. As a major city on the Red Sea coast, Jeddah's plastic pollution profile may be indicative of broader regional trends, offering insights into the challenges faced by other rapidly developing coastal urban centers in the Middle East and beyond [21]. Moreover, given the Red Sea's connection to the Indian Ocean via the Gulf of Aden, understanding microplastic pollution in this region has implications for global oceanic plastic transport and distribution patterns [22].

By providing a detailed assessment of microplastic pollution in a key coastal urban area, the study contributes to the knowledge base necessary for developing effective strategies to reduce marine plastic pollution and promote sustainable urban development.

In conclusion, this study aims to provide a holistic understanding of microplastic pollution in the coastal waters of Jeddah, Saudi Arabia, through multi device particle characterization, environmental analysis, and source identification. The results of this research will not only contribute to the growing body of knowledge on marine microplastic pollution but also inform policy decisions and guide the development of targeted environment management strategies to protect the unique and valuable ecosystem of the Red Sea. As we face the global challenge of plastic pollution, studies like this serve as crucial steps towards safeguarding the marine environments for future generations.

II. MATERIALS AND METHODS

A. Sample Collection and Preparation

Microplastic samples were collected from 16 sites along the south Jeddah coastline using ROCHA guideline for sampling microplastics on sandy beaches. In-Situ Water sampling conducted using YSI Pro-DSS Digital Water Quality Meter concurrently for analysis of physicochemical parameters. Microplastic samples were preserved in 4% formaldehyde solution and transported to the laboratory. Microplastic particles were isolated using density separation with saturated NaCl solution (ρ = 1.2 g/cm^3) and visually identified under a stereomicroscope.

B. Analytical Techniques

The following analytical techniques will be employed to characterize microplastics: Scanning Electron Microscopy (SEM), Energy-Dispersive X-ray Spectroscopy (EDX), X-Ray Diffraction (XRD), Raman Spectroscopy, Fourier-Transform Infrared Spectroscopy (FTIR) and Atomic Force Microscopy (AFM).

C. Scanning Electron Microscopy (SEM)

Scanning Electron Microscopy (SEM) serves as a cornerstone technique in this analysis of microplastics from the Red Sea coast of Jeddah. This high-resolution imaging method allows us to visualize and characterize the surface morphology and topography of microplastic particles at magnifications far beyond the capabilities of optical microscopy. For this study, a FEI Quanta 650 FEG Environmental Scanning Electron Microscope (ESEM) was used. This model is manufactured by FEI Company (now part of Thermo Fisher Scientific) and is capable of operating in high vacuum, low vacuum, and ESEM modes. Key specifications; Resolution: 1.0 nm at 30 kV (high vacuum mode), Accelerating voltage: 200 V to 30 kV and Magnification: 6x to 2,000,000x.

D. Energy-Dispersive X-ray Spectroscopy (EDX

Energy-Dispersive X-ray Spectroscopy (EDX) allow us to delve deeper into the chemical composition of the microplastic particles, providing valuable insights beyond visual characterization. In the context of this research, EDX plays several crucial roles in; Elemental Composition Analysis, Inorganic Additive Identification, it helps us to detect and quantify these additives, which can provide clues about the origin and manufacturing processes of the microplastics. In term of environmental contaminant detection, as microplastics interact with the marine environment of the Red Sea, they may adsorb various contaminants.

EDX systems are often integrated with Scanning Electron Microscopes (SEM) and manufactured by FEI Company (now part of Thermo Fisher Scientific), APEX™ EDS is the software used for analysis.

E. X-Ray Diffraction (XRD)

X-Ray Diffraction (XRD) allows us to probe the internal structure of microplastic particles, providing crucial information about their crystalline nature and polymer composition. XRD fulfills several essential functions; Polymer Identification: XRD enables us to identify specific types of polymers based on their unique crystalline structures. This is particularly valuable for distinguishing between different plastic types found in the study's coastal waters, such as polyethylene terephthalate

(PET), polyethylene (PE), and polypropylene (PP). By comparing XRD results with standard diffraction patterns, we can ensure the accuracy of the polymer identifications and detect any anomalies that may require further investigation. Copper tube was used as a source, While the specific model wasn't mentioned, common XRD systems are manufactured Bruker company, model of D8 discover.

F. Raman Spectroscopy

Raman spectroscopy is a non-destructive analytical technique provides detailed information about the molecular structure and composition of microplastic particles, complementing and extending the data obtained from other methods such as XRD and FTIR. Raman spectroscopy serves several vital functions; allows us to identify specific types of polymers based on their unique vibrational fingerprints. This is particularly valuable for distinguishing between different plastic types found waters, even when they have similar elemental compositions. Raman spectroscopy can detect and identify these additives, providing crucial information about potential toxicity and environmental impacts. Raman spectroscopy provides molecular-level information that complements the elemental data from EDX and the crystalline structure data from XRD, allowing for a more characterization of microplastic particles. Green laser with a wavelength of 532 nm used as a source, Raman spectrometers are produced by Horiba company model of HR revolution.

G. Fourier-Transform Infrared Spectroscopy (FTIR)

Fourier-Transform Infrared Spectroscopy (FTIR) is a powerful method provides crucial information about the chemical composition and structure of microplastic particles, offering complementary data to the other analytical approaches. It identifies characteristic absorption bands and their corresponding wavenumbers with comparing the spectrum with known polymer spectra to identify the microplastic type. FTIR spectrometers are manufactured Thermo Fisher Scientific company.

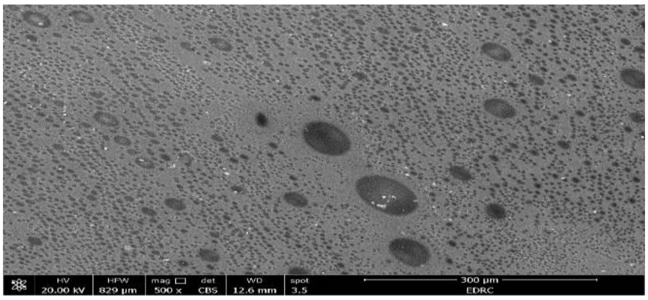
H. Atomic Force Microscopy (AFM)

Atomic Force Microscopy (AFM) serves as a crucial high-resolution imaging technique in this study of microplastics. This advanced method allows us to examine the surface topography and mechanical properties of microplastic particles at the nanoscale, providing unique insights that complement the other analytical approaches. A Bruker Dimension Icon AFM was used for this study. This model is known for its high resolution and versatility. Scan range: 90 µm x 90 µm x 10 µm, Vertical noise floor: <30 pm RMS in appropriate environment, XY sensor noise: <0.15 nm RMS.

III. RESULTS AND DISCUSSION

A. Scanning Electron Microscopy (SEM) Analysis

SEM analysis was performed on 16 microplastic samples. SEM image reveals significant surface modifications of the microplastic particle as shown in figure (1). Heterogeneous surface texture: The particle surface exhibits a variety of features, including pits, cracks, and adhered particles. Pitting: Numerous dark circular to oval-shaped depressions are visible across the surface, ranging in size from approximately 1-5 µm in diameter. Adhered particles: Bright, irregular-shaped particles are scattered across the surface, likely representing inorganic material or smaller plastic fragments. Surface erosion: The overall surface appears rough and uneven, indicative of material loss and degradation [23]. Cracking: Some larger, elongated depressions suggest the formation of cracks or fissures in the plastic material [24].



[Fig.1: Illustrate SEM Image of Sample (14)]

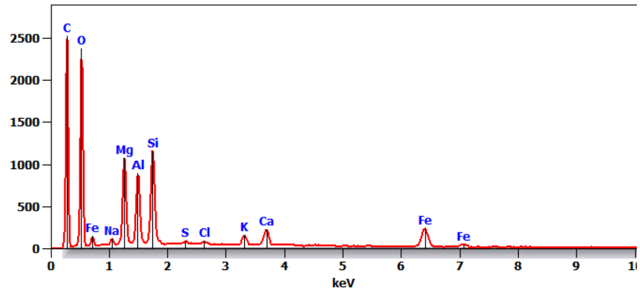
B. Energy-Dispersive X-ray Spectroscopy (EDX

EDS analysis was performed on 16 microplastic samples. The results showed varying compositions, but all samples were predominantly carbon, consistent with organic polymers like PET. Table 1 explains the elemental composition (in weight %) for all 16 samples.

Table I: Elemental Composition (Weight %) of 16 Samples from EDS Analysis

Sample	C	O	Na	Mg	Al	Si	S	Cl	K	Ca	Ti	Fe
1	82.8	10.5	0.2	0.2	0.4	0.3	0.3	-	0.1	4.9	0.2	-
2	87	9.9	-	-	0.2	-	0.4	-	-	2.6	-	-
3	85.6	-	-	-	0.2	-	0.7	-	-	13.5	-	-
4	67.1	0	-	-	0.2	-	0.9	-	-	31.8	-	-
5	64.9	7.6	-	-	0.3	0.2	0.3	-	-	26.7	-	-
6	85.1	3.9	-	-	0.3	-	0.3	-	-	10.4	-	-
7	56.9	3.2	-	0.1	0.3	0.3	0.2	-	-	39	-	-
8	85	11.3	-	-	0.3	0.3	0.4	0.3	0.2	2.4	-	-
9	95.6	1.9	-	-	0.2	-	0.4	-	-	1.9	-	-
10	73.4	0	-	-	0.2	-	0.7	-	-	25.6	-	-
11	28.2	28.6	1.5	2.6	0.7	1.1	1.5	1.2	1	33.2	0.4	-
12	96.2	0	-	-	0.2	0.3	0.2	-	-	2.9	-	-
13	54.6	32.4	1.6	1	1.1	2.1	0.7	0.6	0.5	4.7	0.1	0.6
14	34.3	44.4	0.5	5.6	3.9	5.3	0.1	0.2	0.7	1.1	-	3.8
15	77.7	14.2	2.1	0.6	0.8	0.7	0.7	1.2	0.3	1.8	-	-
16	88	9.2	0.2	-	0.3	0.2	0.2	-	-	1.6	-	-

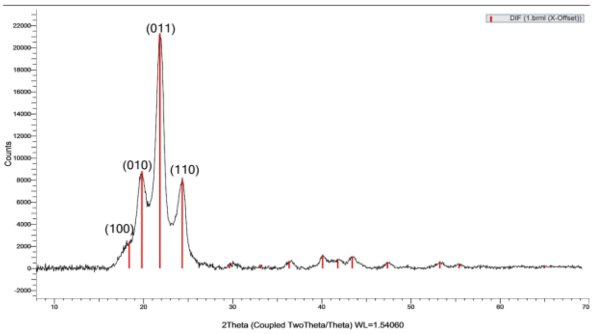
Notable observations from the EDS analysis: All samples contain high percentages of carbon, ranging from 28.2% to 96.2%, consistent with organic polymers. Oxygen is present in most samples, aligning with the oxygen-containing ester groups in PET. Calcium is present in all samples, with concentrations varying widely (1.1% to 39.0%). Various other elements (Na, Mg, Al, Si, S, Cl, K, Ti, Fe) are present in small amounts, possibly indicating the presence of additives or environmental contaminants [25]. The variation in elemental composition across samples suggests that while the base polymer may be consistent (PET), Figure (2) represent the differences in additives or environmental interactions among the microplastic particles [26].



[Fig.2: Illustrate Chart of EDS Study of Sample (14)]

C. X-Ray Diffraction (XRD) Analysis

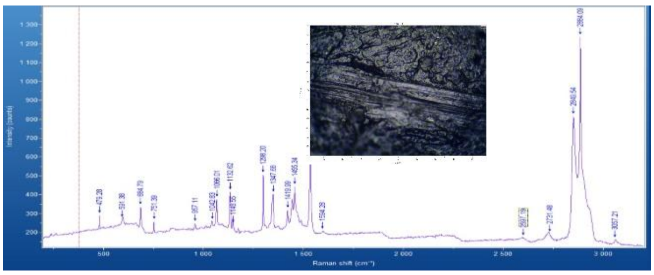
XRD analysis was performed on 16 microplastic samples. The strongest peak (100% relative intensity) is at 21.850° with a d-spacing of 4.06436 Å. Other significant peaks are observed at 19.828° (41.3% intensity, d = 4.47397 Å), 24.354° (38.4% intensity, d = 3.65187 Å), 18.407° (11.2% intensity, d = 4.8Q125 Å). These peak positions and intensities are characteristic of polyethylene terephthalate (PET). The strongest peak at 21.850° corresponds to the (011) plane in PET. The peak at 19.828° likely represents the (010) plane. The peak at 24.354° can be attributed to the (110) plane. The peak at 18.407° may correspond to the (100) plane. The presence of multiple well-defined peaks indicates a semi-crystalline structure, which is typical for PET. The relative intensities and positions of the peaks align well with standard PET diffraction patterns as shown in figure (3). Based on this XRD analysis, the microplastic sample is most likely composed of polyethylene terephthalate (PET) [27]. This aligns with the previous statement that XRD identified the microplastic type as PET. These matches confirm that the sample is indeed PET as indicated by the JCPDS reference 00-061-1103 [28].



[Fig.3: Illustrate the XRD Pattern of Sample (14)]

D. Raman Spectroscopy Analysis

The Raman spectrum of the microplastic sample showed several characteristic peaks associated with PET. The key peaks and their assignments are presented in and figure (4).



[Fig.4: Illustrate Raman Shift and Image of Sample (14)]

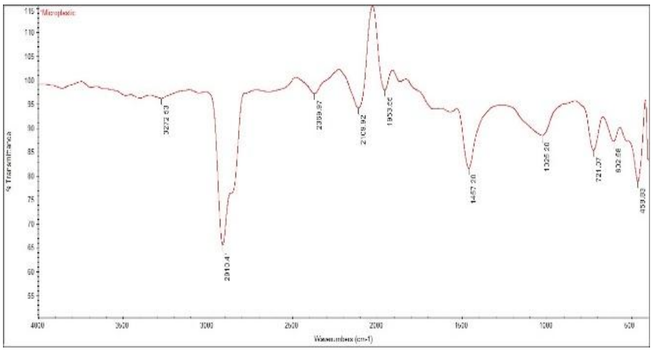
The Raman spectroscopic analysis of these microplastic samples collected revealed a spectral fingerprint that offers valuable insights into their molecular structure. The observed Raman shifts provide strong evidence for the presence of polyethylene terephthalate (PET) in these environmental samples. Strong peak around 2900-3000 cm^{-1}: This represents C-H stretching vibrations, typical in organic compounds including plastics, Prominent peaks observed in the region of 1615 cm^{-1} and 1532 cm^{-1}, which are characteristic of the vibrational modes associated with aromatic ring structures. These peaks are indicative of the terephthalate component in PET, A series of peaks in the spectral range of 1100-1300 cm^{-1}, which correspond to various C-O and C-C stretching modes. These peaks further corroborate the presence of the ester groups and the carbon skeleton characteristic of PET [29]. The combination of these spectral features aligns closely with the known Raman signature of PET, providing strong support for its identification as the primary constituent of the analyzed microplastic particles [30].

E. Fourier-Transform Infrared Spectroscopy (FTIR) Analysis

The FTIR spectrum further confirmed the identification of the microplastic as PET. Key absorption bands and their assignments are listed in Table 2 and figure (5).

Table II: Key FTIR Absorption Bands of Sample (14)

Wavenumber (cm^{-1})	Assignment
2910.41	C-H stretching vibrations (aliphatic)
1935.55	Overtone or combination band (aromatic)
1721.07	C=O stretching (ester group)

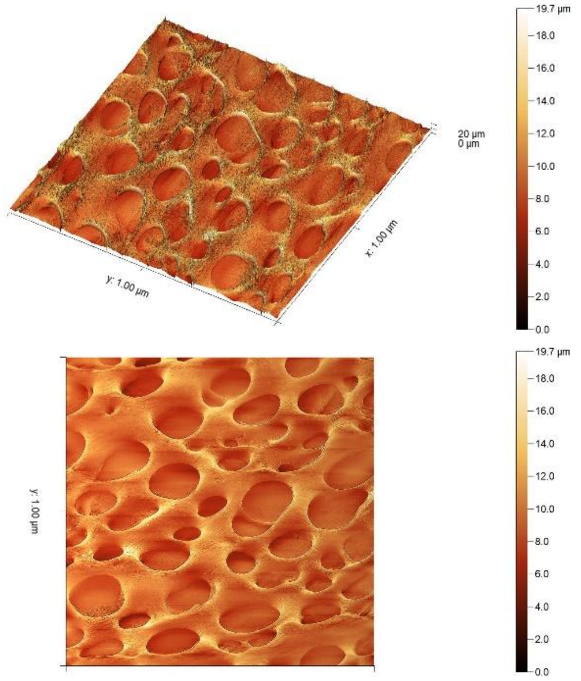


[Fig.5: Illustrate FTIR Curves of Sample (14)]

The strong peak at 1721.07 cm^{-1} (C=O stretching) and the peak at 1025.20 cm^{-1} (C-O stretching) are particularly indicative of the ester linkages in PET [31]. The presence of aromatic peaks also aligns with PET's structure., [32].

F. Atomic Force Microscopy (AFM) Analysis

The AFM image Figure (6) provides a high-resolution 3D topographic map of the microplastic surface. Surface roughness: The image reveals a highly irregular surface with significant height variations. Crater-like formations: Large, circular depressions dominate the topography, corresponding to the pits observed in the SEM image [33]. Elevated ridges: The areas between depressions show elevated regions, forming a network of ridges across the surface. Quantitative roughness parameters (from provided data); Root Mean Square (RMS) roughness (Sq): 1.62514 µm, Mean roughness (Sa): 1.18407 µm, Maximum height (Sz): 19.3000 µm, Surface area: 969.832 µm², Surface slope (Sdq): 1.56344, Skewness (Ssk): 1.08537, indicating an asymmetric height distribution with a bias towards peaks and Kurtosis: 2.85769, suggesting a relatively peaked height distribution [34].

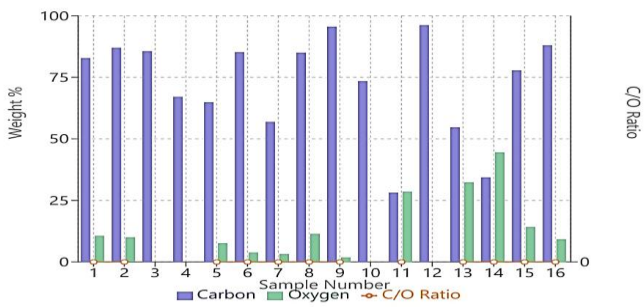


[Fig.6: Illustrated 3D/2D AFM Image Sample (14)]

G. Carbon and Oxygen Stoichiometry

The carbon content ranged from 28.2% to 96.2% (w/w), while oxygen content varied from 0% to 44.4% (w/w). The theoretical C/O ratio for pristine PET is 1.9. The observed C/O ratios, however, deviated significantly from this value, ranging from 0.77 to effectively infinite (in samples with no detectable oxygen) as illustrated in Figure (7).

This variation in C/O ratios suggests different degrees of oxidation or degradation among the samples. Samples with higher oxygen content (e.g., samples 11, 13, 14) may have undergone more extensive weathering or oxidation processes in the environment. Conversely, samples with very high C/O ratios or no detectable oxygen (e.g., samples 3, 4, 10, 12) might represent relatively pristine PET or PET that has undergone different degradation pathways, such as photodegradation leading to decarboxylation [23].



[Fig.7: Distribution of Carbon and Oxygen Content Across the (16) Microplastic Samples with C/O Ratio]

H. Morphological Changes Due to Weathering

Microplastic particles in marine environments undergo significant morphological changes due to weathering processes. This section examines the alterations observed in microplastic samples collected from the Red Sea coast near Jeddah, Saudi Arabia. Through high-resolution imaging techniques, including Scanning Electron Microscopy (SEM) and Atomic Force Microscopy (AFM), we have characterized the surface features that developed as a result of prolonged environmental exposure. These weathering-induced morphological changes not only affect the physical integrity of the microplastics but also influence their interactions with the marine ecosystem. This analysis focuses on key features such as surface erosion, pitting, crack formation, and changes in surface roughness, providing insights into the degradation processes and potential environmental impacts of microplastics in the Red Sea.

Pitting and Crater Formation: The prominent pits observed in both SEM and AFM images are characteristic of weathered microplastics. These features likely result from a combination of photo-oxidation and mechanical abrasion. UV radiation initiates the breaking of polymer chains, creating weak points on the surface. These weakened areas are then more susceptible to erosion by mechanical forces such as water currents or sand abrasion.

Surface Erosion and Material Loss: The overall roughened texture and the presence of adhered particles suggest significant material loss from the original plastic surface. This erosion process contributes to the formation of smaller plastic particles and potentially releases additives into the environment.

Crack Propagation: The observed cracks or fissures indicate stress-induced damage, possibly from repeated expansion and contraction due to temperature fluctuations or mechanical stress. These cracks can serve as initiation points for further fragmentation of the microplastic particle.

Heterogeneous Degradation: The non-uniform surface texture implies that weathering occurs heterogeneously across the particle [35]. This heterogeneity could be due to variations in polymer composition, the presence of additives, or differential exposure to environmental stressors [36].

I. Quantitative Assessment of Surface Roughness

RMS Roughness (Sq) and Mean Roughness (Sa): The high Sq (1.62514 µm) and Sa (1.18407 µm) values indicate a substantially roughened surface compared to virgin plastic, which typically has roughness values in the nanometer range. This increased roughness enhances the surface area-to-volume ratio, potentially increasing the particle's capacity to adsorb contaminants. Maximum Height (Sz): The Sz value of 19.3000 µm represents the vertical distance between the highest peak and lowest valley. This large value further underscores the extreme surface modifications induced by weathering. Surface Area: The measured surface area of 969.832 µm² for a projected area of 1 µm² indicates a nearly 1000-fold increase in surface area due to roughness. This dramatic increase in surface area has significant implications for the particle's interaction with the environment, including enhanced adsorption of organic pollutants and increased microbial colonization. Skewness and Kurtosis: The positive skewness (1.08537) suggests a surface dominated by peaks rather than valleys, which could be the result of differential erosion rates. The kurtosis value (2.85769) indicates a somewhat peaked height distribution, suggesting the presence of extreme height values.

J. Water Analysis

Understanding the aquatic environment in which microplastics are found is crucial for interpreting their behavior, degradation, and potential impacts. This section presents a detail of the water analysis conducted in conjunction with microplastic sampling along the Red Sea coast near Jeddah, Saudi Arabia. We examined key parameters including temperature, pH, salinity, dissolved oxygen, and turbidity, which plays significant roles in the weathering and distribution of microplastics in marine ecosystems. These water quality indicators not only provide insight into the general health of the marine environment but also offer valuable context for interpreting the observed characteristics of the microplastic particles. By correlating water parameters with microplastic properties, we aim to elucidate the complex interactions between these pollutants and their aquatic environment, ultimately contributing to a more understanding of microplastic behavior in the unique ecosystem of the Red Sea. Temperature: Mean 32°C (range: 30.09-33.3°C), pH: Mean 8.50 (range: 8.42-8.65), Salinity: Mean 39.59 PSU (range: 38.83-41.58 PSU), Dissolved Oxygen (DO): Mean 6.40 mg/L (range: 6.13-6.67 mg/L) and Turbidity: Mean 3.94 NTU (range: 1.05-13.72 NTU).

K. Influence of Water Parameters on Microplastic Weathering:

- Temperature: The high mean temperature (32°C) can accelerate chemical reactions and polymer degradation processes. This elevated temperature likely contributes to; Increased rate of photo-oxidation, enhanced thermal degradation of polymer chains, Faster leaching of additives, Relation to observations: The extensive pitting and surface erosion observed in SEM and AFM images could be partially attributed to accelerated degradation due to high temperatures.
- pH: The alkaline conditions (mean pH 8.50) exceed the standard range (6.5-8.5). This high pH can affect microplastics by; Promoting hydrolysis of ester bonds in polymers like PET, Altering the surface charge of microplastics, potentially affecting their interaction with other particles, Relation to observations: The crater-like formations and irregular surface topography seen in the AFM image might be influenced by enhanced hydrolysis under alkaline conditions.
- Salinity: The high salinity (mean 39.59 PSU) can impact microplastics through; Increased ionic strength, potentially affecting the adsorption of contaminants, Promotion of aggregation between microplastics and other particles, Relation to observations: The adhered particles observed in the SEM image could be partially due to enhanced aggregation in high-salinity conditions.
- Dissolved Oxygen (DO): The well-oxygenated water (mean DO 6.40 mg/L) can contribute to; Enhanced oxidative degradation of polymer surfaces, Support of microbial activity, potentially leading to biodegradation, Relation to observations: The high oxygen levels may contribute to the overall degradation observed, particularly the surface erosion and pitting seen in both SEM and AFM images.
- Turbidity: The variable turbidity (mean 3.94 NTU, with a high of 13.72 NTU) suggests; Presence of suspended particles that could cause mechanical abrasion, Potential for microplastics to act as nucleation sites for particle aggregation. Relation to observations [37]: The surface scratches and adhered particles visible in the SEM image could be related to interactions with suspended particles in turbid conditions [38].

L. Microplastic and Water Integrated Analysis

The water analysis results provide crucial context for understanding the observed microplastic degradation, directly addressing this primary research objectives.

- Identification and Classification of Microplastics: The warm, alkaline, saline, and periodically turbid conditions of the Red Sea coastal waters near Jeddah create an environment conducive to accelerated weathering of microplastics. This weathering affects the physical and chemical properties of the particles, potentially complicating their identification and classification. The observed surface modifications, as revealed by SEM and AFM analyses, underscore the importance of considering environmental exposure when characterizing microplastics.
- Analysis of Physical, Chemical, and Morphological Properties: The synergistic effects of thermal degradation, chemical weathering, mechanical abrasion, and biological interactions have resulted in complex and heavily modified microplastic surfaces. The quantitative roughness parameters from AFM analysis (RMS roughness of 1.62514 μm, mean roughness of 1.18407 μm, high surface area of 969.832 μm², and maximum height of 19.3000 μm) provide a quantitative measure of these modifications. These changes in surface properties likely affect the particles' behavior in the marine environment.
- Assessment of Weathering and Environmental Interactions: The water analysis results directly inform the understanding of the weathering processes. The high temperatures contribute to thermal and photo-oxidative degradation, the alkaline pH promotes hydrolysis and oxidation, variable turbidity leads to mechanical abrasion, and high salinity influences particle interactions. These factors collectively explain the observed surface features in SEM and AFM images.
- Investigation of Pollution Sources: While not directly indicative of sources, the water conditions provide insights into the fate of microplastics from various potential sources. The accelerated degradation in these conditions suggests that even relatively recently introduced microplastics may show significant weathering, complicating source identification based solely on particle characteristics.

However [39], this study underscores the critical

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importance of considering local environmental conditions when assessing the fate and impact of microplastics in marine ecosystems [40]. The warm, alkaline, saline [41], and periodically turbid conditions of the Red Sea not only accelerate the degradation of microplastics but also potentially enhance their capacity to interact with other pollutants and marine organisms [42]. These findings contribute significantly to the understanding of microplastic pollution in this unique marine environment and provide a foundation for developing targeted mitigation strategies [43].

M. Analysis of Potential Microplastic Pollution Sources

Identifying the sources of microplastic pollution is crucial for developing effective mitigation strategies and understanding the full scope of the problem in marine ecosystems. This section focuses on analyzing the potential origins of microplastic particles found in the coastal waters of Jeddah, Saudi Arabia, along the Red Sea. By integrating data from the characterization of microplastic samples with information about local geography, urban development, and marine activities, we aim to trace these pollutants back to their likely sources.

This analysis considers multiple factors, including the polymer types identified through the spectroscopic and diffraction analyses, The morphological characteristics and weathering patterns observed via SEM and AFM, The elemental composition determined by EDX, The local water conditions and their potential influence on microplastic transport and degradation and The geographical and socio-economic context of the Jeddah coastal area. By examining these diverse data points, we seek to identify the most probable sources of microplastic pollution in this region of the Red Sea. This information is vital for informing targeted pollution prevention efforts, guiding policy decisions, and ultimately contributing to the preservation of this unique marine environment. These findings not only shed light on the local situation in Jeddah but also contribute to the broader understanding of microplastic pollution sources in coastal urban areas.

- Potential Sources of Microplastic Pollution: Urban Runoff and Wastewater; PET is commonly used in clothing fibers (polyester) and packaging. The presence of weathered microplastics suggests they may have been in the environment for some time, possibly transported via urban runoff or wastewater discharge. High turbidity in some samples could indicate input from terrestrial sources. Coastal Tourism and Recreational Activities. The coordinates suggest a coastal area, potentially with beaches and recreational activities. PET is commonly used in beverage bottles, which are often discarded in coastal areas. The variability in turbidity might reflect periodic increases in human activity.
- Fishing and Maritime Activities: PET is used in fishing gear, including nets and lines. The high salinity and location indicate a marine environment where fishing activities are likely. Weathering patterns could result from prolonged exposure in seawater.
- Industrial Discharge: The alkaline pH could indicate industrial influences, as many industrial processes result in alkaline wastewater. PET is widely used in industrial applications, including packaging and textiles.
- Atmospheric Deposition: While not the primary source, microplastics can be transported through the air. The warm temperatures and coastal location could facilitate atmospheric transport and deposition.

IV. CONCLUSION

This analyzing study of microplastic pollution along the Red Sea coast of Jeddah, Saudi Arabia, has yielded several significant findings that contribute to the understanding of marine plastic pollution in this unique ecosystem. The multi-analytical approach revealed that polyethylene terephthalate (PET) is the predominant type of microplastic in the studied area. The particles exhibited significant surface modifications, including pitting, cracking, and increased roughness, as evidenced by SEM and AFM analyses. These observations indicate extensive weathering, likely due to prolonged environmental exposure. The prevalence of PET microplastics suggests a strong link to urban waste, particularly from beverage containers and synthetic textiles.

The study of water parameters provided crucial context for understanding microplastic behavior in the marine environment. The high mean temperature (32°C) and alkaline pH (mean 8.50) of the Red Sea waters likely accelerate the degradation of microplastics, contributing to the observed weathering patterns. The high salinity (mean 39.59 PSU) may influence the aggregation and distribution of microplastic particles, potentially affecting their bioavailability and ecological impact. By integrating particle characteristics with local geographical and socio-economic factors, we identified several potential sources of microplastic pollution. Urban runoff, wastewater discharge, coastal tourism, and maritime activities emerge as significant contributors. This insight is crucial for developing targeted mitigation strategies that informs urban planning and waste management policies. The extensive surface modifications observed in the microplastic particles suggest an increased potential for interaction with marine biota and other pollutants. The high surface area-to-volume ratio resulting from weathering may enhance the adsorption of persistent organic pollutants and heavy metals, potentially exacerbating the ecological impact of these particles. The study demonstrates the value of a multi-analytical approach in microplastic research. The combination of spectroscopic, microscopic, and diffraction techniques provided a multi-instrument characterization of microplastic particles, offering insights into their composition, morphology, and degradation state. This approach can serve as a model for future studies in other marine environments. The findings of this research have significant implications for environmental management and policy in the Red Sea region. They underscore the urgent need for improved waste management practices, particularly in rapidly developing coastal urban areas like Jeddah. Furthermore, this study contributes to the global body of knowledge on marine microplastic

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pollution, offering insights into the behavior and fate of these particles in warm, saline environments. this study provides a baseline for microplastic pollution in the coastal waters of Jeddah, serving as a foundation for future research and informed decision-making. The results emphasize the global nature of the microplastic problem and the need for concerted efforts at local, regional, and international levels to address this pressing environmental challenge.

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REFERENCES

1. Ziani K, Ioniță-Mîndrican CB, Mititelu M, Neacșu SM, Negrei C, Moroșan E, Drăgănescu D, Preda OT. Microplastics: A Real Global Threat for Environment and Food Safety: A State of the Art Review. Nutrients. 2023 Jan 25;15(3):617. PMID: 36771324; PMCID: PMC9920460. DOI: https://doi.org/10.3390/nu15030617
2. Lee Y, Cho J, Sohn J, Kim C. Health Effects of Microplastic Exposures: Current Issues and Perspectives in South Korea. Yonsei Med J. 2023 May;64(5):301-308. PMID: 37114632; PMCID: PMC10151227. DOI: https://doi.org/10.3349/ymj.2023.0048
3. Chemical Analysis of Microplastics and Nanoplastics: Challenges, Advanced Methods, and Perspectives, Natalia P. Ivleva Chemical Reviews 2021 121 (19), 11886-11936. DOI: https://doi.org/10.1021/acs.chemrev.1c00178
4. M. Fine, M. Cinar, C.R. Voolstra, A. Safa, B. Rinkevich, D. Laffoley, N. Hilmi, D. Allemand, Coral reefs of the Red Sea — Challenges and potential solutions, Regional Studies in Marine Science, Volume 25, 2019, 100498, ISSN 2352-4855, DOI: https://doi.org/10.1016/j.rsma.2018.100498.
5. Abdel Ghani et al., S. (2024). Microplastics Pollution in Aquatic Environment: A Review of Abundance, Distribution, and Composition in the Egyptian Coastal Waters. Egyptian Journal of Aquatic Biology and Fisheries, 28(2), 553-583. DOI: https://doi.org/10.21608/ejabf.2024.349839.
6. Robitzch, V., Kattan, A., Dunne, A., Coker, D.J. (2023). Saudi Arabia Case Study. In: Wolff, M., Ferse, S.C., Govan, H. (eds) Challenges in Tropical Coastal Zone Management. Springer, Cham. DOI: https://doi.org/10.1007/978-3-031-17879-5_6.
7. Alaa El-Din H. Sayed, Mohamed Hamed, Ahmed E.A. Badrey, Rania F. Ismail, Yassein A.A. Osman, Alaa G.M. Osman, Hamdy A.M. Soliman, Microplastic distribution, abundance, and composition in the sediments, water, and fishes of the Red and Mediterranean seas, Egypt, Marine Pollution Bulletin, Volume 173, Part A, 2021, 112966, ISSN 0025-326X, DOI: https://doi.org/10.1016/j.marpolbul.2021.112966.
8. Emenike EC, Okorie CJ, Ojeyemi T, Egbemhenghe A, Iwuozor KO, Saliu OD, Okoro HK, Adeniyi AG. From oceans to dinner plates: The impact of microplastics on human health. Heliyon. 2023 Sep 26;9(10):e20440. PMID: 37790970; PMCID: PMC10543225. DOI: https://doi.org/10.1016/j.heliyon.2023.e20440
9. Kottuparambil S, Ashok A, López P, Amad MH, Duarte CM, Agusti S. High temperature and solar radiation in the Red Sea enhance the dissolution of crude oil from surface films. Environ Sci Pollut Res Int. 2024 Jun;31(29):42034-42048. Epub 2024 Jun 10. PMID: 38856854; PMCID: PMC11219460. DOI: https://doi.org/10.1007/s11356-024-33864-z
10. Hou D, Hong M, Wang Y, Dong P, Cheng H, Yan H, Yao Z, Li D, Wang K, Zhang D. Assessing the Risks of Potential Bacterial Pathogens Attaching to Different Microplastics during the Summer-Autumn Period in a Mariculture Cage. Microorganisms. 2021 Sep 9;9(9):1909. PMID: 34576804; PMCID: PMC8469625. DOI: https://doi.org/10.3390/microorganisms9091909
11. Abdel Rahman, Afaf & Mahboub, Heba & Ezz-Eldin, Rasha & Abdelwarith, Dr: Abdelwahab & Younis, Elsayed & Khamis, Tarek & Aziz, Enas & Basha, Walaa & Elmaghraby, Ibrahim & Davies, Simon & Ismail, Sameh & Reyad, Yasmin. (2024). Lead toxicity in African catfish: Promising role of magnetite nanogel against etho-neurological alterations, antioxidant suppression, gene toxicity, and histopathological/ immunohistochemical disruptions. Aquaculture. 594. 741411. DOI: https://doi.org/10.1016/j.aquaculture.2024.741411.
12. Youssef, Fady & Fouad, Omar & Ismail, Sameh & Mohamed, Gehad. (2024). Therapeutic and Toxicological Aspects of Some Metal Nanoparticles on The Central Nervous System: A Review. Egyptian Journal of Veterinary Sciences. 55. 733-745. DOI: https://doi.org/10.21608/ejvs.2023.234784.1609.
13. Katowah, Dina & Ismail, Sameh & Alzahrani, Hanan & Rahman, Mohammed & Abd el-fadeel, Mohamed. (2024). Design of a novel nanosensor based on nanocomposite hydrogel composed of a PVA-poly(aniline-co-pyrrole) conducting copolymer-(PbO-doped NiO)-OXSWCNTs-coated QCM for rapid detection of cd (II) ions. Journal of Materials Science: Materials in Electronics. 35. DOI: https://doi.org/10.1007/s10854-024-12573-w.
14. Al-Sodies, Salsabeel & Asiri, Abdullah M. & Ismail, Sameh & Alamry, Khalid & Hussein, Mahmoud. (2024). Development of poly(safranine-co-phenosafranine)/GNPs/MWCNTs nanocomposites for quartz crystal microbalance sensor detection of arsenic (III) ions. Materials Research Express. DOI: https://doi.org/10.1088/2053-1591/ad37a5.
15. Abdel Rahman, Afaf & Mahboub, Heba & Elshopakey, Gehad & Darwish, Mahmoud & Gharib, Heba & Shaalan, Mohamed & Fahmy, Esraa & Abdel-Ghany, Heba & Ismail, Sameh & Elsheshtawy, Hassnaa. (2024). Pseudomonas putida infection induces immune-antioxidant, hepato-renal, ethological, and histopathological/immunohistochemical disruptions in Oreochromis niloticus: the palliative role of titanium dioxide nanogel. BMC Veterinary Research. 127. 1-13. DOI: https://doi.org/10.1186/s12917-024-03972-6.
16. Elhagrassy, Abeer & Ismail, Sameh. (2023). PROTOTYPE OF Ag@ZnO CORE SHELL FOR THE STERILIZATION OF MURAL PAINTINGS. International Journal of Conservation Science. 14. 1309-1326. DOI: https://doi.org/10.36868/IJCS.2023.04.03.
17. Hassan, Rushdya Rabee & Hassan, Haidi & Mohamed, Yassmine & Ismail, Mai & Farid, Yara & Mohamed, Hager & Ismail, Sameh & Salem, Mohamed & Abdel-Hamied, Mostafa. (2023). ZnO, TiO2 and Fe3O4/Carbopol hybrid nanogels for the cleaner process of paper manuscripts from dust stains and soil remains. Heritage Science. 11. DOI: https://doi.org/10.1186/s40494-023-01063-7.
18. Kamel, Samar & Ahmed, Shaimaa & Elsayyad, Asmaa & Abdelwarith, Dr: Abdelwahab & Younis, Elsayed & Shaalan, Mohamed & Gaballa, Mohamed & Mahboub, Heba & Khamis, Tarek & Ismail, Sameh & Davies, Simon & Hassan, Zeinab. (2024). Toxicological insight of magnetite nanogel: neuro-ethological, hepato-renal, antioxidant, and histopathological traits in Clarias gariepinus. Aquaculture International. 32. 1-17. DOI: https://doi.org/10.1007/s10499-024-01456-w.
19. Mortula, Maruf & Atabay, Serter & Fattah, Kazi & Madbuly, Ahmad. (2021). Leachability of Microplastic from Different Plastic Materials. Journal of Environmental Management. 294. DOI: https://doi.org/10.1016/j.jenvman.2021.112995.
20. James, Keziya & Vasant, Kripa & S.M., Sikkander & Padua, Shelton & Jeyabaskaran, R. & S., Thirumalaiselvan & G., Vineetha & Benjamin, Liya. (2020). Seasonal variability in the distribution of microplastics in the coastal ecosystems and in some commercially important fishes of the Gulf of Mannar and Palk Bay, Southeast coast of India. Regional Studies in Marine Science. 41. 101558. DOI: https://doi.org/10.1016/j.rsma.2020.101558.

21. Al-Lihaibi, Sultan & Al-Mehmadi, Asmaa & Alarif, Walied & Bawakid, Nahed & Kallenborn, Roland & Ali, Aasim. (2019). Microplastics in sediments and fish from the Red Sea coast at Jeddah (Saudi Arabia). Environmental Chemistry. 16. https://doi.org/10.1071/EN19113.
22. Thiemann, T. (2023) Microplastic in the Marine Environment of the Indian Ocean. Journal of Environmental Protection, 14, 297-359. DOI: https://doi.org/10.4236/jep.2023.144020.
23. Kauts S, Mishra Y, Yousuf S, Bhardwaj R, Singh SK, Alshabrmi FM, Abdurahman M, Vamanu E, Singh MP. Toxicological Profile of Polyethylene Terephthalate (PET) Microplastic in Ingested Drosophila melanogaster (Oregon R+) and Its Adverse Effect on Behavior and Development. Toxics. 2023 Sep 14;11(9):782. PMID: 37755792; PMCID: PMC10537121. DOI: https://doi.org/10.3390/toxics11090782
24. Furfaro, G., D'Elia, M., Mariano, S. et al. SEM/EDX analysis of stomach contents of a sea slug snacking on a polluted seafloor reveal microplastics as a component of its diet. Sci Rep 12, 10244 (2022). DOI: https://doi.org/10.1038/s41598-022-14299-3.
25. Kohutiar, Marcel & Pajtášová, Mariana & Janík, Róbert & Staňová, Papučová, Iveta & Pagacova, Jana & Pecušová, Beáta & Labaj, Ivan. (2018). Study of selected thermoplastics using dynamic mechanical analysis. MATEC Web of Conferences. 157. 07002. DOI: https://doi.org/10.1051/matecconf/201815707002.
26. Gniadek, Marianna & Dąbrowska, Agnieszka. (2019). The marine nano-and microplastics characterisation by SEM-EDX: The potential of the method in comparison with various physical and chemical approaches. Marine Pollution Bulletin. 148. 210. DOI: https://doi.org/10.1016/j.marpolbul.2019.07.067.
27. Moura, Diana & Pestana, Carlos & Moffat, Colin & Hui, Jianing & Irvine, John & Lawton, Linda. (2023). Characterisation of microplastics is key for reliable data interpretation. Chemosphere. 331. 138691. DOI: https://doi.org/10.1016/j.chemosphere.2023.138691.
28. Demirel, Bilal & Yaraş, Ali & ELÇİÇEK, Huseyin. (2011). Crystallization Behavior of PET Materials. Balıkesir Üniversitesi Fen Bilimleri Enstitü Dergisi. 13. 26-35. https://www.researchgate.net/publication/290429725_Crystallization_Behavior_of_PET_Materials
29. Jin, Naifu & Song, Yizhi & Ma, Rui & Li, Junyi & Li, Guanghe & Zhang, Dayi. (2022). Characterization and identification of microplastics using Raman spectroscopy coupled with multivariate analysis. Analytica Chimica Acta. 1197. 339519. DOI: https://doi.org/10.1016/j.aca.2022.339519.
30. Sunil, Megha & Unnimaya, S. & Nelliat, Mithun & Chidangil, Santhosh & Kumar, Satheesh & Lukose, Jijo. (2024). Raman Spectroscopy Based Approaches for Microplastics Investigations. DOI: https://doi.org/10.1007/978-3-031-64253-1_27.
31. Hadiyanto, H. & Muslihuddin, Muslihuddin & Khoironi, Adian & Pratiwi, Wahyu & Fadlilah, Muthia'ah & Muhammad, Fuad & Afiati, Norma & Dianratri, Inggar. (2022). The effect of salinity on the interaction between microplastic polyethylene terephthalate (PET) and microalgae Spirulina sp. Environmental Science and Pollution Research. 29. DOI: https://doi.org/10.1007/s11356-021-16286-z.
32. Kauts, Simran & Mishra, Yachana & Yousuf, & Bhardwaj, Rima & Singh, Sandeep & Mohammed, Fahad & Abdurahman, Mahmoud & Vamanu, Emanuel & Singh, Dr. Mahendra. (2023). Toxicological Profile of Polyethylene Terephthalate (PET) Microplastic in Ingested Drosophila melanogaster (Oregon R +) and Its Adverse Effect on Behavior and Development. Toxics. 11. 782. DOI: https://doi.org/10.3390/toxics11090782.
33. Dąbrowska, Grażyna & Garstecka, Zuzanna & Olewnik-Kruszkowska, Ewa & Szczepańska, Grażyna & Ostrowski, Maciej & Mierek-Adamska, Agnieszka. (2021). Comparative Study of Structural Changes of Polylactide and Poly(ethylene terephthalate) in the Presence of Trichoderma viride. International Journal of Molecular Sciences. 22. 3491. DOI: https://doi.org/10.3390/ijms22073491.
34. Chen, Hui & Chen, Hongmei & Nan, Shugang & Liu, Hongsheng & Chen, Ling & Yu, Long. (2022). Investigation of Microplastics in Digestion System: Effect on Surface Microstructures and Probiotics. Bulletin of Environmental Contamination and Toxicology. 109. DOI: https://doi.org/10.1007/s00128-022-03571-x.
35. Liu, Peng & Zhan, Xin & Wu, Xiaowei & Li, Jinli & Wang, Hanyu & Gao, Shixiang. (2019). Effect of weathering on environmental behavior of microplastics: Properties, sorption and potential risks. Chemosphere. 242. 125193. DOI: https://doi.org/10.1016/j.chemosphere.2019.125193.
36. Kovačić, M.; Tomić, A.; Tonković, S.; Pulitika, A.; Papac Zjačić, J.; Katančić, Z.; Genorio, B.; Kušić, H.; Lončarić Božić, A. Pristine and UV-Weathered PET Microplastics as Water Contaminants: Appraising the Potential of the Fenton Process for Effective Remediation. Processes 2024, 12, 844. DOI: https://doi.org/10.3390/pr12040844.
37. Issac MN, Kandasubramanian B. Effect of microplastics in water and aquatic systems. Environ Sci Pollut Res Int. 2021 Apr;28(16):19544-19562. Epub 2021 Mar 2. PMID: 33655475; PMCID: PMC7924819. DOI: https://doi.org/10.1007/s11356-021-13184-2
38. Ma, H.; Chao, L.; Wan, H.; Zhu, Q. Microplastic Pollution in Water Systems: Characteristics and Control Methods. Diversity 2024, 16, 70. DOI: https://doi.org/10.3390/d16010070.
39. Ghosh, S.; Sinha, J.K.; Ghosh, S.; Vashisth, K.; Han, S.; Bhaskar, R. Microplastics as an Emerging Threat to the Global Environment and Human Health. Sustainability 2023, 15, 10821. DOI: https://doi.org/10.3390/su151410821.
40. Bhardwaj, Laxmi & Rath, Prangya & Yadav, Poornima & Gupta, Urvashi. (2024). Microplastic contamination, an emerging threat to the freshwater environment: a systematic review. Environmental Systems Research. 13. DOI: https://doi.org/10.1186/s40068-024-00338-7.
41. V R, S. (2019). Tidal dynamics along the western coast of the Saudi Arabia, the Red Sea. In International Journal of Innovative Technology and Exploring Engineering (Vol. 9, Issue 2, pp. 280–284). DOI: https://doi.org/10.35940/ijitee.b6161.129219
42. Rajesh, G. V. S. S., S, R., & Nagalakshmi, N. (2020). Micro plastic Pollution in Coastal Water and Beach Sediments at Adyar and Cooum River Estuaries in Chennai Coast. In International Journal of Engineering and Advanced Technology (Vol. 9, Issue 5, pp. 511–514). DOI: https://doi.org/10.35940/ijeat.e9793.069520
43. M., M., R., A. M., K., K., U., Dr. T., & Moorthy A., Dr. A. (2020). LPDE/Alumina Based Bio-Nano Composite Materials for Food Packaging Applications. In International Journal of Recent Technology and Engineering (IJRTE) (Vol. 8, Issue 6, pp. 802–805). DOI: https://doi.org/10.35940/ijrte.e6460.038620

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