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Microplastics (MP) in Drinking Water Linked with Colorectal Cancer Across Urban-Rural Counties of Maryland

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Abstract

Microplastics, defined as plastic particles less than 5 mm in diameter, are evident in the environment and a growing public health concern because they are found in drinking water systems. Here, we investigate the correlation between microplastic levels in drinking water and colorectal cancer rates in Maryland. Drinking water samples were collected and analyzed. Statistical analyses were conducted to test the relationship between microplastic concentration in drinking water and colorectal cancer incidence. Some rural Maryland counties tended to show significantly higher microplastic concentrations in the drinking water than their urbanized counterparts. Even though one would expect urbanized areas with higher population density and plastic waste generation to show higher microplastic concentrations in their drinking water. Adding to this unexpected pattern, the same rural counties (Allegany, Caroline and Dorchester) that had the highest microplastic contamination in their drinking water were also noted to have the highest incidence of colorectal cancer rates in the state of Maryland. This research highlights the importance of addressing microplastic contamination in drinking water, the pathways through which it enters public systems and its broader implications for public health policies and practices. By identifying potential risks, this study contributes to a growing body of knowledge on environmental toxins and their impact on human health, and to our knowledge, it is the first study that shows a correlation between microplastic-contaminated drinking water in rural counties of Maryland and increased colorectal cancer rates.

Keywords: Microplastics (MPs); Drinking water; Colorectal cancer; Rural-Urban Disparities; Public Health; Maryland

Introduction

Microplastics (MP), defined as plastic particles less than 5 mm (about 0.2 in) in diameter, originate from a diverse array of sources, including industrial waste, consumer products, and environmental degradation of larger plastics. Their presence in water systems, including drinking water, has raised significant concerns about potential health impacts. In recent years, researchers have detected microplastics in virtually every corner of the globe, from remote Arctic ice to urban drinking water supplies [1]. This omnipresence underscores the urgency of understanding their implications for human health.

Studies have shown that humans are exposed to microplastics through ingestion, inhalation, and dermal contact [2]. Once inside the body, these particles can interact with tissues, causing inflammation and cellular stress [3]. Furthermore, some polymers and additives used in plastic manufacturing

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are known to leach toxic chemicals, potentially exacerbating health risks [4]. However, the long-term health implications of chronic microplastic exposure remain poorly understood, particularly in the context of cancer. Colorectal cancer is the second leading cause of cancer-related deaths in the US and worldwide when men and women are combined [5]. In the United States, colorectal cancer has the fourth highest incidence of cancer [6].

Urban vs. Rural Disparities

Urban areas are generally associated with higher levels of microplastic contamination compared to rural areas. This is due to factors such as higher population density, greater industrial activity, and increased reliance on municipal water systems [4]. Urban environments often experience more significant plastic waste generation and degradation, contributing to the prevalence of microplastics in drinking water. Conversely, rural areas may benefit from lower levels of pollution and reliance on localized water sources, which can result in reduced microplastic contamination.

These disparities have important implications for public health. Urban populations, already burdened by socioeconomic challenges and environmental stressors, may face an increased risk of diseases linked to microplastic exposure, including cancer. Identifying and addressing these differences is essential for crafting equitable and effective public health interventions.

Existing Literature

Research has linked microplastics to various adverse biological effects. For example, Cox et al. [7], estimated that humans consume tens of thousands of microplastic particles annually through food and water [7]. Laboratory studies have demonstrated that microplastics can cause oxidative stress, DNA damage, and disruption of cellular functions [7]. For instance, a study found microplastic accumulation in the gastrointestinal tract of marine organisms, raising concerns about similar impacts in humans [8]. Another study highlighted endocrine-disrupting chemicals leaching from microplastics, which could act as carcinogens [9].

Despite these findings, correlations between microplastics and specific diseases, such as cancer, remain underexplored. Most studies to date have focused on acute toxicological effects or ecosystem-level impacts, leaving significant gaps in understanding their role in chronic diseases. This study aims to address these gaps by examining microplastic contamination in drinking water and its potential association with cancer incidence in Maryland counties.

Research Objectives

This study aims to:

1. Quantify microplastic levels in drinking water samples from twenty-four Maryland counties.
2. Analyze county-specific cancer incidence data to identify any patterns.
3. Investigate correlations between microplastic concentrations and cancer rates, particularly gastrointestinal- related cancers.
4. Evaluate potential confounding factors, such as socioeconomic conditions and environmental exposures, to enhance the robustness of findings

Materials & Methods

Sample Collection

Drinking water samples were collected from public restaurants in 23 Maryland counties and Baltimore City from October through December of 2024.

Each sample was collected and stored in a 50 ml plastic container and mailed to an outside facility in New York [10] for further analysis as described in the following methods.

Microplastic Analysis

These were performed by an outside testing facility and not by the author of this article. At the outside test facility (source 19), lithographically patterned silicon nitride nanomembrane filters (5.4 × 5.4 mm) silicon chip, three (0.7 × 3.0 mm) rectangular windows, 8 µm slit widths, 400 nm thick membrane, 6.3 mm^2 active area) were produced by SiMPore Inc. (West Henrietta, NY, USA) [11]. These filters were placed in SEPCON™ units and sealed with silicone gaskets. The bottoms of 100 mL glass graduated cylinders were drilled out using a 3 mm diameter glass-drilling bit, and pressure-sensitive adhesive was used to attach a SEPCON device containing the silicon nanomembrane to the cylinder's bottom. This setup allowed for gravity filtration of 50 mL of water through the filters, which were then dried in a 70°C oven. Filters and debris were imaged using brightfield and dissection microscopes to capture particle details.

To confirm that captured debris was plastic, Nile Red staining was performed. The dye binds specifically to plastics and causes them to fluoresce under a special microscope, making it easy to differentiate plastics from other debris. Particles were categorized by size, shape, and type.

Dissolution and Washing Protocol

Eppendorf tubes (1.5 mL) were filled with 0.75 mL of 0.125 M Tris HCl. The SEPCONs containing filtered debris were then placed in the filled tubes. Next, 200 µL of 10% w/v Sodium Dodecyl Sulfate (SDS) and an additional 300 µL of 0.125 M Tris HCl were placed in the SEPCON basket. The Eppendorf-SEPCON unit was then heated to 95°C and stabilized for 5 minutes. An additional 200 µL of 14.6 M 2-mercaptoethanol was added to the SEPCON basket, and the filters were left to process for 1 hour inside a laminar flow hood [12]. SEPCONs were removed, dried on a cleaned petri

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dish, and washed using ultrapure water heated to 90°C. The membranes were gravity-drained three times, dried in a 70°C oven, and imaged.

Image Processing and Data Analysis

Images of the filtered debris were processed using software to separate plastic particles from other material. Advanced tools such as Fiji and ImageJ were used for particle segmentation, classification, and volume calculation [13,14]. Particles were sorted into size categories and analyzed statistically. Images were further processed on a MacBook Pro using Trainable WEKA Segmentation, a Fiji plugin. Classifiers trained with five categories (particle, slot, residue, membrane, edge) generated probability maps to identify debris. Quantification was performed using Diameter J algorithms [15] and Image J's watershed tool for particle separation. The background level (control) of fluorescent debris is counted between 1.00-2.00 particles per/ml.

Cancer Data Collection

Cancer incidence data were sourced from the State Cancer Profiles database [16].

Data was stratified by each county, all ages, all races and both sexes, for colorectal cancers from the latest 5-year period of data (2017-2021) available.

Statistical Analysis

P-value testing was performed to check for statistical significance. Utilizing the two-sample t-test. This test evaluates whether the means of two independent groups are significantly different.

Results

Drinking Water Testing Results

The concentrations of MP in rural counties of Allegany (1.71 particles/ml), Caroline (1.70 particles/ml), and Dorchester (1.69 particles/ml) were the highest of all 24 samples collected across the state of Maryland. The concentrations of MP in the urban counties of Montgomery (1.62 particles/ml), Baltimore City (1.55 particles/ml) and Wicomico (1.54 particles/ml) were the highest three in the urban areas. The concentrations of MP in the counties of Cecil (1.13 particles/ml), Somerset (1.19 particles/ml) and Charles (1.21 particles/ml) were the lowest in all the 24 samples. Figure 1 visually summarizes microplastic concentrations measured across all sampled Maryland counties, highlighting clear variability between counties and between rural and urban classifications. This figure demonstrates the top 3 greatest concentration of microplastics from rural counties of Maryland to urban counties of Maryland and shows the difference in amounts of particles/mL of microplastics through percentages-directly supporting the quantitative findings described above (Figure 1).

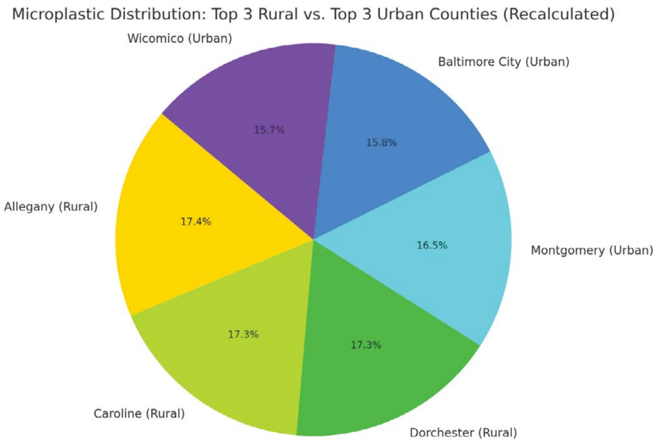

Figure 1: This pie chart compares the proportional contribution of the highest-exposure rural counties (Allegany, Caroline, Dorchester) and urban counties (Montgomery, Baltimore City, Wicomico), illustrating that rural counties collectively account for a larger share of microplastic burden.

Rural vs. Urban

Of the 24 samples collected, seven were rural and seventeen were urban. The average MP particle concentration was statistically significantly higher (p-value < 0.05) in rural areas (1.57 particles/ml) than in urban areas (1.38 particles/ml). Figure 1 illustrates the proportional contribution of the three rural counties and three urban counties with the highest measured microplastic concentrations. The visual comparison reinforces that rural counties accounted for a greater overall share of microplastic burden among the highest-exposure region (Figure 2).

Incidence of Colorectal Cancer in Maryland

The incidence report for both sexes in Maryland counties for all stages, races, and ages from 2017-2021 shows that rural counties of Dorchester, Allegany, and Caroline had the highest reported incidence. Howard, Worchester, and Montgomery County had the lowest incidence.

Correlation of MP with Colorectal Cancer Incidence

Microplastic contaminated drinking water had some correlation with counties that also had the highest incidence rates of colorectal cancer. For example, the rural counties of Allegany, Dorchester, and Caroline had the two highest concentrations of MP in their drinking water and those counties also had the highest three cases in colorectal cancers. Figure 3 depicts the relationship between colorectal cancer incidence rates and measured microplastic concentrations across Maryland counties. Counties with higher microplastic concentrations, particularly rural counties, cluster toward higher colorectal cancer incidence values, supporting the observed correlation described in the text (Figure 3).

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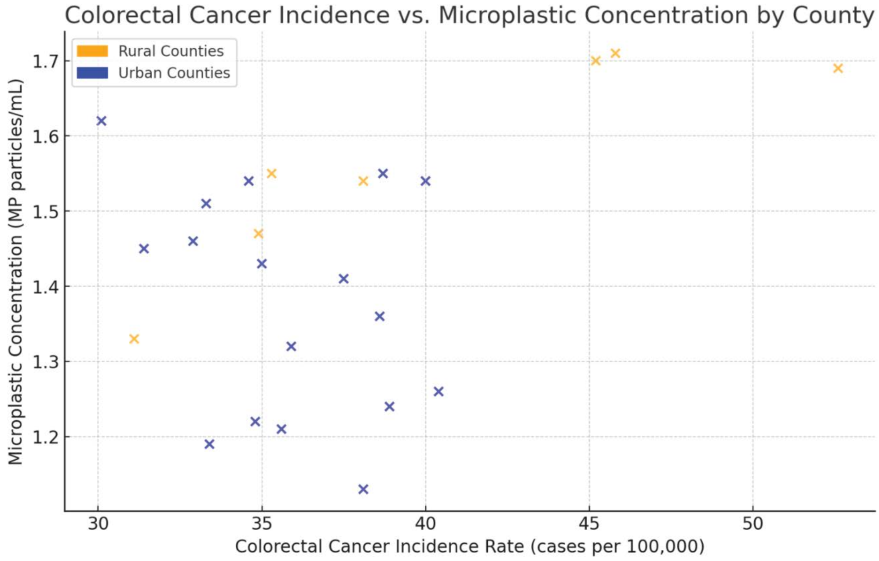

Figure 2: Scatter plot showing colorectal cancer incidence (cases per 100,000) plotted against microplastic concentration (particles/mL), with counties categorized as rural or urban. Higher microplastic concentrations are associated with higher colorectal cancer incidence, particularly among rural counties.

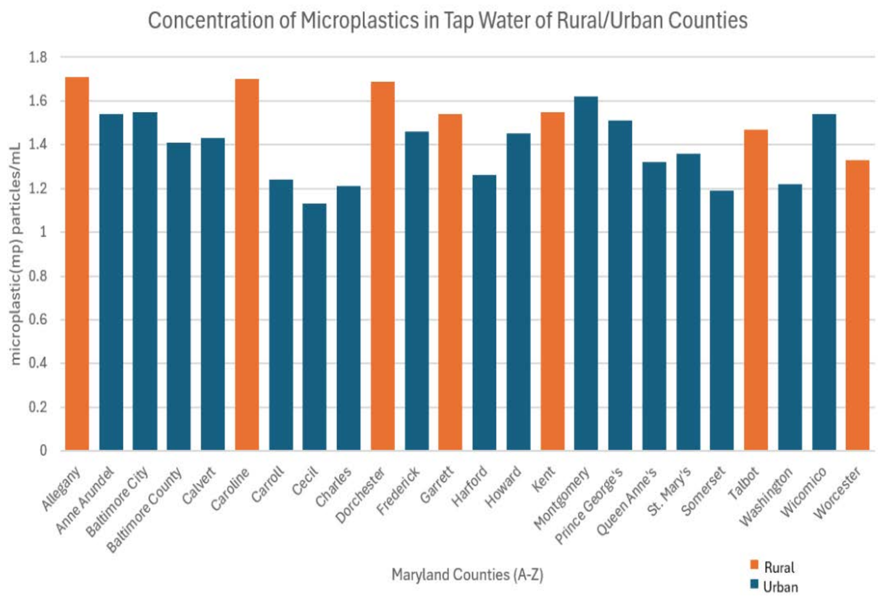

Figure 3: Bar chart displaying microplastic particle concentrations (particles/mL) for all sampled counties, highlighting inter-county variability and the presence of higher concentrations in several rural counties compared to urban counties.

Discussion

Microplastics have become increasingly ubiquitous since the 1950s due to significant rise in plastic production and use in common household items worldwide. They have infiltrated into our ecosystem from industrial waste, everyday products, and the breakdown of bigger plastics in the environment. Finding them in water systems, including drinking water, has caused worries about how they might affect our health. The MP have been detected in the blood, saliva, liver, kidney, breast milk, gut, and even the brain of humans [7]. The majority of MP are typically result from the breakdown of larger plastic items (referred to as secondary plastics) and are chemically comprised of Bisphenol A (BPA) and perfluoroalkyl and polyfluoroalkyl substances (PFAs). These can mimic human hormones, thereby affecting reproduction, growth, and metabolism. Researchers have shown that these chemicals can increase the risk of infertility to cancers [17].

Rural vs. Urban

We hypothesized that the urban counties of Maryland would have increased concentrations of MP in drinking water supply mainly because urban environments often experience more significant plastic waste generation and degradation,

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contributing to the prevalence of MP in drinking water. In fact, our results refuted this hypothesis and showed that some rural counties had some of the highest concentration of MP in the state of Maryland. One explanation for this surprising finding could be that the rural counties have more aged infrastructure, i.e., older water treatment plants and distribution systems may not be able to effectively filter out MP [18]. Also, the proximity of rural areas to agricultural lands could result in increased concentrations of MP due to runoff from fertilizers, pesticides, and other agricultural products. Shallow groundwater tables are also prone to contamination with MP.

Correlation to Colon Rectal Cancer

This is the first study to our knowledge that shows a correlation between MP contaminated drinking water in rural counties of Maryland and increased colorectal cancer rates. Even though the study suggests a link, further studies need to be performed to investigate causative effects. Future randomized and longitudinal studies must be conducted to show causation. In addition, animal studies are critically needed to understand the physiology of MP effects.

Study Limitations and Future Study Design Improvements

This study only had one data point for each Maryland County and Baltimore City. This was due to the financial burden of sample collection. Future study designs ought to incorporate multiple samples from each region; therefore, increasing sample size and reducing bias, minimizing outliers, and thereby increasing the reliability of statistically significant findings.

Detection methodology for MP could also be performed with more sophisticated techniques, e.g., Fourier Transform Infrared Spectroscopy (FTIR) and Raman spectroscopy. FTIR utilizes the absorption of infrared radiation which helps to identify the molecular composition and structure of MP. Raman spectroscopy measures the scattering of light which provides insight into the behavior of MP in different environment. Their combined use can enhance the accuracy and reliability of microplastic analysis, making them valuable tools in environmental studies [19]. Elucidation of the exact chemical types that make up the MP in each sample is also important to note the differences for each county. Differences in water treatment plant processes among the different counties may also confound results and need to be considered if this trend is noted in a future study.

Effects on Society

Environmental pollutants may have direct links to public health, especially in vulnerable or overlooked populations like those in rural areas, and this research adds to the growing awareness of that fact. Environmental justice is highlighted by the surprising discovery that microplastic concentrations and colorectal cancer rates are both higher in rural counties with older infrastructure. It stresses the importance of public health surveillance and improvements to water treatment that are funded fairly. Researchers like this can help inform regulatory reforms, community-level education, and targeted interventions to address environmental exposure and related health outcomes, which is crucial as healthcare leaders and policymakers face increasing cancer rates, particularly in under-resourced areas.

Conclusion

To our knowledge, this is the first study to show elevated microplastic in specific rural counties of Maryland drinking water coincides with increased incidence of colorectal cancer in those same rural counties. This study emphasized the importance of understanding where microplastic pollution in water comes from, how it gets into public infrastructure, and how it affects public health programs and strategies in general. Our understanding of environmental pollutants and their effects on human health is expanding, and this study adds to that knowledge by highlighting potential dangers.

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