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# Assessment of Airborne Microplastics in the Residential Indoor Environment and Their Relationship with Particulate Matter in Najaf City- Iraq: An Environmental Study

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**Abstract |** **Background:** Airborne microplastics are an emerging indoor environmental challenge, however comparisons between research are restricted by way of differences in sampling, infection control, screening standards and polymer-confirmation techniques. Optical particle-counter channels describe aerosol responses by length and do now not identify polymer composition. Objective: To describe particle-counter readings and microscopy-screening observations from living rooms in 30 houses throughout central, northern and southern Najaf city and to explore associations among according to-home counts of objects classified as suspected plastic-like and the recorded counter device per size value and PM2.5/PM10 outputs. **Methods:** The study covered 30 homes (10 per regional stratum), 60-minute sampling record by using portable sniffer device type AVMDS-30 drift values and using 6 channels portable b particulat matter sampler type NOHAWK NK800 device size-channel readings, PM2.5 and PM10 values, 90 object-level microscopy entries (3 logged entries per home) and 12 blank records was measured. **Results:** Mean recorded flow was 29.85 L/min (SD 1.92) and recalculated mean sampled volume was 1.791 $m^3$ (SD 0.115). Of 90 logged objects, 49 (54.4%) have been classified as microplastic of plastic-like particles, 23 (25.6%) as uncertain and 18 (20.0%) as excluded. At home level (n = 30), microplastic-object counts were no significantly associated with PM2.5 ($\rho = -0.135$, $p = 0.477$), PM10 ($\rho = -0.011$, $p = 0.953$), or any sampler count device (all $p \geq 0.142$). The largest positive association was with the ≥0.5 µm count channel device ($\rho = 0.275$, $p = 0.142$). No regional comparison assessment remained significant after Holm adjustment. **Recommendations:** This study provides preliminary statistics on microscopic particle observations and transportable air-particle measurements in residential environments in Al-Najaf city. Future studies ought to check out the relationships between airborne microplastic abundance and residential characteristics, air flow practices, synthetic furniture, cleansing sports and indoor environmental conditions to become aware of capacity determinants of particle occurrence in residential environments.

**Key Words** Airborne Particles, Microplastic Particles, Indoor Air, Particle Counter, Pm2.5, Pm10, Microscopy

## INTRODUCTION

Plastic substances used in textiles, furniture, building merchandise and client goods can fragment or launch fibers via abrasion and degradation. Airborne particles may additionally circulate between indoor and outdoor environments and atmospheric delivery has been documented even in far flung areas [1,2]. Indoor settings merit attention because human beings spend significant time in houses and because indoor sources, resuspension, furniture and human pastime can also affect airborne particle stages [3,4].

Evidence on airborne micro plastics has multiplied, however direct comparisons stay difficult. Reviews become aware of version in collection techniques, sampled air volumes, clear out substrates, particle-length thresholds, infection manipulate and identity criteria as major resources of uncertainty [5-8]. Studies of indoor and outside air have stated differing concentrations and morphology patterns, underscoring that findings are technique-established and must now not be transferred directly among places [9,10].

Microscopy affords records about appearance, shade, shape and approximate dimensions. Fluorescence staining can help screening; however, a fluorescent sign isn't always equivalent to chemical confirmation of a polymer; unbiased techniques along with micro-FTIR or Raman spectroscopy are usually used for polymer identification [11,12]. Visual class also calls for explicit guidelines due to the fact non-plastic substances can resemble plastic fibers or fragments.

Optical particle counters provide length-channel variety readings and, relying at the device, anticipated particulate-remember mass concentrations. These outputs aren't chemically particular to plastics. Therefore, the prevailing study treats the counter and microscopy results as complementary

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however wonderful signs and does now not count on that a correlation would show that the counter selectively measures plastic debris.

### Aim and Objectives

The intention becomes to signify recorded particulate-count number measurements and microscopy-screened plastic-like objects in 30 residential living rooms in Al. Najaf City, Iraq and to discover association among the two sets of observations.

- Describe sampler flow, recalculated sampled-air volume, six NK800 size-channel readings device and PM2.5/PM10 outputs as recorded
- Summarize object level microscopy classifications and recorded morphology, color, fluorescence response and dimensions
- Explore association between the variety of logged suspected plastic-like items per home and the six NK800 channels portable device and PM2.Five/PM10 outputs
- Compare recorded instrument measurements across the central, northern and southern residential strata, with correction for multiple comparisons
- Summarize blank records and identify methods, quality control and data-provenance limitations that affect interpretation

## MATERIALS AND METHODS

### Study Design and Placing

This was a cross-sectional exploratory assessment of 30 residential living rooms in Al.Najaf City, Iraq. The home turned into the unit of evaluation for tool readings. Ten records have been assigned to every of 3 strata labelled Central Najaf, Northern Najaf and Southern Najaf within the provided sampling sheet.

### Instruments and Measurements

The sampling sheet identifies an portable air sniffer type AVM DS-30 energetic air sampler and a portable particulate matter type NOHAWK NK800 particle counter portable device. The recorded sampling length turned into 60 minutes consistent in each examin at all studied home.

The recorded mean drift values had been used to recalculate sampled quantity as: volume ($m^3$) = glide (L/min) × duration (min) ÷ 1,000. The NK800 channels were retained the usage of the scale labels supplied in the sheet (0.3, 0.5, 1.0, 2.5, 5.0 and 10.0 μm) and the recorded PC/L label.

### Sampling Position and Process

The take a look at protocol described sampling within the residing-room surroundings and a standardized device peak of 1.50 m on a stand with the human respiration line, the windows kept closed in the course of the 60-minute interval. The two instruments had been intended to sample the same room microenvironment.

### Microscopy Screening and Class

The microscopy sheet contained 90 item-level facts connected to houses H01–H30 and filters F01–F30, with three logged entries per domestic. Recorded fields covered shape, colour, fluorescence reaction, duration, width and type as suspected, uncertain, or excluded. Length and width are summarized as entered [5,6, 11-13].

### Blank Records and Great Manage

12 clean facts had been supplied: six labeled field blanks and 6 labeled laboratory blanks. The recorded blank log includes 28 gadgets in total (12 in field blanks and 16 in laboratory blanks). Airborne micro plastic approach reviews emphasize infection prevention, blanks, transparent reporting and prespecified coping with rules [5-8].

### Statistical Evaluation

Continuous variables were summarized the usage of mean, standard deviation, median, interquartile range and range; specific microscopy classifications were summarized as counts and possibilities of 90 entries. The quantity of suspected gadgets changed into aggregated in step with home (0–3) and used as the final results for exploratory Spearman rank correlations. Kruskal–Wallis checks compared device measures across the 3 nearby strata and Holm adjustment was carried out in the study..

### Data Integrity and Ethics

Home identifiers had been anonym zed and no family names or street addresses have been covered.

## RESULTS

The evaluation protected 30 family device facts, ninety microscopy item statistics and 12 blank statistics. The sample blanketed 10 houses in each nearby stratum. Flow and quantity values had been reviewed for inner consistency; recalculated volumes based totally on glide and duration were used for the summary under.

In Table 1 the overall of 30 residential houses have been included in the analysis. The sampling mean flow was 29.850±1.920 L/min and the mean recalculated air-sampling extent was 1.79±0.12 $m^3$. Among the instrument-pronounced particle-count channels, the highest mean value was found in the 0.3-μm particle count (9,382.20 PC/L), while the lowest mean value was in the 10.0-μm particle count (32.47 PC/L). The mean PM2.5 and PM10 readings had been 22.12±10.20 μg/$m^3$ and 37.50±17.36 μg/$m^3$, respectively. For microscopy-based class, the mean number of objects classified as suspected per home was 1.63±0.89 out of three logged objects, with a mean suspected-object proportion of 0.54±0.30.

The Table 2 was showed that of the 90 microscopy-tested objects were, 49 (54.4%) have been categorized as plastic-like particles, 23 (25.6%) as uncertain and 18 (20.0%) as excluded. Regarding morphology, fragment-like objects were the most frequent category (25; 27.8%), observed by way of film-like and irregular objects (22; 24.4% each), even as fiber-like objects accounted for 21 (23.3%). Black became the most often recorded color (20; 22.2%), accompanied with the aid of blue and white (18; 20.0% each). Moderate fluorescence was the most common response (26; 28.9%), whereas weak and strong responses were each observed in 22 objects (24.4%) and no fluorescence was determined in 20 objects (22.2%).

The Table 3 was shows the spearman correlation analysis discovered no statistically significant association between the number of microscopy-classified plastic-like objects microplastic per home and any of the measured airborne particle or PM indicators (all p≥0.5). The most powerful positive correlation was observed into with the 0.5 μm particle-count (ρ = 0.275, p = 0.142), whereas the strongest negative correlation was observed with the 10.0-μm (ρ = −0. A hundred ninety, p = 0.314). Correlations with PM2.5 (ρ = −0.135, p = 0.477) and PM10 (ρ = −0.011, p = 0.953) had been additionally weak and not statistically significant. Overall, the results did not exhibit a statistically significant monotonic relationship among the microscopy- based plastic-object counts and the instrument measurements.

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Table 1: Descriptive Statistics of Airborne Particle Measurements, Sampling Parameters and Microscopy-Based Classification of Collected Objects in Residential Homes

| Variable (unite) | n | M±SD | Median | Q1-Q3 | Min-Max |
|---|---|---|---|---|---|
| Mean Sampler flow (L/min) | 30 | 29.850±1.920 | 29.800 | 29.50-30.40 | 22.20-35 |
| Recalculated Sampled air volume ($m^3$) | 30 | 1.790±0.120 | 1.790 | 1.77-1.82 | 1.33-2.10 |
| Particle count (0.3 PC/L) | 30 | 9382.200±3058.210 | 9439 | 6911.50-11794.25 | 3233-15559 |
| Particle count (0.5 PC/L) | 30 | 4755.330±1699.590 | 4633.500 | 3603.50-5854.50 | 1919-7942 |
| Particle count (1.0 PC/L) | 30 | 1553.500±607.450 | 1632 | 1196.75-2098.75 | 362-2371 |
| Particle count (2.5 PC/L) | 30 | 435.670±244.860 | 412.500 | 227.75-646.75 | 81-869 |
| Particle count (5.0 PC/L) | 30 | 100.330±64.960 | 91.500 | 39-148.50 | 17-212 |
| Particle count (10.0 PC/L) | 30 | 32.470±16.230 | 34.00 | 27.25-42 | 1-60 |
| PM2.5 Concentration (µg/$m^3$) | 30 | 22.120±10.200 | 18.750 | 13.62-31.95 | 8.50-39.20 |
| PM10 Concentration (µg/$m^3$) | 30 | 37.500±17.360 | 32.550 | 24.18-48.48 | 17.50-82.60 |
| Objects classified as suspected per 3 logged (objects/home) | 30 | 1.630±0.890 | 2.00 | 1. -200 | 0.00-3.00 |
| Proportion of logged objects classified suspected | 30 | 0.450±0.300 | 0.670 | 0.33-0.67 | 0.00-1.00 |

Table 2: Classification, Morphological Characteristics, Colour and Fluorescence Responses of Microscopy-Examined Objects (n = 90)

| Characteristic | Category | Number | Percentage of 90 objects |
|---|---|---|---|
| Classification | Plastic-like particles | 49 | 54.400 |
| Classification | Uncertain | 23 | 25.600 |
| Classification | Excluded | 18 | 20.000 |
| Morphology | FRAGMENT-like | 25 | 27.800 |
| Morphology | Film-like | 22 | 24.400 |
| Morphology | Irregular | 22 | 24.400 |
| Morphology | Fiber-like | 21 | 23.300 |
| Colour | Black | 20 | 22.200 |
| Colour | Blue | 18 | 20.000 |
| Colour | White | 18 | 20.000 |
| Colour | Transparent | 17 | 18.900 |
| Colour | Red | 17 | 18.900 |
| Fluorescence response | Moderate | 26 | 28.900 |
| Fluorescence response | Weak | 22 | 24.400 |
| Fluorescence response | Strong | 22 | 24.400 |
| Fluorescence response | None | 20 | 22.200 |

Table 3: Spearman Correlations Between Microscopy-Based Plastic-Like Particle (micoplastic) Counts and Airborne Particle Measurements in Residential Homes (n = 30)

| Variable | n | Spearman ρ | p | Interpretation |
|---|---|---|---|---|
| Particle count (≥0.3 µm) | 30 | 0.072 | 0.707 | Positive, no significance |
| Particle count (≥0.5 µm) | 30 | 0.275 | 0.142 | Positive, no significance |
| Particle count (≥1.0 µm) | 30 | -0.115 | 0.544 | negative, no significance |
| Particle count (≥2.5 µm) | 30 | 0.042 | 0.824 | Positive, no significance |
| Particle count (≥5.0 µm) | 30 | 0.093 | 0.626 | Positive, no significance |
| Particle count (≥10.0 µm) | 30 | -0.190 | 0.314 | negative, no significance |
| PM2.5 (µg/$m^3$) | 30 | -0.135 | 0.477 | negative, no significance |
| PM10.0 (µg/$m^3$) | 30 | -0.011 | 0.953 | negative, no significance |

Table 4: Regional Differences in Sampling Parameters and Airborne Particle Measurements Across Residential Areas

| Variable | H statistic | Raw p | Holm-adjusted p | Significant after adjustment |
|---|---|---|---|---|
| Mean Sampler Flow (L/min) | 0.572 | 0.751 | 1.000 | NO |
| Recalculated sampled air volume ($m^3$) | 0.572 | 0.751 | 1.000 | NO |
| Particle count (≥0.3 µm) | 3.956 | 0.138 | 1.000 | NO |
| Particle count (≥0.5 µm) | 1.634 | 0.442 | 0.458 | NO |
| Particle count (≥1.0 µm) | 6.165 | 0.046 | 1.000 | NO |
| Particle count (≥2.5 µm) | 0.932 | 0.628 | 1.000 | NO |
| Particle count (≥5.0 µm) | 2.656 | 0.265 | 1.000 | NO |
| Particle count (≥10.0 µm) | 2.817 | 0.244 | 1.000 | NO |
| PM2.5 (µg/$m^3$) | 2.108 | 0.348 | 1.000 | NO |
| PM10.0 (µg/$m^3$) | 1.210 | 0.546 | 1.000 | NO |

Table 5: Regional Distribution of Airborne Particle Measurements and Microscopy-Based Plastic-Like Objects (microplastic) in Residential Homes in AL- Najaf City

| Region | n | Particle count (≥0.3 µm) Median (IQR) | PM10- Median (IQR) | Plastic-Like logged object/home, Median (IQR) |
|---|---|---|---|---|
| Central Najaf | 10 | 8122 (6586-11383) | 26.2 (24.7-31.9) | 2.0 (1.0-2.0) |
| Northern Najaf | 10 | 9106 (6856-9571) | 40.2 (24.3-54.7) | 2.0 (1.0-2.0) |
| Southern Najaf | 10 | 10878 (9314-12473) | 40.0 (24.7-527) | 1.5 (1.0-2.0) |

In the Table 4 the Kruskal–Wallis test was showed there no statistically significance regional differences in any of the assessed sampling parameters or airborne particle measurements after Holm adjustment for multiple comparisons (all adjusted p≥0.458). Although the 1.0-µm particle-be counted was showed a nominally significant different before adjustment (H = 6.165, p = 0.046), this difference was not statistically significant after adjustment (Holm-adjusted p = 0.458). Therefore, no statistically significant regional differences have been diagnosed after accounting for multiple comparisons.

In Table 5 each region included 10 residential houses. The median particle count in the 0.3-µm channel was highest in Southern Najaf (10.878; IQR: 9.314–12.473), accompanied by using Northern Najaf (9.106; IQR: 6.856–9,571) and Central Najaf (8.122; IQR: 6.586–11.383). Median PM10 values have been higher in Northern Najaf (40.2) and Southern Najaf

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Table 6: Summary of Field and Laboratory Blank Records and their Microscopic Observations

| Blank ID | Type | Filter ID | Objects observed | Description | Same processing | Included |
|---|---|---|---|---|---|---|
| B1 | field | FB1 | 0 | Fragment-like | Yes | No |
| B2 | field | FB2 | 3 | Fragment-like | Yes | No |
| B3 | field | FB3 | 3 | No visible object | Yes | No |
| B4 | field | FB4 | 1 | Fragment-like | Yes | No |
| B5 | field | FB5 | 2 | Fragment-like | Yes | No |
| B6 | field | FB6 | 3 | No visible object | Yes | No |
| B7 | lab | FB7 | 1 | Fragment-like | Yes | No |
| B8 | lab | FB8 | 5 | Fragment-like | Yes | No |
| B9 | lab | FB9 | 2 | Fragment-like | Yes | No |
| B10 | lab | FB10 | 4 | Fiber-like | Yes | No |
| B11 | lab | FB11 | 3 | No visible object | Yes | No |
| B12 | lab | FB12 | 1 | Fragment-like | Yes | No |

(forty.0) than in Central Najaf (26.2). The median number microscopy-classified Plastic-Like objects per home was 2.0 in Central and Northern Najaf and 1.5 in Southern Najaf. These descriptive outcomes imply nearby variation in the observed measurements.

The Table 6 showed that the total of 12 blank records have been documented, comprising 6 field blanks and 6 laboratory blanks. The number of objects observed ranged from 0 to 5 per blank. All blanks have been processed the use of the identical procedure as indicated within the records; however, none was included in the primary analysis. Fragment-like objects were the most frequently recorded description, while fiber-like items were recorded in one blank. No blank correction was applied to the study results.

## DISCUSSION

### Principal Findings

The primary findings have been recorded go with the flow values implied an average sampled extent of approximately 1.79 $m^3$ for the duration of each 60-minute c programming language; 49 of 90 logged gadgets (54.4%) were categorised as plastic-like of microplastic, with 23 unsure and 18 excluded; in keeping with-domestic suspected-object counts have been not significantly related to any of the six NK800 channels or with PM2.5/PM10; and the nominal local difference for the ≥1.0 μm channel did now not remain sizeable after Holm adjustment.

### Interpreting the Microscopy Classifications

The morphological distribution found inside the present take a look at discovered a noticeably balanced illustration of fragment-like (27.8%), movie-like (24.4%), irregular (24.4%) and fibre-like objects (23.3%). This sample differs from findings pronounced in Birmingham, United Kingdom, wherein Ageel *et al*. [6], diagnosed fibres as the main class of airborne microplastics in residential indoor air, accompanied with the aid of fragments and foam-like debris. The predominance of fibres within the British study changed into related to the ability contribution of indoor textiles, carpets and different household materials. In comparison, the fairly even distribution determined in Al-Najaf highlights the range of particle morphologies encountered in residential environments and shows that indoor particle profiles may additionally range in line with furnishing traits and environmental situations [6].

Similarly, study conducted in Islamabad, Pakistan, via Sharaf Din *et al*. [14], diagnosed fibres because the fundamental morphological category in indoor and outside air samples, accompanied through fragments. The prevalence of fragments in both the Pakistani investigation and the existing study shows a degree of agreement between the two datasets. However, the incredibly better illustration of film-like and abnormal gadgets in Al-Najaf city distinguishes the present findings from the fibre-dominated pattern pronounced in Islamabad. These differences can also reflect versions in family substances, indoor sports, air flow conditions and the environmental traits of the sampled places [14].

Evidence from families in Eskisehir, Turkiye, additionally demonstrates the range of airborne particle morphologies. Bhat [15], reported several classes, including fibres, fragments, films, lines, foam and pellets, with fibres representing the principal category. The identity of both fragments and films inside the Turkish families is steady with the occurrence of those categories within the present observe. Nevertheless, their relative proportions differed, as fragments and films collectively represented a considerable percentage of the microscopy classifications in Najaf. This evaluation supports the significance of thinking about more than one morphological category whilst characterizing airborne particles in residential environments [15].

In the US, Yao *et al*. [16], investigated microplastics in indoor and ambient air in northern New Jersey and documented distinctive particle morphologies, which include fibres, movies and fragments. Their findings demonstrate that airborne particle profiles can range throughout indoor settings and sampling environments. The presence of those morphological classes in each their observe and the existing investigation offers a basis for evaluation, at the same time as the differences of their distribution emphasize the ability impact of nearby environmental conditions and indoor particle resources [16].

A in addition comparison can be made with research carried out in Ahvaz, Iran, via Kaydi *et al*. [17], who investigated airborne microplastics in residential, workplace and business environments and pronounced a predominance of spherule-fashioned debris. This pattern contrasts with the findings in Najaf, where fragment-like items shaped the biggest category, followed with the aid of film-like and irregular gadgets. The distinction illustrates the range of airborne particle morphology throughout neighboring nearby settings and reinforces the price of accomplishing place-particular investigations to signify indoor environmental conditions [17].

### Particle Counter and PM Measurements

The observe recognized weak and statistically non-widespread correlations among microscopy-recorded suspected-item counts and $PM_{2·5}$ (ρ = -0. A 135, p = 0.477), $PM_{10}$ (ρ = −0.011, p = 0.953) and the six NK800 particle-size channels portable device (ρ ranging from −0.190 to 0.275; all p≥0.142). A similar locating turned into reported with the aid of Sharaf Din *et al*. [14], in Islamabad, Pakistan, wherein the relationships among airborne microplastic abundance and environmental elements, which includes $PM_{2·5}$, were statistically non-widespread. This settlement indicates that the abundance of microscopically identified airborne debris does now not always range in parallel with conventional particulate-matter measurements. Differences in particle size, assets and distribution can also make contributions to this sample [14].

In assessment, the strong positive correlation among $PM_{2·5}$ and $PM_{10}$ within the gift examine (Spearman's ρ = 0.931, p≤0.001) shows that the two measurements various collectively

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throughout the sampled houses. This relationship is physically manageable due to the fact $PM_{10}$ consists of the great-particle fraction represented by using $PM_{2.5}$, further to larger particles. Consequently, changes in shared particle resources may also have an impact on each measurement inside the identical path. The found correlation consequently supports the presence of a strong statistical courting among the 2 recorded variables [18].

Overall, the findings imply that microscopy-recorded item counts had been not extensively related to the particle-counter channels or the PM measurements, while $PM_{2.5}$ and $PM_{10}$ were strongly correlated. This difference indicates that particle range, particulate-count number mass and microscopy-primarily based observations may additionally mirror exceptional traits of residential aerosols. Similar warning in decoding airborne microplastic abundance along $PM_{2.5}$ is supported by means of the non-significant associations stated by way of Sharaf Din *et al*. [14].

**Regional Comparisons**

The assessment of NK800 particle-counter portable device readings across the sampled residential areas of Al-Najaf city diagnosed an unadjusted distinction in the ≥1.0 μm channel. However, this difference changed into not statistically significant after Holm correction for the ten comparisons. Research carried out in Kufa, Iraq, with the aid of Khadhr and Alduhaidahawi [19], documented version in indoor air-pollutant concentrations throughout 51 homes and mentioned that elements consisting of climatic situations, constructing characteristics, residence length and home sports influenced pollutant degrees. These findings provide applicable neighborhood context for decoding the variation determined in Najaf, as residential particle concentrations might also fluctuate with family and environmental traits in place of geographical vicinity alone [19].

The absence of statistically good-sized regional differences after multiple-comparison adjustment does now not establish that the sampled areas have identical particle concentrations. Rather, the effects suggest that the discovered differences were inadequate to illustrate a statistically dependable regional sample beneath the present analysis. From an environmental perspective, variations in air flow, out of doors dirt infiltration, cooking, cleansing and resuspension of settled particles may additionally contribute to version amongst houses. The significance of household characteristics and home activities in explaining indoor pollutant variation has also been stated in residential settings in Kufa [19].

**Quality Assurance and Blank Contamination**

The clean statistics within the gift study confirmed non-0 particle counts in both area and laboratory blanks. This remark is consistent with findings suggested by way of Noonan *et al*. [20], who confirmed that airborne and laboratory-derived infection can contribute debris to clean samples in the course of microplastic analysis. Their investigation additionally showed that contamination stages can vary according to laboratory conditions and pattern-processing tactics. The blank findings in the present take a look at consequently highlight the importance of considering heritage particle deposition whilst interpreting microscopic observations from residential air samples [20].

The function of clean controls in improving the reliability of microplastic investigations has additionally been emphasized by Shruti and Kutralam-Muniasamy [21], who reviewed the use of blanks and the ability for infection-related bias in microplastic studies. Their assessment highlighted the significance of standardized blank approaches and transparent reporting while decoding particle counts. In the present look at, blank samples had been excluded from the residential sample counts; therefore, the recorded blank observations are best considered as first-rate-manage statistics in place of as a basis for applying an unverified numerical correction to the residential results [21].

**Data Quality and Interpretation**

The sampled air volume turned into recalculated from the recorded airflow and sampling period the use of the relationship among flow charge, time and extent. For example, a recorded drift rate of 35.0 L/min over 60 mins corresponds to a theoretical sampled quantity of two.10 $m^3$. This calculation presents a constant foundation for summarizing the recorded sampling situations. The importance of documenting sampling procedures and ensuring consistency throughout the sampling and analytical tiers has been emphasized in reviews of airborne microplastic size, which become aware of methodological harmonization as an important requirement for reliable comparison among research [5,6,8].

The microscopy facts supplied object-stage facts for comparing the morphological categories located throughout the sampled houses. However, due to the fact the recorded entries did now not represent a documented complete count number of all qualifying objects on every filter, the results are maximum as it should be interpreted as microscopy-screening observations rather than as a entire particle concentration according to cubic metre. This distinction is constant with pointers through Zheng *et al*. [8], who emphasized the significance of standardized sampling, analytical tactics and reporting methods while estimating airborne micro- and nanoplastic abundance. Such consistency is critical whilst evaluating consequences throughout exclusive residential environments and studies [8].

The dataset additionally combines particle-counter readings, particulate-be counted measurements, microscopy classifications and blank statistics. These complementary records assets offer unique perspectives on the airborne particle situations discovered in residential environments. Azari *et al*. [5,6], emphasised that airborne microplastic evaluation entails numerous tiers, consisting of series, particle characterization and analytical identity and that differences in techniques can affect the comparability of consequences. Accordingly, the incorporated technique used in the present have a look at affords a basis for inspecting relationships among particle-counter measurements and microscopy observations in residential homes [5,6].

**Strengths and Limitations**

A key power of the existing observe is the aggregate of residential particle-counter measurements, $PM_{2.5}$ and $PM_{10}$ readings, microscopy-primarily based morphological classifications and clean information inside the equal research. The inclusion of 30 homes disbursed similarly throughout three residential strata also offers an possibility to explore variant between sampled places. Furthermore, recording man or woman microscopic observations permits the morphological distribution to be described instead of relying solely on mixture particle-counter readings. The price of integrating sampling records with virtually documented analytical techniques is steady.

## CONCLUSIONS

- Of the 90 gadgets recorded for the duration of microscopic screening of samples from 30 residential houses in Al-Najaf metropolis, 49 (54.4%) had been labeled as microplastic, whilst 23 (25.6%) remained uncertain and 18 (20.0%) had been excluded from further consideration
- The range of suspected particles according to domestic showed no statistically significant association with the measured NK800 particle-counter channels or PM2.Five and PM10 readings

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- The determined correlation between PM2.5 and PM10 measurements was strong and positive
- Although some differences between residential areas have been observed in character comparisons, none remained statistically significant after Holm adjustment for multiple comparisons. Therefore, the findings do now not provide enough proof of nearby variations inside the measured particle characteristics
- Microscopic screening diagnosed objects with traits consistent with microplastic particles was found

**Recommendations**

- This study provides preliminary statistics on microscopic particle observations and transportable air-particle measurements in residential environments in Al-Najaf city
- Future studies ought to check out the relationships between airborne microplastic abundance and residential characteristics, air flow practices, synthetic furniture, cleansing sports and indoor environmental conditions to become aware of capacity determinants of particle occurrence in residential environments
- Conduct studies related to a larger quantity of homes and repeated sampling classes across specific seasons to assess temporal and spatial variability
- In future research, integrate verified airborne microplastic concentrations with time–hobby patterns to estimate ability residential inhalation publicity

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