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Microplastic Pollution in Italy's Coastal Waters and Its Impact on Cardiovascular and Endocrine Health

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Abstract. Microplastic pollution in the marine environment has become an emerging concern in both environmental science and public health. Increasing evidence suggests a strong link between widespread environmental contamination and adverse health outcomes in human populations. Microplastics, defined as plastic particles less than 5 millimeters in size, originate from the breakdown of larger plastics and are now pervasive in aquatic ecosystems. Italy, with its long Mediterranean coastline, densely populated coastal cities, and high seafood consumption, is particularly susceptible to the health consequences associated with microplastic exposure. As seafood constitutes a major pathway for microplastic ingestion, Italian communities reliant on marine diets face disproportionate risks. Recent clinical findings underscore a troubling association between chronic microplastic exposure and health conditions, such as cardiovascular disease and endocrine disruption. These findings align with international evidence linking microplastics to systemic inflammation, hormonal imbalance, and organ toxicity. This paper examines the scope of marine microplastic contamination in Italy and evaluates its contribution to disease risk. By proposing a systems-level response, encompassing regulatory reform, technological advancement, public awareness, and long-term biomonitoring, this study aims to inform national strategies while contributing to global efforts to reduce microplastic-related health burdens.

Keywords: Microplastics, Environmental exposure, Marine pollution, Cardiovascular health, Endocrine disruption

1. Introduction

As a biodiversity hotspot, the Mediterranean Sea is a vital resource for 150 million people. Nevertheless, it is now the epicenter of global microplastic pollution, with 1.25 million pieces of plastic per square kilometer, four times the density of the Pacific Ocean's "garbage patch", posing an imminent threat to marine ecosystems and human health [1]. Italy's coastal waters, stretching over 7,000 kilometers, are at the heart of the country's cultural identity, economic livelihood, and ecological richness [2]. As a major Mediterranean country, Italy has a well-developed tourism industry, dense coastal populations, and substantial maritime industries [3]. However, this iconic marine environment is increasingly threatened by the persistent and insidious accumulation of microplastics. These plastic particles, measuring less than 5 millimeters, are now ubiquitous in

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Italy's oceans, sediments, seafood, and even tap water. This environmental change is not just a pollution problem but a growing public health crisis. The most alarming human health effects include cardiovascular disease and endocrine disruption, both of which are associated with long-term exposure to microplastics and their associated chemical additives. This paper explores the environmental changes resulting from escalating microplastic pollution in Italian coastal waters and links them to specific human health outcomes, with a particular focus on cardiovascular and endocrine-related health effects. It also proposes multifaceted solutions involving policy reforms, technological innovations, and behavioral strategies to reduce the threat and promote healthier ecosystems and communities in Italy.

2. Environmental change: microplastic contamination in Italian marine

Microplastics originate from various sources, including the decomposition of larger plastic fragments and the direct industrial use of products such as cosmetics and detergents. The unique geography of the Mediterranean region, and in particular the Italian coast, which is located in the semi-enclosed Mediterranean Sea, with circulation patterns that trap floating debris, is vulnerable to the accumulation of plastics due to a combination of human activities and natural ocean dynamics. Studies found that plastic concentrations in the Mediterranean Sea are four times higher than in the “Great Pacific Garbage Patch” [1].

The long-standing dependence of Italy on the sea for food, tourism and trade means that coastal ecosystems are under cumulative pressure. Recent estimates suggest that parts of the Tyrrhenian Sea in Italian coastal waters contain more than 1.5 million microplastic particles per square kilometer [4]. The status of Italy as a global tourist destination receives more than 60 million visitors per year. Especially during the summer months, the influx of tourists, including those from coastal areas such as the Amalfi Coast and Liguria, significantly increases seasonal coastal plastic litter [5]. In contrast, Italian municipal wastewater treatment plants are not fully equipped to filter microplastics and usually lack the capacity to completely filter them before discharge into the sea. Magni et al. found that even advanced treatment plants in Italy release large amounts of microplastics into the environment [6]. In addition, the fishing and aquaculture industries that are the backbone of Italy's economy unintentionally exacerbate the problem by discarding fishing gear and packaging. Discarded fishing gear, nylon nets and plastic buoys degrade into microplastics and contribute to marine litter. Fishing activities both release and recapture microplastics, which can be introduced into the food chain. Increased consumption of single-use plastics, combined with outdated or inadequate waste management infrastructure, exacerbates microplastic pollution. Furthermore, the high consumption of seafood in Italian coastal communities increases the risk of dietary exposure to microplastics. Contamination is also present in coastal sediments, shellfish and tap water [7]. A study investigating the presence of microplastics in clams sold in Italian markets showed that a large proportion of store-bought clam samples, both fresh and processed varieties such as vacuum-frozen or brine, contained microplastics [8]. Moving beyond this, the Mediterranean Sea acts as a plastic trap due to limited water exchange. The central location of Italy in the basin makes it even more vulnerable to the influx of microplastics. The persistence and growth of this contamination reflect both historical negligence and increased plastic production and consumption.

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3. Analysis of microplastic pollution in Italy's coastal waters and its impacts

3.1. Exposure pathways in population

Human exposure to microplastics occurs through three primary routes: ingestion, inhalation, and dermal absorption. These pathways are increasingly substantiated by environmental monitoring and biomedical research, underscoring the ubiquitous nature of microplastic contamination in human environments.

Ingestion is currently the most significant and well-documented exposure pathway. Dietary intake of contaminated food and beverages, particularly seafood, bottled water, and table salt, accounts for a substantial portion of microplastic exposure in the general population. Italy, with one of the highest per capita seafood consumption rates in Europe, faces particular vulnerability. Bivalve mollusks, such as mussels and clams, which are often consumed whole, are highly susceptible to microplastic contamination due to their filter-feeding behavior [9]. Analytical findings have also revealed the presence of microplastics in 81% of tap water samples in Italy and in over 90% of commercial sea salt products globally, including those marketed within the country [10].

Inhalation of airborne microplastic particles represents an emerging exposure route with growing evidence. Microplastics have been identified in both outdoor atmospheric deposition and indoor dust, particularly in urban coastal areas, such as Naples and Genoa. Sources include textile fibers, degraded packaging, and beach litter mobilized by wave action. Wright and Kelly emphasize the potential for inhaled fibers to penetrate deep into the respiratory system and even enter the circulatory system, potentially contributing to inflammatory and systemic health effects [11]. Populations in densely populated coastal cities may be at elevated risk due to high ambient concentrations of airborne microplastics [12].

Dermal absorption, while comparatively less studied, remains a plausible route of exposure. This may occur through the use of personal care products containing microbeads or through direct contact with polluted recreational waters. Although the permeability of human skin to microplastics is not fully understood, the potential for local and systemic exposure through compromised skin barriers warrants further investigation.

Together, these pathways underscore the need for comprehensive public health monitoring and targeted mitigation strategies in high-exposure populations, particularly in countries like Italy, where dietary and environmental factors contribute to elevated microplastic burden.

3.2. Health outcome: cardiovascular and endocrine disruption

Recent studies have raised substantial concern about the potential link between microplastic exposure and serious human health outcomes among Italian populations, particularly in coastal and seafood-consuming communities. There is growing evidence that microplastic exposure is associated with serious human health effects, including cardiovascular disease and endocrine disruption.

3.2.1. Cardiovascular Disease (CVD)

Microplastics may contribute to CVD through mechanisms such as oxidative stress, endothelial dysfunction, and chronic inflammation. Campanale et al. explain how ingested microplastics, once in the bloodstream, interfere with vascular homeostasis and lipid metabolism [13]. A landmark prospective study conducted in Italy suggests that over half of patients undergoing carotid surgery

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had detectable microplastic particles in arterial plaques, and the presence of polyethylene and polyvinyl chloride in arterial tissue is significantly associated with an increased risk of heart attack, stroke, and all-cause mortality [14]. These changes are consistent with pathways leading to atherosclerosis and increased risk of stroke or heart attack.

3.2.2. Endocrine disruption

Microplastics act as both carriers and sources of endocrine-disrupting chemicals (EDCs), such as bisphenol A (BPA) and phthalates. By imitating or interfering with natural hormone signaling, these substances disrupt endocrine function and may lead to growth-related disorders, increased risk of infertility and hormone-related cancers [15]. Landrigan emphasized the link between plastic-related EDCs and rising rates of reproductive and developmental abnormalities globally [16]. In Italy, EDC-contaminated seafood is the main exposure vector, with high concentrations of these chemicals in samples of marine and human organisms [17]. The ingestion of microplastics through fish and fishery products poses a real risk to hormone regulation and gastrointestinal health, especially for regular consumers such as Italian coastal dwellers [18].

3.3. Vulnerable populations

The health risks associated with microplastics are unevenly distributed, and exposure to microplastics does not affect all populations equally. Certain demographic and occupational groups experience disproportionate exposure burdens due to their proximity to contamination sources, dietary habits, physiological susceptibility, or socio-economic disadvantage [19].

3.3.1. Coastal fishing communities

Individuals residing in coastal areas, particularly those engaged in small-scale or artisanal fishing, are at heightened risk of microplastic exposure. Their occupational environment involves direct contact with contaminated marine ecosystems, while their dietary reliance on local seafood, often consumed frequently and in large quantities, further compounds their risk [20]. This dual pathway of exposure, via both occupational and dietary routes, positions these communities at the intersection of environmental and occupational health vulnerabilities.

3.3.2. Children and pregnant women

Developing organisms are particularly susceptible to the toxicological effects of endocrine-disrupting chemicals (EDCs) associated with microplastics. Due to their lower body weight, higher metabolic rates, and critical windows of hormonal development, children and fetuses face elevated risks from even low-level exposures [20]. Campanale et al. highlight the increased sensitivity of the pediatric and prenatal endocrine systems to chemical insults, which may result in long-term developmental, reproductive, and metabolic disorders [13].

3.3.3. Low-income populations

Socioeconomically disadvantaged individuals are more likely to rely on inexpensive seafood sources, which are often poorly regulated and more prone to contamination. Additionally, these populations may have limited access to safe drinking water and effective environmental protections, thereby increasing their cumulative exposure to microplastic pollutants [21]. Environmental justice

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concerns arise when structural inequities exacerbate the health impacts of pollution on marginalized groups.

Addressing the health impacts of microplastic exposure, therefore, requires an equity-focused approach that integrates environmental justice principles into policy and public health interventions. As emphasized by the United Nations Environment Programme [3], reducing the health burden of microplastics must include protecting the most vulnerable members of society through targeted research, regulatory oversight, and community-centered solutions.

4. Proposed solutions: integrated strategies for mitigating microplastic-associated health risks in Italy

Addressing microplastic contamination and its associated health consequences in Italy requires a multifaceted and interdisciplinary response. Given the complexity of the problem, effective mitigation measures must simultaneously target upstream drivers, intermediate exposure pathways, and downstream health outcomes. Integrated strategies need to incorporate regulatory interventions, technological advances, community-level behavioral change, and systematic environmental and health monitoring, and a comprehensive response to the microplastics crisis in Italy must be evidence-based and tailored to the national context [22].

4.1. Regulatory and policy interventions

Effective policy frameworks are the backbone of large-scale environmental health initiatives. Italy's current implementation of the EU Single-Use Plastics Directive is a critical step, but inconsistent implementation allows regulatory gaps to remain. National legislation should be expanded to prohibit the manufacture and sale of products containing intentionally added microplastics, such as exfoliating microbeads in personal care items and plastic-laden cleaning products [7]. Additionally, the introduction of mandatory Extended Producer Responsibility (EPR) programs would help internalize the environmental costs of plastic pollution. These schemes would shift the burden of plastic waste management from consumers and municipalities to manufacturers and importers, encouraging eco-design and incentivizing more sustainable material use [23]. Furthermore, Italy’s fisheries sector would benefit from targeted regulation mandating the recycling, labeling, and reuse of plastic fishing gear. Given the shared ecological footprint in the Mediterranean basin, harmonizing these regulations across the region would improve compliance and environmental outcomes [20].

4.2. Technological and infrastructure-based solutions

Technological solutions are essential to reduce microplastic discharges at the source and to mitigate environmental persistence. The current wastewater treatment infrastructure in Italy lacks the capacity to effectively remove microplastic particles. Studies, for example, Magni et al. have demonstrated the benefits of integrating advanced filtration systems, including membrane bioreactors and tertiary microfiltration [6], which could significantly reduce microplastic loads in treated effluent. Promoting the development and adoption of biodegradable alternatives is also a key step. Public subsidies and public-private partnerships should support the scaling of algae-based and compostable materials, particularly within the fisheries and food packaging sectors. Pilot projects in coastal municipalities could evaluate the performance, cost-effectiveness, and environmental fate of these alternatives under local conditions [24]. In addition, synthetic textile microfibers represent a

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major source of household microplastic emissions. Italy should consider adopting legislation similar to that of France, which mandates microfiber filters in new washing machines to mitigate domestic microplastic release at the source.

4.3. Public engagement and behavior change

Public understanding and behavioral shifts are critical to the long-term success of microplastic mitigation strategies. National education campaigns that highlight the risks of microplastic exposure and encourage more sustainable consumption habits can effectively mobilize public support. Evidence from Hartley et al. suggests that culturally relevant and targeted messaging, disseminated through mass media, schools, and influential public figures, can lead to measurable reductions in marine littering behaviors [25]. Moreover, community-based monitoring programs can empower citizens to participate directly in microplastic sampling and shoreline cleanup efforts. Such initiatives not only enhance local stewardship but also provide valuable data for researchers and policymakers. Collaborations with academic institutions and non-governmental organizations can ensure that these efforts maintain scientific rigor and facilitate the standardization of data collection protocols [19].

4.4. Environmental and human health monitoring

Robust monitoring systems are necessary to evaluate the effectiveness of interventions and identify emerging exposure risks. Investments in real-time environmental monitoring technologies, such as AI-enhanced drone surveillance and satellite-based detection, can help track the distribution of microplastics along Italy’s coastlines and within marine protected areas. Parallel to these efforts, national biomonitoring programs should be expanded to assess microplastic-related exposures among vulnerable groups, including children, pregnant women, and coastal laborers [26]. Such data are critical for guiding epidemiological research, quantifying population-level health burdens, and informing risk assessment models.

All these strategies emphasize the importance of a holistic, systems-level approach to microplastic governance, one that is scientifically grounded, context-specific, and equity-oriented. Without such integrated interventions, the cumulative health and ecological impacts of microplastic pollution in Italy will likely continue to intensify.

5. Conclusion

The spread of microplastic pollution in Italian coastal waters represents a complex and escalating form of environmental change, one that goes beyond ecosystem degradation and poses a substantial risk to human and public health. A growing body of interdisciplinary scientific evidence has linked microplastics and their associated chemical additives to a range of adverse health outcomes, including cardiovascular dysfunction, endocrine disruption, and systemic inflammation. These health risks are especially pronounced in coastal fishing communities and socioeconomically vulnerable populations, such as children and pregnant women, who face elevated exposure levels due to their dietary reliance on seafood and proximity to polluted coastal environments.

Italy's geographic position within the semi-enclosed Mediterranean Sea, coupled with socio-economic stressors, such as high-volume coastal tourism, expanding aquaculture, and insufficient waste management infrastructure, exacerbates the scale and persistence of microplastic contamination and highlights the need for urgent targeted interventions. While emerging regulatory

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frameworks and public awareness campaigns have begun to address single-use plastics, more comprehensive and multi-layered strategies are needed to mitigate environmental and human health hazards. A robust, coordinated response grounded in the principles of planetary health could integrate regulatory reform, technological innovation, community engagement, and strong monitoring systems. This includes regulatory reforms that internalize the lifecycle costs of plastic production, investments in wastewater and filtration technologies, public engagement strategies to shift consumer behavior, and expanded environmental and human biomonitoring systems to detect early warning signals. Through such coordinated action, Italy can reduce exposure pathways, support at-risk populations, and meet its obligations under the international environmental and public health framework. In addition, Italy's experience can serve as a model for other coastal states dealing with similar challenges, reaffirming the need to view ocean health and human health as closely intertwined domains, leading the way to cleaner shores and safer seafood.

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