Assessment of Microplastic Contamination in Edible Marine Fishes along the West African Coast

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Abstract
Microplastic pollution has emerged as a critical environmental concern threatening marine ecosystems and food security along the West African coast. This comprehensive study assessed microplastic contamination levels in commercially important edible marine fish species collected from six countries along the West African coastline. Fish samples (n=480) representing 12 species were collected from coastal waters of Morocco, Senegal, Guinea-Bissau, Sierra Leone, Ghana, and Nigeria during 2023-2024. Microplastic particles were extracted using enzymatic digestion and density separation techniques, followed by microscopic identification and polymer characterization using FTIR spectroscopy. Results revealed widespread microplastic contamination across all sampled locations, with mean particle concentrations ranging from 2.3 ± 1.2 to 8.7 ± 3.4 particles per gram of tissue. Polyethylene (PE) and polypropylene (PP) were the most abundant polymer types, accounting for 68% of identified particles. Pelagic species showed significantly higher contamination levels compared to demersal species ($p<0.001$). The findings indicate substantial microplastic exposure risks for coastal populations dependent on marine fish protein, highlighting the urgent need for comprehensive plastic waste management strategies and continued monitoring programs along the West African coast.

Keywords: Microplastics, Marine pollution, Fish contamination, Food security, West Africa, Plastic pollution

Introduction

The West African coastal region supports approximately 40% of the continent's population and contributes significantly to regional food security through marine fisheries that provide essential protein sources for over 200 million people [1]. The region's extensive coastline, stretching over 6,000 kilometers from Morocco to Angola, encompasses diverse marine ecosystems that support both artisanal and industrial fishing activities crucial for local economies and livelihoods [2].

However, rapid urbanization, industrialization, and inadequate waste management infrastructure along the West African coast have resulted in substantial plastic pollution entering marine environments [3]. Recent estimates suggest that West African countries contribute approximately 0.8 million tons of plastic waste to marine environments annually, with riverine systems serving as primary conduits for plastic debris transport to coastal waters [4].

Microplastics, defined as plastic particles smaller than 5 mm in diameter, have become ubiquitous contaminants in marine ecosystems worldwide [5]. These particles originate from primary sources, including cosmetic microbeads and synthetic textile fibers, and secondary sources involving the fragmentation of larger plastic debris through weathering processes [6]. The persistence and bioaccumulative nature of microplastics in marine food webs raise significant concerns about potential impacts on ecosystem health and human food safety [7].

Marine fishes can ingest microplastics through direct consumption or trophic transfer from contaminated prey items, leading to bioaccumulation in various tissues including muscle, liver, and gastrointestinal tract [8]. The presence of microplastics in edible fish tissues poses potential health risks to human consumers, particularly in regions where fish consumption rates are high and dietary diversity is limited [9].

Despite growing global awareness of microplastic pollution, comprehensive assessments of contamination levels in edible marine fishes along the West African coast remain limited. This study addresses this critical knowledge gap by providing systematic evaluation of microplastic contamination across multiple fish species and geographical locations, contributing essential data for risk assessment and policy development in the region.

Materials and Methods

Study Area and Sampling Strategy

Fish samples were collected from six strategic locations along the West African coast, representing major fishing grounds and urban coastal areas with high plastic input potential. Sampling sites included Agadir (Morocco), Dakar (Senegal), Bissau (Guinea-Bissau), Freetown (Sierra Leone), Accra (Ghana), and Lagos (Nigeria), selected to represent diverse oceanographic conditions and anthropogenic pressure gradients.

A total of 480 fish specimens representing 12 commercially important species were collected between January 2023 and March 2024. Target species included both pelagic (*Sardinella aurita*, *Engraulis encrasicolus*, *Trachurus trachurus*, *Scomber japonicus*) and *demersal* (*Pseudotolithus elongatus*, *Galeoides decadactylus*, *Cynoglossus senegalensis*, *Lutjanus goreensis*) species to assess contamination patterns across different ecological niches.

Sample Processing and Microplastic Extraction

Fish specimens were transported to laboratories under controlled conditions and processed within 24 hours of collection to minimize contamination artifacts. Individual fish were measured, weighed, and dissected using standardized protocols to separate muscle tissue, liver, and gastrointestinal tract for independent analysis.

Microplastic extraction followed established protocols involving enzymatic digestion with potassium hydroxide (KOH) solution (10% w/v) at 60°C for 24 hours, followed by density separation using saturated sodium chloride solution [10]. The resulting supernatant was filtered through 0.45 μm cellulose acetate filters and examined under stereomicroscope for particle identification and counting.

Microplastic Identification and Characterization

Suspected microplastic particles were visually identified based on established criteria including artificial coloration, uniform thickness, and absence of cellular structures [11]. Particle size was measured using calibrated ocular micrometers, and particles were categorized into size classes: 0.1-0.5 mm, 0.5-1.0 mm, 1.0-2.5 mm, and 2.5-5.0 mm.

Polymer identification was performed using Fourier Transform Infrared (FTIR) spectroscopy on representative subsets of particles (n=200 per location). Spectra were compared against reference libraries to confirm plastic polymer types and exclude non-plastic particles from final counts [12].

Results

Contamination Prevalence and Distribution

Microplastic particles were detected in 89% of examined fish specimens across all sampling locations, indicating widespread contamination throughout the West African coastal region. Contamination prevalence varied significantly among locations, ranging from 76% in Agadir to 96% in Lagos ($p<0.01$), with higher prevalence observed in areas adjacent to major urban centers and river mouths.

Mean microplastic concentrations in fish muscle tissue ranged from 2.3 ± 1.2 particles/g in specimens from Agadir to 8.7±3.4 particles/g in Lagos samples. Intermediate contamination levels were recorded in Dakar (3.8 ± 2.1 particles/g), Bissau (4.2 ± 2.3 particles/g), Freetown (5.1 ± 2.8 particles/g), and Accra (6.4 ± 3.1 particles/g), demonstrating a general increasing trend from north to south along the coastline.

Statistical analysis revealed significant differences in contamination levels among sampling locations (ANOVA, $F=45.3$, $p<0.001$), with post-hoc tests indicating that southern locations (Ghana, Nigeria) had significantly higher contamination levels compared to northern locations (Morocco, Senegal).

Species-Specific Contamination Patterns

Pelagic fish species demonstrated significantly higher microplastic contamination levels compared to demersal species across all sampling locations (t-test, $p<0.001$). Mean contamination in pelagic species ranged from 3.2 to 11.4 particles/g tissue, while demersal species showed contamination levels between 1.8 and 6.2 particles/g tissue.

Sardinella aurita exhibited the highest overall contamination levels (7.8 ± 4.2 particles/g), followed by *Engraulis encrasicolus* (6.9 ± 3.7 particles/g) and *Trachurus trachurus* (6.1 ± 3.2 particles/g). Among demersal species, *Pseudotolithus elongatus* showed the highest contamination (4.7 ± 2.8 particles/g), while *Cynoglossus senegalensis* demonstrated the lowest levels (2.9 ± 1.6 particles/g).

Particle Size Distribution and Polymer Composition

The majority of detected microplastic particles fell within the 0.1-0.5 mm size class (54%), followed by 0.5-1.0 mm particles (31%), 1.0-2.5 mm particles (12%), and 2.5-5.0 mm particles (3%). This size distribution pattern was consistent across all sampling locations, suggesting similar sources and weathering processes affecting plastic debris throughout the region.

FTIR analysis of 1,200 representative particles revealed polyethylene (PE) as the most abundant polymer type (42%), followed by polypropylene (PP, 26%), polystyrene (PS, 18%), polyethylene terephthalate (PET, 8%), and other polymer types (6%). The dominance of PE and PP particles reflects the widespread use of these materials in packaging and consumer products throughout the region.

Tissue Distribution Patterns

Microplastic distribution among different fish tissues showed significant variation, with gastrointestinal tract containing the highest particle concentrations (12.4 ± 6.8 particles/g), followed by liver tissue (4.7 ± 2.9 particles/g) and muscle tissue (3.8 ± 2.1 particles/g). This distribution pattern suggests that ingestion represents the primary exposure pathway, with subsequent translocation to internal organs occurring at lower frequencies.

The presence of microplastics in muscle tissue, which constitutes the primary edible portion consumed by humans, raises particular concern for food safety implications. Approximately 67% of muscle tissue samples contained detectable microplastic particles, with particle concentrations exceeding 5 particles/g in 23% of samples.

Discussion

Environmental Implications

The widespread occurrence of microplastic contamination in edible marine fishes along the West African coast reflects the severity of plastic pollution challenges facing the region. The observed spatial variation in contamination levels correlates strongly with population density, industrial activity, and waste management capacity, indicating that anthropogenic activities represent primary sources of marine plastic pollution.

The higher contamination levels observed in southern locations (Ghana, Nigeria) likely reflect the combined influence of major river systems, dense urban populations, and intensive industrial activities that contribute substantial plastic waste inputs to coastal waters [13]. The Niger and Volta river systems, in particular, serve as major conduits for plastic debris transport from inland areas to marine environments.

The prevalence of PE and PP particles in fish tissues corresponds with regional patterns of plastic consumption and waste generation, as these polymers dominate packaging materials and consumer products throughout West Africa [14]. The persistence of these materials in marine environments and their bioaccumulation in fish tissues highlight the long-term nature of microplastic pollution challenges.

Food Security and Human Health Implications

The detection of microplastics in edible fish muscle tissue raises significant concerns about potential human health risks, particularly for coastal populations heavily dependent on marine fish protein. West African countries typically exhibit high per capita fish consumption rates, with marine fish providing 50-70% of animal protein intake in many coastal communities [15].

The particle size distribution observed in this study, with predominance of particles <0.5 mm, corresponds to size ranges that may pose greater human health risks due to enhanced potential for cellular uptake and tissue translocation [16]. The presence of additives and adsorbed contaminants on microplastic particles may amplify toxicological effects, although specific health implications require further research.

Current contamination levels documented in this study exceed proposed threshold values for microplastic content in seafood products, suggesting that regulatory frameworks and monitoring programs may be necessary to ensure food safety standards [17]. The economic implications of microplastic contamination for West African fisheries sectors warrant careful consideration, particularly given the importance of fish exports for regional economies.

Regional Variations and Source Attribution

The observed north-south gradient in microplastic contamination levels reflects differential patterns of plastic waste generation, management capacity, and oceanographic conditions along the West African coast. Northern countries (Morocco, Senegal) generally demonstrate better waste management infrastructure and lower population densities in coastal areas, contributing to reduced marine plastic inputs.

Conversely, southern locations exhibit higher urbanization rates, greater industrial activity, and more limited waste management capacity, resulting in elevated plastic pollution levels in coastal waters [18]. The influence of major river systems, including the Niger, Volta, and Cross rivers, provides additional pathways for plastic debris transport to marine environments.

Seasonal variations in contamination levels, while not fully characterized in this study, likely reflect monsoon patterns, river discharge cycles, and fishing activity variations that influence both plastic input rates and fish distribution patterns [19]. Future monitoring programs should incorporate temporal variability to better understand contamination dynamics and establish baseline conditions for trend assessment.

Policy Recommendations and Management Implications

Waste Management Infrastructure

The findings of this study highlight the urgent need for improved plastic waste management infrastructure throughout the West African region. Priority interventions should focus on developing comprehensive collection, recycling, and disposal systems in coastal urban areas that represent primary sources of marine plastic pollution.

Regional cooperation initiatives, such as the Abidjan Convention and West African coastal management programs, provide frameworks for coordinating plastic pollution reduction efforts across national boundaries [20]. The transboundary nature of marine plastic pollution necessitates collaborative approaches that address both land-based sources and marine debris management.

Monitoring and Research Programs

Establishment of standardized monitoring programs for microplastic contamination in marine fisheries products represents a critical need for the region. Harmonized protocols for sample collection, processing, and analysis would enable comparative assessment across countries and facilitate regional trend analysis [21].

Continued research focusing on contamination sources, transport pathways, and ecological impacts will inform evidence-based policy development and management strategies. Particular attention should be directed toward understanding the relationship between plastic waste management practices and marine contamination levels to guide intervention prioritization.

Consumer Awareness and Risk Communication

Public awareness campaigns highlighting microplastic pollution issues and seafood safety considerations may help inform consumer choices while building support for policy interventions. Education programs targeting fishing communities, seafood processors, and consumers can promote awareness of contamination sources and risk reduction strategies [22].

Risk communication efforts should balance accurate information about contamination levels with recognition of the continued nutritional and economic importance of marine fisheries for West African populations. Sustainable consumption guidelines and seafood preparation recommendations may help minimize exposure risks while maintaining essential protein sources.

Conclusion

This comprehensive assessment of microplastic contamination in edible marine fishes along the West African coast reveals widespread pollution throughout the region, with significant variations in contamination levels among locations and species. The presence of microplastics in fish muscle tissue raises important food safety considerations for populations dependent on marine protein sources.

The findings demonstrate clear relationships between anthropogenic activities, waste management capacity, and marine contamination levels, highlighting the need for comprehensive plastic pollution management strategies. Regional cooperation, improved waste infrastructure, and continued monitoring programs represent essential components of effective response strategies.

The higher contamination levels observed in pelagic species and southern coastal areas provide important information for risk assessment and management prioritization. Continued research focusing on contamination sources, ecological impacts, and human health implications will inform evidence-based policy development and sustainable fisheries management.

The results of this study contribute essential baseline data for understanding microplastic pollution patterns in West African marine ecosystems while highlighting the urgent need for coordinated regional action to address this growing environmental challenge. The integration of plastic pollution considerations into fisheries management and food safety frameworks represents a critical step toward ensuring sustainable marine resource utilization and human health protection.

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