Materials International
Open-Access Journal (ISSN: 2668-5728)

Article
Volume 7, Issue 3, 2025, 24
https://doi.org/10.33263/Materials73.024

Occurrence of Microplastics in Surface Water of Xuanwu Lake, Nanjing, PR China

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Received: 22.11.2024; Accepted: 5.08.2025; Published: 10.09.2025

Abstract: Recently, microplastics have gained widespread attention. It is now spreading in containment and is found almost everywhere in the environment, especially in water. It can affect the quality of water and damage human and aquatic life. This study comprehensively investigates microplastic pollution in the surface water of Xuanwu Lake, a popular urban lake in Nanjing, China. Surface water samples were collected from four sites using a 300 μm Manta trawl, processed through wet peroxide oxidation, and analyzed using microscopy and Raman spectroscopy to identify and characterize microplastics. The detected microplastics varied in size, color, and morphology. Microplastics of smaller size (<1mm) were more dominant (45%) than those of other sizes (1-5mm). Most of the microplastics identified were black (40%) and blue (30%) in color and fibrous in shape. The main microplastic compositions detected by Raman spectroscopy were polycarbonate (PC), polypropylene (PP), and polyethylene (PE). Tourism and riverine input were observed as the main sources of the pollution. By linking microplastic characteristics with their likely sources, this study offers valuable insights into the pathways and distribution of microplastics in urban freshwater ecosystems. The findings highlight the urgent need for improved waste management and policy measures to mitigate microplastic pollution, particularly in high-traffic recreational water bodies.

Keywords: microplastics; water pollution; environmental issues; polycarbonate (PC); polypropylene (PP); polyethylene (PE).

1. Introduction

Plastic pollution has become a pressing environmental issue due to the widespread and often improper use of plastic products. The stability, persistence, and slow biodegradability of plastics have led to their accumulation across various ecosystems [1-5]. Recently, plastic waste has been detected in various environmental media, including water, soil, and the atmosphere [6-11]. Waste plastic can be broken down into tiny particles by sunlight, soil erosion, weathering, soaking, etc. [12]. These small particles, known as microplastics (MPs), typically range from 0.1 μm to 5 mm in size and are now recognized as emerging contaminants of global concern [13]. Microplastics have a wide range of sizes, shapes, polymer types, and colors. Microplastics are grouped into six types of morphology: fragments, foam, film, fiber, pellets, and sheet. The fabric forms are considered elongated, mainly derived from the textile industry. The plastics and polymer industry uses the primary form of (MPs) pellets. The larger plastics break down into the form of MPs with irregular shapes. In the end, foam is made of soft, microporous fragments, while sheet and film are rigid or soft with laminar structures [14-16]. Moreover, small plastics added to personal care products such as soap and detergents are also sources of microplastics. These microplastics are introduced into waterbodies through various sources, including industrial production, surface runoff, fishing gear, plastic industries, and personal care products, as visually summarized in Figure 1 [17]. The presence and accumulation of MPs in various water bodies, including urban water, wastewater, and drinking water, have raised public and scientific concerns due to their harmful effects on human and aquatic life [18-20]. However, few researchers have addressed human health [21-23]. Their potential hazards to humans include emerging anxiety, and they are increasingly recognized as emerging contaminants, especially in drinking water [24-26]. Microplastics pose a threat to aquatic life due to their harmful properties and the presence of additives. Although initial research emphasized marine environments, attention has increasingly shifted to inland water bodies, where MP contamination is widespread. With nearly 50% of the global population living within 50 miles of coastlines or large water bodies, rivers and wastewater treatment plants (WWTPs) serve as major conduits for microplastics into aquatic ecosystems [27-30].

To monitor microplastic pollution, researchers commonly use plankton nets or surface trawls, such as manta and neuston nets, which typically have mesh sizes of 300–350 μm [31,33]. These tools have facilitated estimates of microplastic abundance in water, which in 2014 ranged between 15 and 51 trillion particles—equivalent to 93,000 to 236,000 metric tons [34-35]. However, over 80% of field studies sample only particles larger than 300 μm, leading to an underestimation of smaller MPs, such as cosmetic microbeads and synthetic microfibers [36]. Although manta and neuston nets are widely accepted for surface sampling, they differ in mesh size, towing depth, and net opening dimensions, resulting in variable volumes of water filtered.

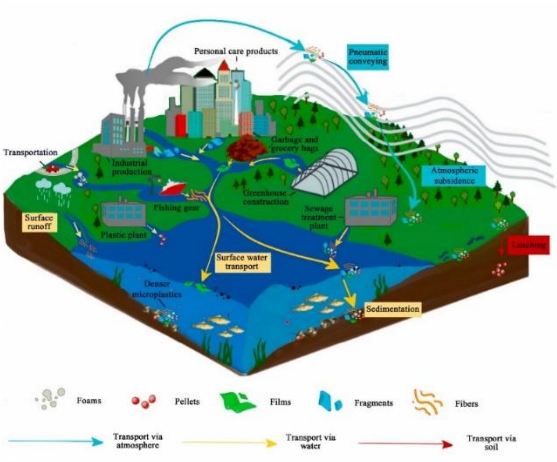

Figure 1. Transport of microplastics is driven by several factors, including ingestion, sinking, and accumulation, as adapted from ref [17].

These variations can influence microplastic concentration data and highlight the importance of standardized sampling techniques [37-39]. In this study, we address and detect microplastics in the surface water of Xuanwu Lake, a prominent urban freshwater lake in Nanjing, China. The lake is highly frequented for recreational use. It is situated near densely populated and industrialized areas, making it particularly vulnerable to microplastic contamination. The objective of this study is to investigate the presence, size distribution, and polymer composition of microplastics in the lake's surface water using field sampling and Raman spectroscopy.

2. Materials and Methods

2.1. Study area.

Xuanwu Lake is a small urban lake. The entire surface area is 3.7 square kilometers, the drainage area is 5.5 square kilometers, and the circumference is 15 kilometers [40]. At a surface water level of 10 m, the average water depth is 1.14 m, and the total storage capability is 4,290,000 m^3. The highest water level is 11.15 m, while the minimum surface water level is 9.8 m, with an annual surface water level range of 9.8 m to 10.2 m [41]. The diversion water source originates in the Yangtze River. The lake's water eventually passes through four gates to supply the city's interior rivers. Xuanwu Lake comprises four distinct areas: Northwest (NW, #1) Lake, Northeast (NE, #2) Lake, Southwest (SW, #3) Lake, and Southeast (SE, #4) Lake, as shown in Figure 2.

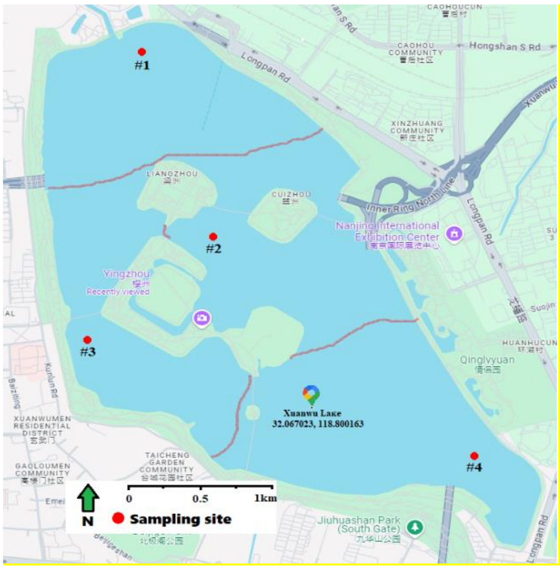

Figure 2. Sampling sites at different locations in Xuanwu Lake.

2.2. Sampling.

In this study, four areas of Xuanwu Lake were examined to determine the presence and distribution of microplastic pollution. A total of 12 water samples at four sampling sites (#1-#4) were collected between the 15th and 22nd of September 2024 using the standard collection method. Specifically, a Manta Trawl, aperture size: 30 x 15 cm, was used with a 235 cm long net, a 300 µm mesh bag, and a 300 µm removable cod-end. Towing ranged between 10 and 15 minutes. After retrieving the net, all the materials were collected at the cod-end of the trawl. The material collected was transferred to a glass jar, and for further examination, it was preserved in 70% isopropyl alcohol.

2.3. Sample preparation and identification.

All the samples were filtered in the laboratory using a brass-made 250 µm mesh sieve. All the rough fragments were washed with deionized water and removed with the help of forceps from the sieve. The residual material was treated using wet peroxide oxidation (WPO) [42,43]. Each sample received a Fe (II) (0.05M) solution and 30% H_2O_2 and was stirred continuously at 75°C for half an hour. During the reaction, degassing was allowed, and tin foil was used as a cover to prevent atmospheric deposition. For further degradation of organic compounds, more hydrogen peroxide (30%) was added to each sample as required during heating and stirring. The samples were kept for 24 hr to digest completely. After 24 hours, the samples were again filtered through the brass sieve and treated with DI water. The digested samples were then observed under a stereomicroscope (SZ61, Olympus, Japan). The particles examined ranged from 300 µm (our net mesh size) to 5 mm, in various shapes and colors, as shown in Figure 3. After a thorough examination, the particles were believed to be microplastics. The microplastics from all samples were separated into fine white cardboard with the help of cleaned forceps. After transferring, the particles were photographed, with all particles moved to the cardboard and photographed using a digital camera (Sony Alpha A7R IV, Japan) for color identification and size measurement. Presumed microplastic particles were picked from each sample to be examined through a Raman spectrometer (inVia, Renishaw, UK). Each step was carried out very carefully to prevent contamination in microplastics.

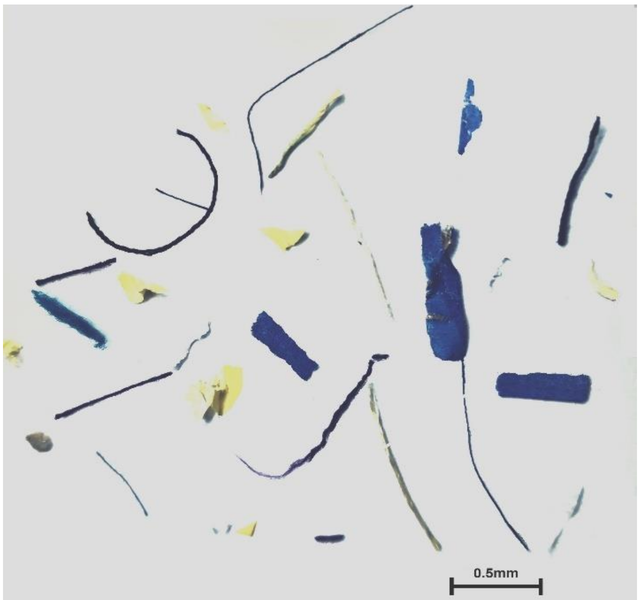

Figure 3. Microplastics collected from Xuanwu Lake under a microscope.

3. Results and Discussion

3.1. Morphology of microplastics.

Microplastics are classified by size into fragments, thick fibers, pellets, foam, and film [44]. In the present study, the identified microplastics were categorized into two primary types: fibers and fragments. This observation is consistent with previous research, which also found fibers to be the dominant microplastic form in freshwater environments, including studies conducted in Wuliangsuhai Lake, Dongting Lake, and Taihu Lake. [28]. The fiber form of MP appears thin and long, while fragments are smaller pieces or parts of larger plastic products [29,45]. These fibers typically originate from synthetic textiles shed during laundering, atmospheric deposition, and the deterioration of plastic-based fishing gear, and the fragments may have arisen from the degradation of various plastic items [46]. The study examined microplastic pollution in China's inland water systems and found that fibers were the predominant form identified in 10 of the 14 studies analyzed [47,48]. Fibers are the primary byproducts linked to WWTPs, as they can be generated during the washing process and evade complete treatment inside these facilities. Fibers may also come from the textile industry and atmospheric deposition [45]. Here, it is determined that the exact sources of microplastic distribution include the surrounding environment, tourist activities, and lake functions. These all affect the morphology distribution of microplastics.

The presence of cracks in polypropylene (PP), as shown in Figure 4, provides visual evidence of its physical degradation, which likely facilitates its fragmentation into microplastics. This observation supports the identification of PP as one of the dominant polymer types found in this study. The surface damage suggests that PP items—commonly used in packaging and frequently discarded by tourists—are more prone to environmental breakdown, contributing significantly to the microplastic load in Xuanwu Lake. Thus, the cracked morphology of PP particles helps explain both the material's abundance and the mechanism by which it enters and persists in the aquatic environment as microplastics, suggesting that physical and human activity together drive the continuous release and accumulation of PP-derived microplastics in freshwater systems.

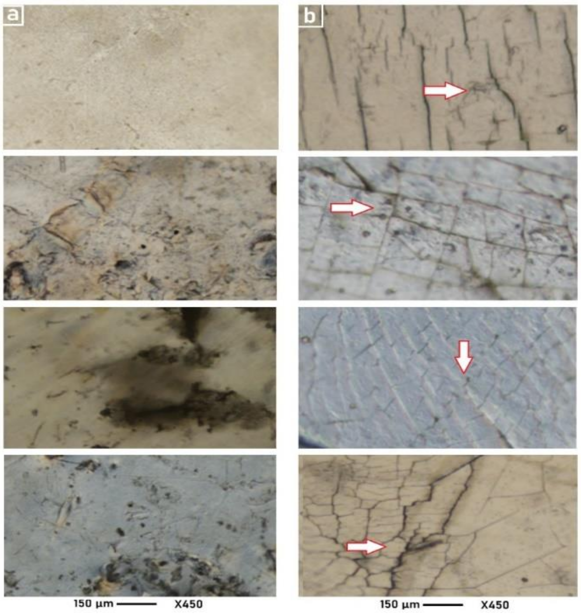

Figure 4. Microscopic images of **(a)** Polyethylene; **(b)** Polypropylene at X450.

3.2. Color, size, and distribution of micro-plastics.

The size and color of all microplastic samples were studied and presented in Figure 5. The microplastics identified in all samples were red, yellow, blue, transparent, green, and black. Six different colors of MPs were identified, among which black represented the predominant color, almost 40%, blue 30%, and yellow 15%. The different colors of microplastics may be linked to packaging plastic for food and other products [49]. The research team analyzed 14 papers examining microplastics in China's inland waters. It was found that transparent microplastics are predominant in all samples from lakes with low human density; however, colorful microplastics are frequently observed in urban estuaries [50]. This conclusion aligns with the current results, as Xuanwu Lake is predominantly located near urban estuaries, where most observed microplastics are colorful.

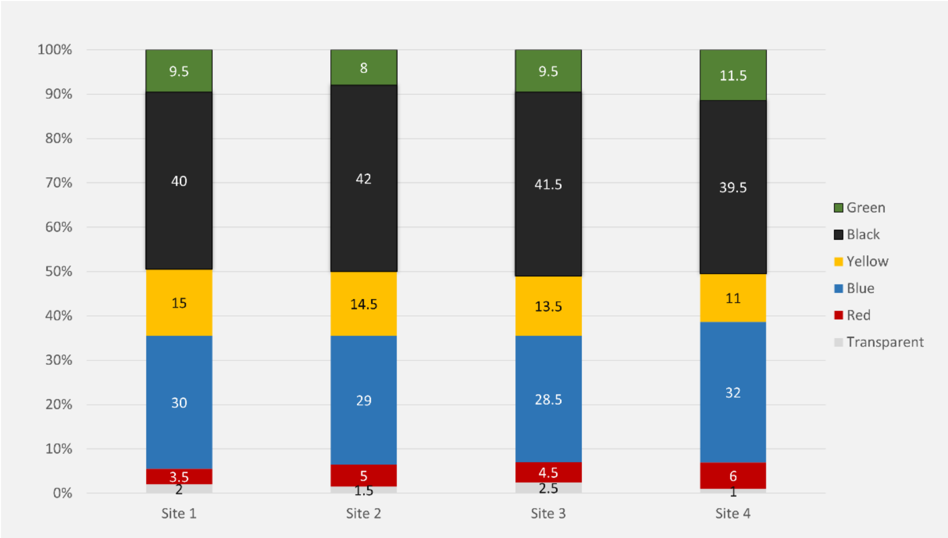

Figure 5. Color distribution of microplastics in samples from Xuanwu Lake.

Furthermore, the results obtained indicated that multiple sources supply microplastics to the lake. Figure 6 illustrates the size distribution of microplastics in the lake water. The tiny plastic particles are categorized into five sizes: <1 mm and 1-2 mm, 2-3 mm, 3-4 mm, and 4-5 mm. Microplastics with a size of less than 1mm constituted almost all (45%) across all sample locations. Previous research has assessed MPs across various size ranges, yielding diverse size classifications [51]. The current study determined that most of the observed microplastics were in fiber form, ranging from less than 1mm. Microplastics measuring 1-2 mm accounted for around 27%, whereas those measuring 2-3 mm accounted for roughly 19%. The investigation showed that MPs ranging from 3-4 mm and 4-5 mm were hardly detected. The size distribution of microplastics in Xuanwu Lake is shaped by a synergy of factors—material properties (like polymer type and degradation susceptibility), dominant sources (especially tourism-related waste and textile fibers), and environmental influences (UV exposure, water currents, and atmospheric conditions). The composition of microplastics was determined using Raman Spectroscopy, with the findings presented in Figure 7. The most common constituents of identified microplastics were Polypropylene (PP), Polycarbonate (PC), and Polyethylene (PE).

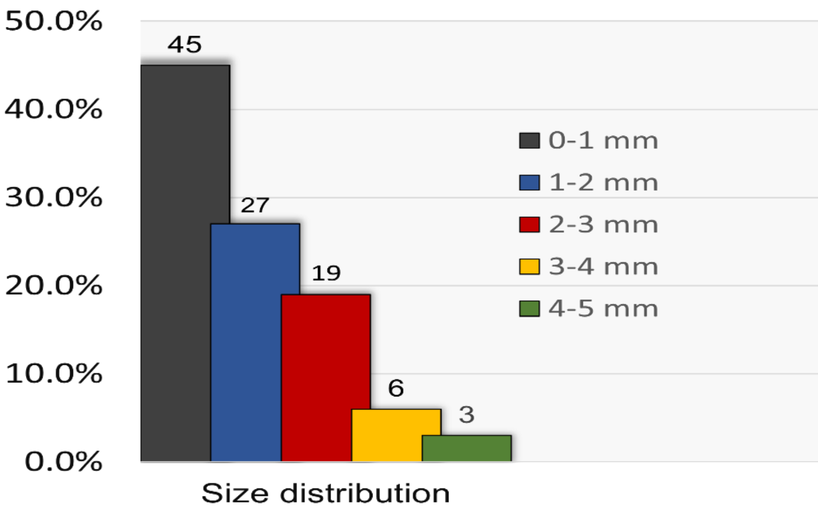

Figure 6. Size distribution of microplastics found in Xuanwu Lake.

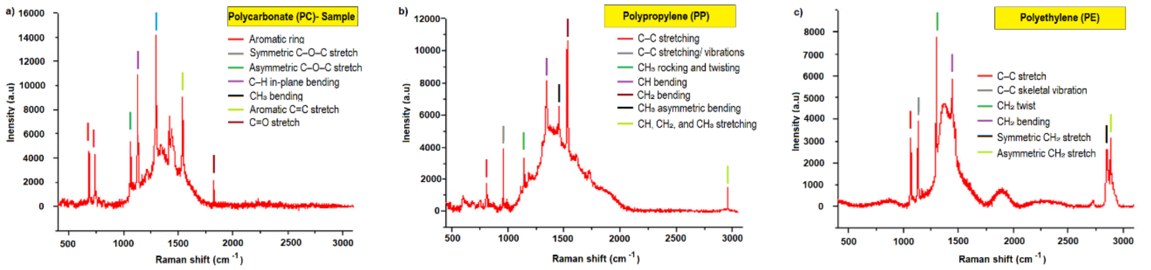

Figure 1. Raman spectra of **(a)** Polycarbonate; **(b)** Polypropylene; **(c)** Polyethylene samples.

3.3. Distribution and sources of microplastics in Xuanwe Lake.

Water currents are considered the main factor for the carriage of plastic particles to the convergence zones of subtropical areas [52]. The same findings are reported for the Laurentian Great Lakes, where lake currents are identified as a major driver of microplastic distribution [53]. At the same time, the direction of the wind and the source input are identified as other important factors contributing to plastic debris dispersion in lake water bodies [54,55]. In Xuanwu Lake, tourism at the Nanjing city wall main gate may have contributed to the higher microplastic abundance observed in the southwestern area of the lake. Normally, wind and river outflow drive the lake currents. Therefore, the lake current carries plastic materials to accumulate in different circulation zones and to remain there for a long time. Thus, the lake's current can be one of the main factors in the distribution of MPs in Xuanwu Lake. Also, a large number of tourists visit the lake, and most use boats to sail across it, which can carry MPs from one area to another. For this reason, another significant factor is the sailing boats for microplastic distribution in Xuanwu Lake. An additional distribution pathway is through aquatic organisms in the lake, which can ingest MPs at one location and later release them at another. Similarly, the transport of microplastics to different locations can be facilitated by their adsorption onto the skin and other body parts of aquatic organisms. On top of that, MPs can be readily carried into the atmosphere by wind and then precipitated back into the lake water through rain, dewdrops, or snow.

The prior studies found that the extent of MPs pollution depends on population density, industrialization, and urbanization rate [56]. However, there is no industry in the vicinity of the lake. Still, it is located downtown, and there are multiple educational institutions and famous tourist spots within the Xuanwu Lake watershed. Therefore, many tourists visit the Xuanwu Lake area and leave their garbage behind. Insufficient garbage collection facilities and a shortage of proper waste management allow the disposal of garbage into the environment. At the same time, garbage comprises a great portion of plastic waste. Earlier studies of remote lakes in Italy and Mongolia also reported tourism as a key source of MPs [57-59]. Similarly, in coastal areas, it has been observed that beaches with large numbers of tourists have a higher abundance of microplastics [60,61]. As shown in Table 1, microplastics' color, shape, and composition also indicate that tourism is one of the main sources of MPs. In this study, PC, PP, and PE were found in almost all samples, which are commonly used for food packaging and deliveries and are often carried out and discarded by tourists [62]. The presence of transparent microplastics also shows the use of food boxes, plastic bags, and disposable raincoats. While inflow from the Yangtze River may contribute significantly to the overall microplastic burden in Xuanwu Lake, our findings indicate that local human activities—particularly tourism—are the dominant source of microplastic pollution, based on polymer types, distribution patterns, and localized abundance.

Table 1. Summarize the size, color, composition, morphology, and sources of microplastics.

Parameter	Category	Details/Distribution
Morphology	*Main Types*	Fibers (90%), Fragments (7.2%)
	Description	Fibers: thin and long (mainly from fishing tools, textiles); Fragments: degraded plastics
Color	*Total Colors Identified*	Black, Blue, Yellow, Red, Green, Transparent
	Predominant Colors	Black (40%), Blue (30%), Yellow (15%)
	Interpretation	Black: low population areas; Colorful: urban/tourist activities
Size	*Size Categories*	<1 mm, 1–2 mm, 2–3 mm, 3–4 mm, 4–5 mm
	Predominant Sizes	<1 mm (45%), 1–2 mm (27%), 2–3 mm (19%)
	Rare Sizes	3–4 mm, 4–5 mm (hardly detected)
Composition	*Main Polymers Identified*	Polypropylene (PP), Polycarbonate (PC), Polyethylene (PE)
	Source Interpretation	Linked to food packaging, plastic bags, disposable raincoats, and tourist waste
Main Sources		Tourism, lake currents, wind, aquatic organisms, and urban runoff from the Yangtze River

4. Conclusions

In this study, microplastics of different sizes and colors were detected in surface water at various locations in Xuanwu Lake. The colors identified included transparent, red, blue, yellow, black, and green. Most of the MPs were polycarbonate, polypropylene, and polyethylene. The dominant color of microplastics observed in surface water was black, and the dominant size observed in all samples was less than 1 mm. Therefore, a detailed classification of the plastics with a size of less than 1 mm should be attempted in future studies. Tourism-related activities are identified as the dominant source of microplastic pollution in Xuanwu Lake, with additional input likely from the Yangtze River; this underscores the need for strengthened waste management, eco-friendly tourism practices, and targeted regulatory measures to protect freshwater ecosystems. Further study is needed to trace MP sources into the lakes to effectively control their contamination in freshwater systems.

Authors Contributions

Conceptualization, M.J. and S.M.; methodology, U.A.; software, M.C.; validation, K.J.; formal analysis, M.J.; investigation, resources, data curation, S.M.; writing—original draft preparation, M.J.; writing—review and editing, M.J.; visualization, S.M.; supervision, U.A.; project administration, K.J.; All authors have read and agreed to the published version of the manuscript.

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

Data supporting the findings of this study are available upon reasonable request from the corresponding author.

Funding

This research received no external funding.

Acknowledgments

We like to express our sincere gratitude to our mentor, Dr. Umar Ali, Department of Chemistry, Government Degree College No. 2, Mardan, Abdul Wali Khan University Mardan, KPK, Pakistan, for his valuable guidance, support, and insightful input throughout the preparation of this work.

Conflicts of Interest

The authors declare no conflict of interest in the content of the manuscript.

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