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Occurrence, Abundance and Spatial Variation of Suspected Microplastic Particles in Surface Water and Borehole Drinking-Water Sources in Marigat Town, Baringo County, Kenya

Lagat Kipkios Robinson*, Magero Denis, Okoth O. Maurice and Odiwuor Onyango Vincent

Department of Chemistry and Biochemistry, School of Science, University of Eldoret, P.O. Box 1125-30100, Eldoret, Kenya

Abstract

Microplastic occurrence is increasingly documented in freshwater systems, yet evidence from semi-arid drinking-water towns in Kenya remains scarce. This study quantified and compared the abundance of suspected microplastic particles less than 5 mm. The nominal minimum particle size was set by the 1.2 µm filter pore size. In Perkerra River and five borehole sources serving Marigat Town, Baringo County, and examined how abundance varied among sampling locations. A descriptive and analytical cross-sectional design was used. Twenty-four 2-L water samples were collected in a single sampling period (9–10 February 2026, wet season): nine from the river (three each from upstream, midstream and downstream reaches) and fifteen from boreholes (three from each of MLBW, MHBW, MMJBW, MRBW and MMBW). Samples were sieved, density-separated in sodium chloride solution, digested with hydrogen peroxide and filtered, and particles were identified, classified and counted visually by microscopy; polymer identity was not confirmed in this study and is addressed in a companion FTIR paper. Six blanks of pre-filtered deionized water (five field and one laboratory) contained no particles. Fifty particles were recovered from 48 L, an overall concentration of 1.04 ± 0.66 particles/L (mean ± SD of sample concentrations), and particles were detected in 22 of 24 samples (91.7%). Concentration was higher in river samples (1.50 ± 0.61 particles/L) than in borehole samples (0.77 ± 0.53 particles/L), a Poisson rate ratio of 1.96 (95% CI 1.12–3.41, p = 0.018); ANOVA, Welch's t-test and the Mann-Whitney U test gave concordant results. Along the river, mean concentration was 1.00 ± 0.50, 1.50 ± 0.50 and 2.00 ± 0.50 particles/L at the upstream, midstream and downstream reaches, an ordered pattern that is exploratory because only three reaches were sampled. Among boreholes, MRBW had the highest mean (1.33 ± 0.58 particles/L) and MHBW the lowest (0.50 ± 0.50 particles/L), but differences among the eight locations were not consistently

significant (ANOVA p = 0.026; Kruskal-Wallis p = 0.074; Poisson likelihood-ratio test p = 0.16). Fragments dominated borehole particles (69.6%) and fibres dominated river particles (51.9%); overall, fragments comprised 54% and fibres 38%, and blue (54%) and black (28%) were the leading colours. The study documents occurrence and concentration only; it did not assess exposure, toxicity or health risk. These single-period, small-sample results provide a location-specific baseline and support repeated seasonal sampling, polymer confirmation, and follow-up investigation of the downstream river reach and the MRBW borehole.

Keywords: microplastics, suspected microplastic particles, drinking water, Perkerra River, boreholes, spatial variation, Baringo County

Correspondence: kipkiosrobin@gmail.com

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Introduction

Safe drinking water is central to public health and household welfare, yet water-quality assessment has traditionally focused on established microbial and chemical hazards. Concern has since broadened to include microplastics, plastic particles smaller than 5 mm that are either manufactured at microscopic size or generated when larger plastic items fragment through weathering, abrasion and ultraviolet exposure (Zhang et al., 2021). Detection of microplastics does not in itself establish a health risk, as the World Health Organization (WHO, 2019) concluded that the available evidence was insufficient to fully characterise the potential health risks associated with microplastics in drinking water. The public-health rationale for studies such as this one is therefore water-quality surveillance and evidence generation, particularly establishing whether, where and at what concentrations suspected particles occur in water sources on which communities depend.

Plastics used in packaging, water storage, agriculture, clothing and other consumer products can enter aquatic systems at multiple stages of their life cycle. Rivers receive particles from runoff, drainage, wastewater and the breakdown of litter, while rapid urbanisation that outpaces municipal waste-management infrastructure is widely identified as a driver of plastic leakage in sub-Saharan

freshwater systems (Alimi et al., 2018; Dube & Okuthe, 2024; Mogusu et al., 2023). Groundwater is generally better protected than surface water because soil and geological media can filter and retain particles, but several pathways could potentially deliver particles to boreholes. These include recharge and infiltration through shallow or coarse soils, preferential flow along fractures, root channels and other macropores that bypass the filtering soil matrix, and surface-water–groundwater exchange near rivers (Mintenig et al., 2019; Panno et al., 2019; Oladoja & Unuabonah, 2021). Particles may also be introduced at or after the point of abstraction, for example through poorly sealed wellheads, degrading plastic well casings and polypipes, pumping equipment, plastic storage tanks and distribution lines. These are possible pathways rather than established mechanisms at any borehole in Marigat, as the present study did not investigate the sources or pathways of particle contamination.

Microplastics have been reported in raw water, treated tap water, bottled water and groundwater, although reported concentrations vary widely (Koelmans et al., 2019; Mintenig et al., 2019). Part of this variation is methodological rather than environmental. Reported concentrations depend on sample volume, minimum particle size, filter pore size, density-separation medium, digestion procedure, whether particles are identified visually or spectroscopically, contamination control and recovery efficiency (Koelmans et al., 2019; Cowger et al., 2020). African evidence is limited relative to that from Europe, Asia and North America. Reviews document increasing reports from the continent's rivers, lakes and sediments alongside persistent gaps in standardised drinking-water monitoring (Mogusu et al., 2023; Dube & Okuthe, 2024). However, studies differ in water type, geographical setting, size threshold, sampling volume and polymer confirmation. For example, an FTIR-based study of borehole drinking water on Lagos Island, Nigeria, reported 206–1,691 particles m^{-3} (approximately 0.2–1.7 particles/L) in particles measuring 0.02–0.5 mm (Oni & Sanni, 2022). These findings provide a useful regional comparison, although direct numerical comparisons require caution because identification methods and particle-size thresholds may differ. Within Kenya, microplastics have been investigated in Lake Naivasha and the Njoro River–Lake Nakuru system (Migwi et al., 2020; Chui et al., 2024), but drinking-water sources in semi-arid settings have received relatively little attention.

Marigat Town lies on the floor of the Rift Valley in Baringo County, a semi-arid setting characterised by low and unreliable rainfall. Perkerra River rises in the wetter highlands and flows towards Lake Baringo; it is one of the perennial rivers draining into the lake, although its discharge falls markedly during dry seasons (ILEC, n.d.). The river supplies the Perkerra Irrigation Scheme near Marigat, which was established in the mid-twentieth century. Flow varies seasonally, and the river can run very low during prolonged dry periods, making the availability of different water sources important for the town. Consequently, the local water supply draws on both surface water and groundwater obtained from boreholes. The catchment combines irrigated and rain-fed agriculture, livestock keeping, a growing urban population and informal solid-waste disposal, all of which are plausible sources of plastic debris to the river. Earlier work in the town sampled drinking water from boreholes, rivers and wells (Osiemo et al., 2019), while the urban population of Marigat was projected at approximately

9,400 in 2018 (Baringo County Government, 2018).

In this setting, the two source types differ in how directly they are exposed to catchment activities. Perkerra River integrates runoff and drainage from the catchment, whereas borehole water receives some protection through subsurface filtration but may still be influenced by local hydrogeological conditions, wellhead integrity, pumping infrastructure and water handling. These differences provide a basis for comparing the occurrence and abundance of suspected microplastic particles in the selected water sources. Nevertheless, observed differences between river and borehole samples cannot, on their own, establish the mechanisms responsible for particle occurrence. It is also important to distinguish raw water sources from treated drinking water and water actually available to consumers, since river water that undergoes treatment before use should not be treated as equivalent to the water residents consume.

Earlier work in Marigat documented microbiological contamination of drinking water, confirming that water safety is already a practical local concern (Osiemo et al., 2019). However, evidence on the occurrence and abundance of suspected microplastic particles in the selected water sources remains limited. Without measured occurrence and spatial data, water managers have a limited evidence base for determining where microplastic surveillance and further source investigations could be prioritised.

To address these knowledge gaps, this study provides a location-specific baseline of the occurrence, numerical abundance, spatial distribution, morphology and colour of suspected microplastic particles identified through microscopy in surface water from Perkerra River and groundwater-derived water from five selected boreholes in Marigat Town. Specifically, the study determines and compares particle concentrations between the two water-source categories, assesses spatial variation among the selected sampling locations, and describes the morphology and colour composition of the recovered particles. The findings are intended to contribute to water-quality surveillance and provide baseline evidence for future investigations of suspected microplastic particles in drinking-water sources in semi-arid settings.

Objectives

The general objective was to quantify and compare the abundance of suspected microplastic particles in the principal drinking-water sources of Marigat Town in order to generate evidence relevant to water-resource management and surveillance. The specific objectives were:

1. To determine and compare the concentration of suspected microplastic particles in Perkerra River and borehole water.
2. To assess spatial variation in particle abundance among the selected Perkerra River and borehole sampling locations.
3. To describe the morphology (shape) and colour composition of the recovered particles by water source.

Research Questions

1. What are the concentrations of suspected microplastic particles in Perkerra River and borehole water, and how do they compare?
2. How does particle abundance vary spatially among the selected Perkerra River and borehole sampling locations?
3. What morphological and colour characteristics distinguish the

particles recovered from river and borehole water?

Materials and Methods

Study area

The study was conducted in Marigat Town, Baringo County, Kenya, in the Rift Valley lowlands south of Lake Baringo. The area is semi-arid, with low and unreliable rainfall. Marigat lies at an altitude of approximately 1,000 m above sea level in the Lake Baringo basin, between latitudes 0°12′ and 1°36′ N and longitudes 35°36′ and 36°30′ E. Rainfall is erratic, averaging 150–450 mm annually, and temperatures range between 25 °C and 30 °C (Osiemo et al., 2019). Annual evaporation in the wider Lake Baringo basin is approximately 1,650–2,300 mm (International Lake Environment Committee [ILEC], n.d.). The urban population of Marigat was projected at approximately 9,400 in 2018, within a sub-county population of about 110,000 people (Baringo County Government, 2018).

Sampling was conducted on 9–10 February 2026, during the wet season, when rainfall occurred. Approximately 50% of the town's population reportedly depends on borehole water and 50% on river water during the wet season. During the dry season, approximately 60% reportedly depends on borehole water and 40% on river water (Osiemo et al., 2019). Land use includes irrigated agriculture around the Perkerra Irrigation Scheme, pastoralism and urban settlement. Perkerra River drains the highlands to the south, flows past Marigat and empties into Lake Baringo.

Three river reaches were sampled: an upstream reach at Chemususu (PUPC), a midstream reach at the bridge (PMIDB), and a downstream reach at Ngambo (PDNN). Five boreholes within Marigat Town were also sampled: Marigat Lokodo borehole (MLBW), Marigat Hospital borehole (MHBW), Marigat Moran Junction borehole (MMJBW), Marigat Riverside borehole (MRBW) and Marigat Mosque borehole (MMBW). Borehole water at these sites is used directly for drinking without treatment. Both river and borehole samples were collected as source water at the point of sampling. Sampling locations and coordinates are presented in Table 1 and Figure 1.

Study design and sampling strategy

A descriptive and analytical cross-sectional environmental sampling design was used. All samples were collected during a single sampling period, 9–10 February 2026, during the wet season. Rain fell at the time of sampling. Consequently, the study did not capture seasonal variation in suspected microplastic particle abundance. The descriptive component summarised particle concentration, abundance, morphology and colour, while the analytical component assessed differences between the two water-source categories and among individual sampling locations. Completing the sampling within two consecutive days minimised temporal and meteorological variation between locations, allowing river and borehole water to be compared under broadly similar conditions.

Sampling locations were selected purposively within two source categories: surface water and borehole water. Three reaches of Perkerra River and five boreholes serving Marigat Town were sampled. Boreholes were selected based on the populations they serve and their locations within the town, where improper solid-waste disposal is a concern.

Table 1: Sampling locations, replication and coordinates

Location code	Description	Replicates	Volume (L)	Coordinates (lat., long.)
Upstream	Perkerra River, upstream reach at Chemususu (PUPC)	3	6	0.090406, 35.638533
Midstream	Perkerra River, midstream reach at the bridge (PMIDB)	3	6	0.458740, 35.969843
Downstream	Perkerra River, downstream reach at Ngambo (PDNN)	3	6	0.474585, 35.988887
MLBW	Marigat Lokodo borehole	3	6	0.471756, 35.987737
MHBW	Marigat Hospital borehole	3	6	0.478737, 35.983815
MMJBW	Marigat Moran Junction borehole	3	6	0.462792, 35.972802
MRBW	Marigat Riverside borehole	3	6	0.481532, 35.983234
MMBW	Marigat Mosque borehole	3	6	0.471778, 35.987722
Total	3 river reaches × 3 = 9 samples; 5 boreholes × 3 = 15 samples	24	48	

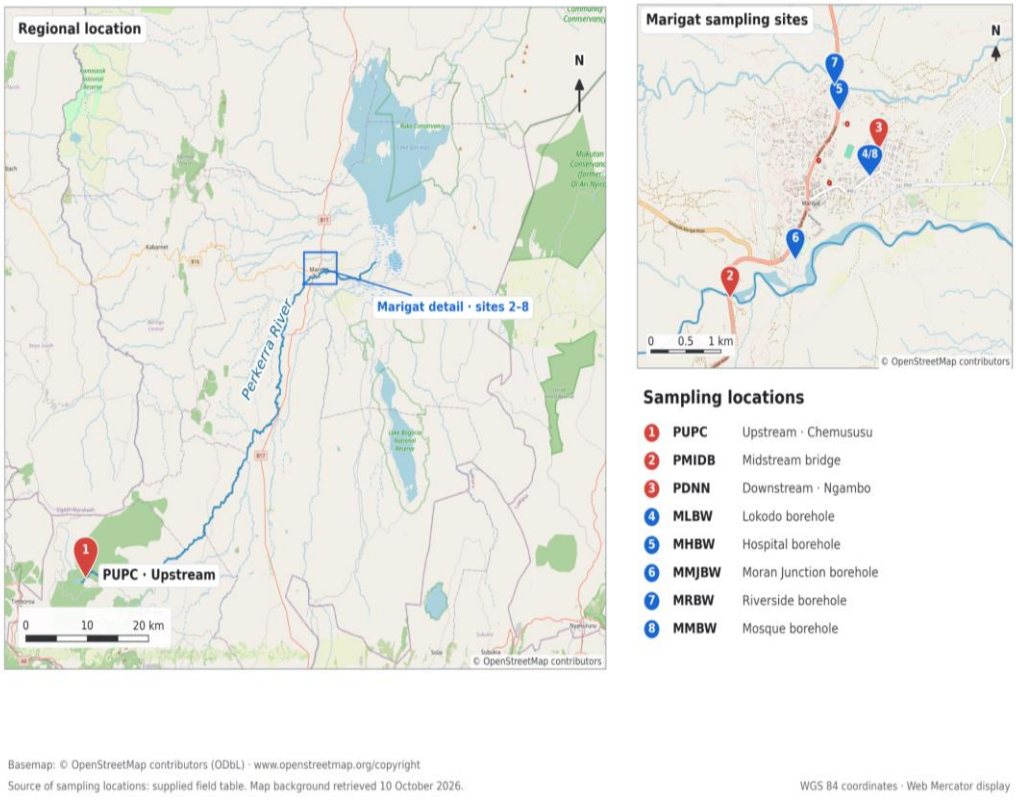


Figure 1: A study-area map showing Marigat Town, Perkerra River with the upstream, midstream and downstream sampling points and the five boreholes

The upstream reach at Chemususu was selected as a reference location, the midstream reach near the town represented an area exposed to human activities and irrigation, and the downstream reach at Ngambo represented a location towards Lake Baringo where inputs from upstream areas may accumulate.

Each of the eight sampling locations was sampled in triplicate, giving 24 samples in total: nine river samples and 15 borehole samples. At each river reach, three spatially distinct grab samples were collected at 30 m intervals along the river channel to capture local spatial heterogeneity. At each borehole, three temporal replicates were collected at 10-minute intervals during continuous purging. Replicates collected from the same location were treated as field replicates rather than as fully independent sampling locations.

Sample collection and contamination prevention

At each sampling point, 2 L of water was collected in pre-cleaned glass bottles to minimise the introduction of plastic particles from sampling containers. At boreholes, samples were collected from the discharge piping before water entered the storage tanks. The outlet was allowed to run for 2 minutes before collection to reduce the influence of stagnant water. Subsequent borehole replicates were collected at 10-minute intervals. At river sites, bottles were pre-cleaned with deionised water and immersed to a depth of approximately 20 cm in the mid-channel to collect water samples. Cotton clothing was preferred during sample handling to minimise contamination from synthetic fibres.

Bottles were labelled using unique identification codes indicating the sampling location and replicate, for example, MHBW R2. Following collection, samples were placed in ice-cooled boxes, protected from sunlight and transported to the University of Eldoret laboratory within 24 hours. Samples were maintained at approximately 4 °C during transport.

To minimise background and airborne microplastic contamination, a quality assurance and quality control (QA/QC) protocol was applied throughout sample collection and laboratory processing. Laboratory work surfaces were cleaned with pre-filtered deionised water before each sample batch was processed. Glass apparatus and filtration units were covered with aluminium foil or glass lids when not in use. Laboratory personnel wore natural cotton garments under cotton laboratory coats, together with full hair coverings and powder-free nitrile gloves, throughout the extraction and identification procedures (Munno et al., 2023).

Six independent 2 L ultrapure-water blanks were included in the sampling and extraction design. Five field blanks were assigned across the sampling stations: one each at the upstream and downstream river reaches and at MMBW, MRBW and MHBW. One laboratory blank was used to monitor background atmospheric deposition. Each blank underwent the same analytical procedures as the environmental samples, including sieving, density separation, digestion and filtration.

Laboratory processing

Each 2 L water sample was passed through a 5 mm stainless-steel sieve (Retsch GmbH, Germany), which was pre-cleaned three times with deionised water to remove residual debris. Particles retained by the sieve were excluded from the analysis. The sample then underwent density separation using saturated

sodium chloride (NaCl) solution, with a density of approximately 1.2 g cm^{-3}, and was allowed to settle for 24 hours.

Organic matter was digested using Fenton's oxidation. A 0.05 M Fe(II) catalyst solution was used, and 30% hydrogen peroxide (H_2O_2) was added in 50 mL increments to initiate oxidation. The mixture was stirred continuously and heated on a hot plate at 65 °C until bubbling ceased. The resulting suspension was vacuum-filtered through pre-baked 47 mm Whatman glass-fibre filters with a pore size of 1.2 µm. The filters were placed in glass Petri dishes and left to dry for 24 hours before microscopic examination.

The 5 mm sieve and 1.2 µm filter pore size defined the nominal operational size window of the analysis, approximately 1.2 µm–5 mm. Particles smaller than this nominal lower threshold were not specifically assessed. The lower limit should not, however, be interpreted as a verified optical detection limit because particle recognition also depended on microscopic resolution and the identification criteria applied.

Sodium chloride was used because it is inexpensive, non-toxic and widely available. However, its density of approximately 1.2 g cm^{-3} is lower than that of some common polymers, including polyethylene terephthalate (PET) and polyvinyl chloride (PVC), which may therefore have been under-recovered. Consequently, the reported concentrations may underestimate particle abundance, depending on polymer composition. Digestion efficiency and overall particle recovery were not validated through spiking experiments, and this is acknowledged as a methodological limitation.

Microscopic identification and classification

Dried filters were examined using a JAPSON HG 671572 dissecting microscope at magnifications of up to ×40. Incident and reflected LED surface lighting was directed at an angle onto the filter surface to improve the visibility of particle boundaries. Unpolarised light was used throughout the screening process.

Particles with apparent dimensions of 5 mm or less were screened and recorded, while larger macroplastics were excluded. Suspected microplastic particles were identified using morphological criteria, including the absence of cellular or recognisable organic structures, uniform colour across the particle body, homogeneous texture and resistance to manipulation with fine forceps. Two observers conducted the visual screening independently and cross-verified particle counts to improve consistency and minimise subjective counting bias.

Visual identification alone cannot establish polymer identity. Accordingly, particles identified through microscopy are referred to as suspected microplastic particles throughout this study. Polymer identity was assessed separately by FTIR spectroscopy on a subset of 13 of the 50 recovered particles.

Particles were classified into four morphological categories: fibres, fragments, beads and films. Fibres were identified as thin, thread-like strands with a relatively uniform width along their length. Fragments consisted of thicker, rigid pieces with irregular or jagged edges. Beads were smooth, round or oval particles, while films appeared as thin, flexible sheets. Flat or irregularly shaped particles were assessed using fine forceps to distinguish films from fragments: particles that bent easily under pressure were classified as films, whereas those

that remained rigid were classified as fragments.

Particle colour was assessed under steady white LED lighting positioned at a fixed angle to minimise glare and shadows. Each particle was assigned a colour category according to the shade covering most of its surface. The categories were blue, black, red-brown, pink/red and white/translucent. For heavily weathered, faded or unusually coloured particles, two observers examined the particle independently and conservatively assigned it to the white/translucent category where appropriate.

Particle size was not measured individually. Therefore, the study did not generate a particle-size distribution, and the nominal size window was defined by the 5 mm sieve and 1.2 µm filter pore size. The smallest particles within this window may not have been resolvable at ×40 magnification. Morphology and colour were treated as descriptive characteristics and were not used independently to establish polymer identity or contamination source.

Quality assurance, data recording and detection limit

All six blanks, comprising five field blanks and one laboratory blank, contained zero particles. Consequently, no blank correction was applied to the sample counts. Particle counts were recorded for each sample and reconciled against the corresponding morphology and colour records to ensure consistency between the classification totals and overall particle counts. During reconciliation, an unlabelled continuation entry beneath sample MHBW R2 was consolidated with that replicate, and a film entry in the PDNN R2 record was standardised as one white/translucent film particle. No values were added to smooth spatial patterns or strengthen statistical contrasts, and all 24 planned samples were retained in the dataset.

Particle concentration was calculated by dividing the number of particles recovered from each sample by the sample volume of 2 L. Concentrations were expressed as particles/L:

Concentration (particles/L) = Number of particles recovered ÷ Sample volume (L)

Because every sample had a volume of 2 L, one recovered particle corresponded to 0.5 particles/L. Thus, the smallest non-zero concentration reportable under the sampling design was 0.5 particles/L, and concentrations occurred in discrete multiples of 0.5 particles/L. A zero count was interpreted as no particle detected under the applied analytical conditions, including the nominal size window, recovery procedures and identification criteria, rather than proof of complete absence.

Statistical analysis

Descriptive statistics, including the mean, median, standard deviation, range and 95% confidence intervals, were computed for particle concentration by source category and sampling location.

Inferential analysis was used to compare river and borehole samples using a Poisson generalised linear model (GLM) fitted to particle counts, with source category as the explanatory variable and the logarithm of sample volume as an offset. The exponentiated source coefficient was interpreted as the rate ratio for river relative to borehole water. Overdispersion was assessed using the Pearson chi-square statistic divided by the residual degrees of freedom. A negative-binomial model was specified as an alternative if overdispersion was detected.

One-way analysis of variance (ANOVA), Welch's t-test and the Mann–

Whitney U test were conducted as sensitivity analyses of the source-category comparison. These analyses were not treated as independent tests of the primary hypothesis. Differences among the eight sampling locations were assessed using a Poisson likelihood-ratio test, with location included as a categorical factor and the same sample-volume offset. One-way ANOVA and the Kruskal–Wallis test were used as sensitivity analyses. Given the three replicates per location, location-level and post-hoc comparisons had limited statistical power and were interpreted as exploratory.

For Perkerra River, an exploratory trend in particle concentration across the ordered reaches was examined using linear regression and quasi-Poisson regression, with upstream, midstream and downstream coded as 1, 2 and 3, respectively. This analysis did not account for clustering of samples within reaches; therefore, its inferential strength was limited by the three river reaches sampled.

Zero counts were retained in all analyses and were not treated as missing values. Morphology and colour were summarised descriptively. Fisher's exact test was used once as an exploratory assessment of the proportion of fibres by source category because of the small counts. Effect sizes and 95% confidence intervals were reported alongside p-values. The river–borehole comparison was designated as the primary analysis, while all other tests were considered secondary or exploratory. No adjustment for multiple comparisons was applied; consequently, secondary p-values were interpreted descriptively, using a significance level of $\alpha = 0.05$.

Replicates within each location were spatially distinct for river samples and temporally distinct for borehole samples, but all were collected from the same respective site. They were therefore field replicates rather than independent samples from separate locations. Treating replicates as fully independent may inflate the apparent precision of location-level estimates through pseudoreplication. A hierarchical or mixed-effects model would be more appropriate for a larger nested sampling design, and this limitation was considered when interpreting the results.

Results

Occurrence and overall abundance

As presented in Table 2, a total of 50 suspected microplastic particles were recovered from the 48 L of environmental water processed, corresponding to an overall concentration of 1.04 particles/L (median = 1.00, SD = 0.66, 95% CI: 0.76–1.32 particles/L). Particles were detected in 22 of the 24 samples (91.7%), while the two samples with no detected particles were borehole replicates MHBW R1 and MMJBW R3. All nine river samples contained at least one particle.

Table 2: Overall and source-specific concentrations of suspected microplastic particles

Source	n	Volume (L)	Particles	Mean (particles/L)	SD	Median	95% CI	Range
Boreholes	15	30	23	0.77	0.53	0.50	0.47–1.06	0.00–2.00
Perkerra River	9	18	27	1.50	0.61	1.50	1.03–1.97	0.50–2.50
Overall	24	48	50	1.04	0.66	1.00	0.76–1.32	0.00–2.50

At the location level, particles were detected at all eight sampling locations, indicating that occurrence varied among individual samples but was not restricted to particular locations. Source-specific results showed that the Perkerra River yielded 27 particles from 18 L of water, giving a concentration of 1.50 particles/L, compared with 23 particles from 30 L of borehole water, equivalent to 0.77 particles/L.

River versus borehole comparison

In the primary analysis, the Poisson model gave a river-to-borehole rate ratio of 1.96 (95% CI 1.12–3.41, p = 0.018). The Pearson dispersion statistic was 0.65 (residual deviance 16.2 on 22 degrees of freedom), so there was no evidence of overdispersion and a negative-binomial model was not required. The absolute difference in mean concentration was 0.73 particles/L (Welch 95% CI 0.21–1.26 particles/L). Sensitivity analyses agreed in direction and magnitude: one-way ANOVA F(1,22) = 9.60, p = 0.005 ($\eta^2 \approx 0.30$; Cohen's d ≈ 1.31); Welch's t-test t = 2.98, df = 15.07, p = 0.009; and Mann-Whitney U = 110.5, p = 0.009 (Table 5). Replicate ranges overlapped (boreholes 0–2.00 particles/L; river 0.50–2.50 particles/L), so the contrast is an upward shift of the river distribution rather than complete separation between sources.

Spatial variation among locations

Among boreholes, MHBW had the lowest mean (0.50 particles/L); MLBW, MMJBW and MMBW each averaged 0.67 particles/L; and MRBW had the highest mean (1.33 particles/L) and was positive in all three replicates (Table 3). Among river reaches the mean was 1.00 particles/L upstream, 1.50 particles/L midstream and 2.00 particles/L downstream. Across all eight locations, the Poisson likelihood-ratio test did not indicate that location explained variation in counts beyond chance (χ^2 = 10.56, df = 7, p = 0.16), and neither did the Kruskal-Wallis test (H = 12.91, df = 7, p = 0.074). The conventional one-way ANOVA was significant (F(7,16) = 3.18, p = 0.026; $\eta^2 \approx 0.58$). Because the tests disagree, the location-level result is treated as suggestive and exploratory.

Table 3: Location-level concentrations of suspected microplastic particles

Location	Source	Particles	Volume (L)	Mean (particles/L)	SD	Median	Range	Positive replicates
MLBW	Borehole	4	6	0.67	0.29	0.50	0.50–1.00	3/3
MHBW	Borehole	3	6	0.50	0.50	0.50	0.00–1.00	2/3
MMJBW	Borehole	4	6	0.67	0.76	0.50	0.00–1.50	2/3
MRBW	Borehole	8	6	1.33	0.58	1.00	1.00–2.00	3/3
MMBW	Borehole	4	6	0.67	0.29	0.50	0.50–1.00	3/3
Upstream	River	6	6	1.00	0.50	1.00	0.50–1.50	3/3
Midstream	River	9	6	1.50	0.50	1.50	1.00–2.00	3/3
Downstream	River	12	6	2.00	0.50	2.00	1.50–2.50	3/3

The mean for MRBW (1.33 particles/L) approached that of the river midstream reach. Location-level 95% confidence intervals were wide (for example MRBW −0.10 to 2.77 particles/L, based on three replicates), reflecting the small number of replicates.

Longitudinal pattern along Perkerra River

Total particle counts rose from six upstream to nine midstream and twelve downstream, with 6 L processed per reach. In the exploratory ordered-reach analysis of the nine river samples, concentration increased by 0.50 particles/L per reach (SE 0.19; $R^2 = 0.50$, p = 0.033); a quasi-Poisson model gave a rate ratio of 1.40 per reach (95% CI 1.08–1.83). Because there are only three reaches and the model does not account for clustering of samples within reaches, this is an observed pattern, not formal evidence of a persistent downstream gradient (Figure 1).

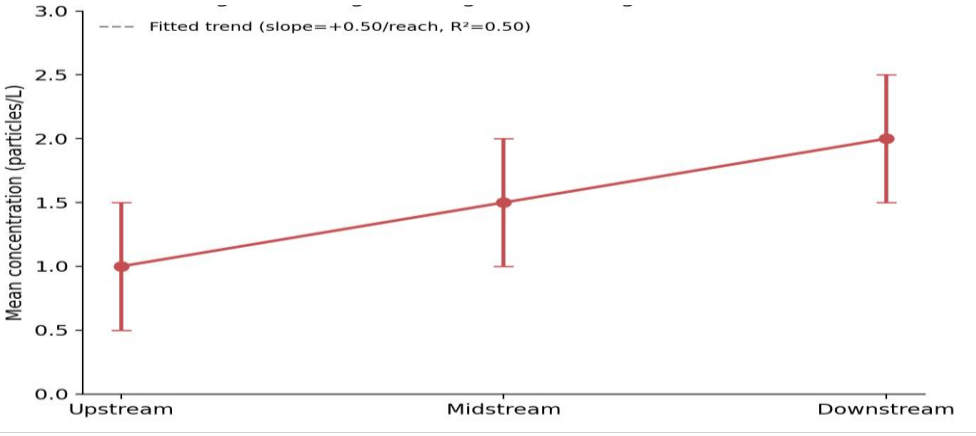


Figure 1: Observed pattern of particle concentration along Perkerra River (upstream to downstream)

Morphology and colour

Fragments were the most abundant morphology overall (27 particles, 54%), followed by fibres (19 particles, 38%); beads and films were uncommon (2 particles each, 4%) (Table 4, Table 4). Borehole particles were fragment-dominated (69.6% fragments, 21.7% fibres of 23 particles), whereas river particles were fibre-dominated (51.9% fibres, 40.7% fragments of 27 particles). In an exploratory Fisher's exact test, the proportion of fibres differed between sources (river 14 of 27 versus borehole 5 of 23; unadjusted p = 0.042); with 50 particles in total this is presented as descriptive.

Table 4: Morphological and colour composition of recovered particles by source

Source	Fibres	Fragments	Beads	Films	Blue	Black	Red-brown	Pink/red	White/translucent
Boreholes	5 (21.7 %)	16 (69.6%)	1 (4.3 %)	1 (4.3 %)	9 (39.1 %)	10 (43.5 %)	3 (13.0 %)	1 (4.3%)	0
Perkerra River	14 (51.9 %)	11 (40.7%)	1 (3.7 %)	1 (3.7 %)	18 (66.7 %)	4 (14.8 %)	1 (3.7%)	3 (11.1 %)	1 (3.7%)
Overall	19 (38%)	27 (54%)	2 (4%)	2 (4%)	27 (54%)	14 (28%)	4 (8%)	4 (8%)	1 (2%)

Blue (54%) and black (28%) together accounted for 82% of colour assignments. Blue represented two-thirds of river particles but under two-fifths of borehole particles, while black was the leading borehole colour (Figure 2). All six upstream particles were blue, whereas midstream and downstream assemblages were more colour-diverse; because only six particles were recovered upstream, this uniformity should be read together with the small absolute count.

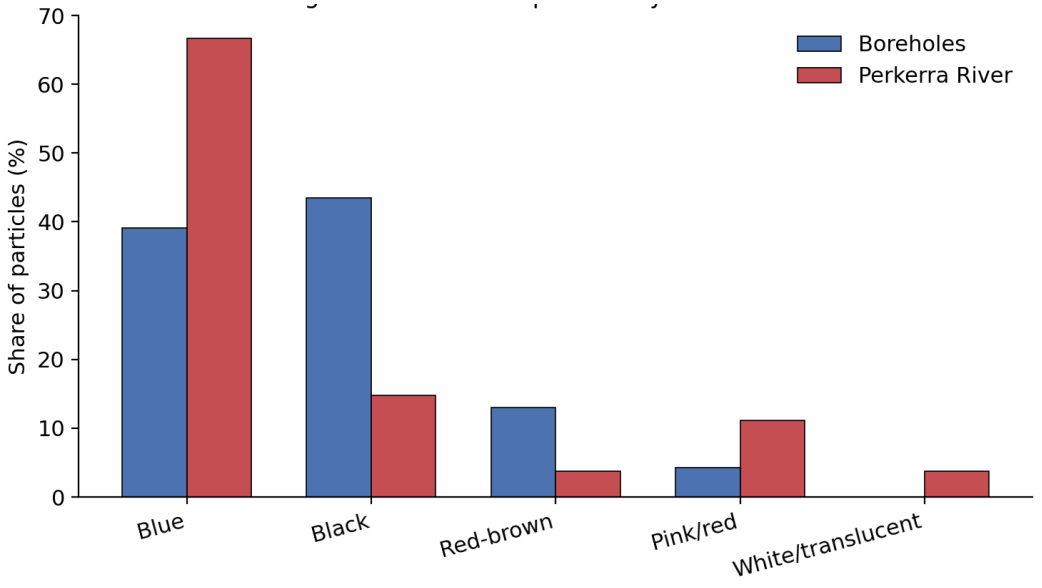


Figure 2: Colour composition of recovered particles by water source.

Table 5: Summary of inferential statistical results

Analysis (status)	Comparison	Statistic	Effect size / 95% CI	p-value
Poisson GLM, log(volume) offset (primary)	River vs boreholes	RR = 1.96	1.12–3.41	0.018
One-way ANOVA (sensitivity)	River vs boreholes	F(1,22) = 9.60	$\eta^2 \approx 0.30$; $d \approx 1.31$	0.005
Welch's t-test (sensitivity)	River vs boreholes	t = 2.98; df = 15.07	$\Delta = 0.73$; 0.21–1.26 particles/L	0.009
Mann-Whitney U (sensitivity)	River vs boreholes	U = 110.5	–	0.009
Poisson likelihood-ratio test (exploratory)	Eight locations	$\chi^2 = 10.56$; df = 7	–	0.16
One-way ANOVA (exploratory)	Eight locations	F(7,16) = 3.18	$\eta^2 \approx 0.58$	0.026
Kruskal-Wallis (exploratory)	Eight locations	H = 12.91; df = 7	–	0.074
Ordered-reach regression (exploratory)	Upstream to downstream, n = 9	Slope = +0.50; R^2 = 0.50	Quasi-Poisson RR 1.40 per reach; 1.08–1.83	0.033

Physico-chemical parameters

Temperature, total dissolved solids (TDS), pH and electrical conductivity (EC) were recorded for each river sample and for each borehole (Table 6). Field measurements were obtained using a calibrated multi-parameter water quality meter. The instrument was calibrated prior to field deployment using standard calibration protocols: pH was adjusted via a two-point calibration using technical buffer solutions (pH 4.01 and 7.01), while the EC and TDS sensors were calibrated using a 1413 µS/cm potassium chloride (KCl) reference standard. Values for TDS are reported in parts per million (ppm, equivalent to mg/L), and EC values are expressed in microsiemens per centimeter (µS/cm).

River temperature increased from 21.5 °C upstream to 25.8 °C midstream and 27.0 °C downstream, and mean pH from 7.21 to 7.52 and 7.75 over the same reaches. Mean TDS rose from 30 ppm upstream to 52 ppm midstream and 60 ppm downstream, and mean EC from 49 to 94 and 121 µS/cm. Borehole water was warmer (29.0–30.1 °C) and considerably more mineralised than river water, with TDS of 234–346 ppm and EC of 471–691 µS/cm; pH ranged from 7.18 to 7.80 across all sources. Within the boreholes, MRBW and MMBW had the highest TDS and EC. These are single-period field readings reported for site description only; they were not tested statistically against particle counts, and no relationship between water chemistry and particle abundance is inferred.

Table 6: Physico-chemical parameters of the sampled water (river values are the mean of three samples ± SD; borehole values are single readings)

Location	Temperature (°C)	TDS (ppm)	pH	EC (µS/cm)
Perkerra River				
Upstream (PUPC)	21.5 ± 0.1	30.3 ± 4.0	7.21 ± 0.02	49.0 ± 15.9
Midstream (PMIDB)	25.8 ± 0.1	52.3 ± 0.6	7.52 ± 0.09	94.3 ± 10.4
Downstream (PDNN)	27.0 ± 0.2	60.0 ± 1.0	7.75 ± 0.10	121.3 ± 5.8
Boreholes				
MLBW	29.4± 0.1	234± 0.2	7.18± 0.10	471± 10.6
MHBW	30.1± 0.1	251± 0.2	7.51± 0.04	503± 12.4
MMJBW	29.1± 0.1	252± 0.1	7.70± 0.02	504± 10.1
MRBW	30.1± 0.1	346± 0.2	7.61± 0.10	691± 9.4
MMBW	29.0± 0.1	337± 0.2	7.80± 0.02	645± 15.4

Discussion

Occurrence and abundance in the context of other studies

Suspected microplastic particles were found in both surface-water and groundwater-derived sources in Marigat, in 22 of 24 samples and at all eight locations, at an overall concentration of 1.04 particles/L. This concentration reflects the specific sampling volume (2 L per sample), size window (approximately 1.2 µm–5 mm) and visual identification used here, and particles smaller than the 1.2 µm filter pore size, which the method did not target, would have been missed.

Comparison with other studies must therefore be cautious. The Lagos Island borehole study (Oni & Sanni, 2022), for example, reported about 0.2–1.7 particles/L, a range that overlaps with the present borehole values, but it targeted a different size window (0.02–0.5 mm) and used FTIR for identification. Studies in Kenyan lakes and rivers (Migwi et al., 2020; Chui et al., 2024) and African reviews (Mogusu et al., 2023; Dube & Okuthe, 2024) likewise differ in water type, size threshold, volume and polymer confirmation, so apparently higher or lower concentrations may reflect methodology rather than genuine environmental differences (Koelmans et al., 2019). The main contribution of this study is a drinking-water-focused, semi-arid case, and its value lies mainly in the within-study comparisons, which share one protocol.

River and borehole sources

Concentrations were higher in the river than in borehole water during the study period (rate ratio 1.96, 95% CI 1.12–3.41), an approximately two-fold difference in observed particle rates under these conditions. This is consistent with the expectation that rivers integrate material from the catchment, such as litter fragments, agricultural plastics and fibres mobilised by runoff and drainage, whereas groundwater benefits from filtration through soil and geological media (Oladoja & Unuabonah, 2021). However, the design does not show that the river is the source of particles in the boreholes, nor that groundwater is inherently protected, and the explanations offered here are hypotheses that require testing. The finding of particles in every borehole location is nonetheless important because groundwater is generally less directly exposed to surface inputs. The study cannot determine whether particles entered through recharge, subsurface transport, borehole infrastructure, pumping equipment, storage or other pathways, so these remain possible explanations only (Mintenig et al., 2019; Panno et al., 2019).

Statistical significance should not be equated with environmental importance. The difference is of the order of 0.7 particles/L, the confidence interval is wide and the replicate ranges overlap, so the finding is best read as a modest, uncertain difference in observed concentrations rather than as a demonstration of an important environmental or health effect. The study did not measure exposure, ingestion, dose or toxicity, and nothing here shows that the detected concentrations pose a hazard.

Spatial variation

Along Perkerra River, concentration increased from upstream to downstream (1.00, 1.50 and 2.00 particles/L). With only three reaches, three replicates each and a model that ignores clustering, this is an observed pattern that is consistent with increasing abundance downstream, not evidence of a persistent gradient. The processes responsible were not measured. Possible explanations include increasing anthropogenic input, runoff, wastewater inputs, bank erosion and accumulation, but these remain hypotheses; targeted source-tracking and repeat sampling across seasons and flow conditions would be required to test them. Among boreholes, MRBW had the highest mean (1.33 particles/L) and MHBW the lowest (0.50 particles/L). Given three samples per borehole and wide confidence intervals, these are observed differences that warrant further investigation, not evidence that MRBW is a confirmed contamination hotspot. The disagreement among the location-level tests (ANOVA $p = 0.026$; Kruskal-Wallis $p =$

0.074; Poisson likelihood-ratio test p = 0.16) indicates that the evidence for heterogeneity among the eight locations is weak. Wellhead protection, infrastructure, pumping systems, land use and recharge conditions could influence particle abundance at individual boreholes, but they were not assessed here.

Particle morphology and colour

Fragments dominated borehole particles and fibres dominated river particles. Such patterns may be consistent with fragmentation of larger plastic items contributing to fragments and with textile- or laundry-related inputs contributing to fibres (Li et al., 2018; Zhang et al., 2021), but morphology alone cannot establish a source (Silva et al., 2018), and fibres are especially prone to airborne and clothing-related contamination during sampling and analysis. Fragments, fibres, films and beads are physical categories, not polymer categories, and the colour distribution, dominated by blue and black particles, cannot substitute for FTIR or Raman identification; colour has limited source specificity because pigments occur across many products and weathering can alter apparent colour (Cowger et al., 2020). Statements linking specific colours to specific products would require independent evidence. Given the small total (50 particles), the morphological contrast between sources is descriptive.

6.5 Implications for monitoring

The results support differentiated surveillance priorities rather than demonstrated source control needs. The higher river concentration and the downstream pattern justify additional monitoring of the downstream reach and of land use and waste-disposal points along the river corridor. The higher mean at MRBW justifies further investigation of that borehole, including sequential sampling at the wellhead, after pumping and after storage to determine whether concentrations change within the supply chain. Where centralised treatment exists, conventional coagulation, sedimentation and filtration can remove a substantial fraction of larger particles, while membrane technologies offer higher removal at greater cost (Novotná et al., 2019). The current data do not demonstrate that waste disposal, damaged infrastructure or any particular human activity caused the observed concentrations.

Limitations

This study is a single-period baseline. It has a small number of sampling locations and replicates (three per location, which are field replicates that may not be fully independent), a 2-L sample volume that produces discrete concentration increments of 0.5 particles/L, and a nominal minimum particle size set by the 1.2 µm filter pore size (the smallest particles were probably not resolvable under the ×40 dissecting microscope).

Particles were identified visually, and chemical confirmation is reported separately for a subset only. NaCl density separation may under-recover higher-density polymers, and no spiking or recovery experiments were conducted, so measured concentrations may underestimate true concentrations to an unknown degree. Although six blanks (five field and one laboratory) contained no particles, only a single laboratory blank monitored airborne deposition, so contamination, especially by fibres, cannot be excluded entirely. Particle size distributions were not measured. Sampling was conducted in a single period during the wet season (9–10 February 2026) and does not capture dry-season conditions or other seasonal variation.

These limitations do not invalidate the findings but constrain how broadly they can be generalised; the river gradient and the elevated MRBW mean in particular require repeated wet- and dry-season sampling, larger volumes and more replicates before they can be treated as stable features.

Conclusion

This study provides a baseline of the occurrence of suspected microplastic particles (approximately 1.2 µm–5 mm) in Marigat Town's principal drinking-water sources. Particles were detected at all eight sampled locations and in 91.7% of samples, at an overall concentration of 1.04 particles/L, showing that occurrence is not confined to surface water. Particle concentration was about twice as high in Perkerra River as in borehole water (1.50 versus 0.77 particles/L; rate ratio 1.96, 95% CI 1.12–3.41), and the river showed an increasing upstream-to-downstream pattern that should be regarded as exploratory.

Borehole water was not uniformly low, but differences among individual locations were not consistently significant. Fragments dominated borehole particles and fibres dominated river particles. The study did not identify polymers, did not establish pollution sources or seasonal patterns and did not assess exposure or health risk. It nevertheless provides an evidence base for targeting future monitoring and investigation in the study area.

Recommendations

1. Baringo County water-management authorities should consider periodic, standardised microplastic surveillance at the Perkerra River reaches and boreholes examined here, retaining fixed sample volumes and procedural blanks for comparability over time.
2. The downstream Perkerra River reach should be prioritised for further monitoring, including mapping of drainage channels, waste-disposal points and settlement density along the river corridor, to test whether these are associated with the observed pattern.
3. The MRBW borehole and its surrounding infrastructure should be investigated, with sequential sampling at the wellhead, after pumping and after storage.
4. Strengthening solid-waste collection and enforcement around waterways is a reasonable general measure to reduce plastic debris entering rivers, although this study did not test its effect.
5. Future studies should repeat sampling across wet and dry seasons with larger volumes, more replicates, recovery experiments, particle-size measurement and polymer confirmation by FTIR or Raman spectroscopy.

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