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Microplastics as Potential Drivers of Cholera Persistence and Outbreaks: A Mini Review

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Microplastics as Potential Drivers of Cholera Persistence and Outbreaks: A Mini Review

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Abstract

Cholera continues to impose a heavy disease burden in regions with limited sanitation, where *Vibrio cholerae* survives in aquatic systems shaped by climatic and ecological drivers. Recent research suggests that microplastics (MPs), once regarded as inert pollutants, may actively influence the persistence and virulence of this pathogen. This mini-review puts together information that points to MPs as potential drivers of cholera outbreaks. MPs are widespread across rivers, lakes, and wastewater streams, and their textured, hydrophobic surfaces readily attract organic matter and microbes. These features promote the establishment of biofilms in which *V. cholerae* can persist, protected from environmental stress. Laboratory investigations show that exposure to MPs can alter bacterial behaviour, increasing motility, enhancing adhesion, and stimulating pathways linked to pathogenicity. Field studies further demonstrate that MPs become hotspots for microbial enrichment and rapidly accumulate antimicrobial resistance (AMR) genes, creating mobile reservoirs that facilitate gene exchange. In cholera-endemic regions, this interaction between plastic pollution, pathogen ecology, and antibiotic resistance raises serious concerns for both outbreak dynamics and treatment outcomes. The evidence points to MPs as hidden amplifiers of cholera risk, suggesting the need for integrated strategies that address plastic waste management, strengthen cholera surveillance, and promote antimicrobial stewardship in a One Health framework.

Keywords: microplastics; plastic pollution; Cholera; *Vibrio cholerae*

Background

Cholera remains one of the most devastating waterborne diseases globally, particularly in low- and middle-income countries where sanitation and waste management are inadequate. The causative agent, *Vibrio cholerae*, thrives in aquatic ecosystems, persisting in rivers, lakes, and drainages, where environmental drivers such as temperature, rainfall, and dense nutrients may regulate its dynamics. Over the past two decades, the scientific community has come to recognize that microplastics (MPs), synthetic particles <5 mm in size, are not only pervasive pollutants but also active agents in microbial ecology. MPs accumulate across freshwater, marine, and wastewater systems, where their surface properties and chemical reactivity foster microbial colonization, biofilm formation, and the spread of antimicrobial resistance (Hossain et al., 2019; Jiang et al., 2023; Stabnikova et al., 2021). This mini-review puts together emerging data concerning the potential role of MPs in driving outbreaks of cholera across the globe.

Microplastic Properties that Promote V. cholerae Growth

The intrinsic physical and chemical properties of MPs make them uniquely suited for microbial colonization. Roughened surfaces caused by UV weathering, abrasion, or cracks create niches that shelter bacteria from shear forces and washing, resulting in undisturbed growth. When bacteria encounter MPs, they generate extracellular polymetric substances (EPS) that result in the formation of a protective layer with which they cover themselves, known as a biofilm. On the other hand, hydrophobic polymer types promote adhesion by binding dissolved organic matter that feeds microbial communities by providing dissolved organic carbon and other beneficial additives (Jiang et al., 2023; Sheridan et al., 2022). Experimental work confirms that even small-sized classes of MPs provide disproportionately large surface areas for microbial attachment (Hossain et al., 2019).

Microplastics as Active Modifiers of V. cholerae Physiology

Beyond acting as substrates, MPs can actively alter microbial physiology. Controlled laboratory experiments have shown that *V. cholerae* exposed to MPs undergoes profound phenotypic and genotypic changes. Cells become more hydrophobic and motile, with fluid membranes that facilitate self-aggregation and thick biofilm formation (Gu et al., 2025). Transcriptomic analysis reveals upregulation of pathways linked to chemotaxis, flagellar motility, energy metabolism, and antioxidant defenses. These shifts are not merely environmental adaptations; they increase virulence. Gu et al. (2025) demonstrated that *V. cholerae* pre-exposed to MPs adhered to and invaded intestinal epithelial cells at significantly higher rates than unexposed controls. This suggests that MPs can prime pathogens not only for environmental persistence but also for enhanced host colonization, raising concerns about their role in outbreak amplification. Such findings demand urgent validation in endemic regions where cholera remains a public health threat and where visible plastic pollution is common. The possibility that MPs actively "train" *V. cholerae* to become more virulent could fundamentally alter how outbreaks are understood and managed.

Case Study: The Oder River and Rapid Pathogen Enrichment

Evidence from natural systems indicates how quickly MPs can reshape microbial communities. In the Oder River, Cholewińska et al. (2025) found that microbial communities incubated with MPs shifted dramatically within seven days, enriching *E. coli*, *Salmonella*, *Aeromonas*, and *Vibrio* species. At the same time, MPs accumulated antimicrobial resistance (AMR) genes, highlighting their role as hotspots of resistance dissemination. Such findings are striking for two reasons. First, they show that MPs can transform into pathogen-rich plastispheres within days. Second, they highlight how MPs in nutrient-rich rivers can act as both pathogen and AMR amplifiers. For cholera-endemic regions, this raises the possibility that contaminated rivers and aquaculture ponds seeded with MPs could serve as overlooked environmental reservoirs of *V. cholerae*, sustaining transmission even in the absence of acute outbreaks.

Microplastics and Antimicrobial Resistance in Cholera Contexts

One of the most concerning aspects of MP biofilms is their role in AMR dynamics. Biofilm matrices provide ideal conditions for horizontal gene transfer, including plasmid exchange, transformation, and transduction (Liu et al., 2021; Yu et al., 2023; Yuan et al., 2022). In the dense microbial communities that coat MPs, resistance genes are concentrated and readily exchanged. Metagenomic surveys have identified a broad repertoire of ARGs in MP biofilms, including tetracyclines (*tetM, tetQ, tetX2*), sulfonamides (*sul1, sul2*), macrolides (*ermB, mefA, mphE*), β-lactams (*blaTEM*), aminoglycosides (*aac, aph, ant2ia*), and multidrug efflux systems (*acrA, oqxB, qepA4*) (Cholewińska et al., 2025; Jaafarzadeh Haghighi Fard et al., 2025; Xu et al., 2023). Particularly notable is the role of polyvinyl chloride MPs, which appear to act as especially potent carriers of ARGs in water (Li et al., 2024). In the context of cholera, this is troubling because outbreaks often occur in settings already strained by limited antibiotic availability and high empirical antibiotic use. If MPs amplify both *V. cholerae* persistence and ARG dissemination, they could contribute to more persistent, treatment-resistant cholera outbreaks in endemic regions.

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Implications for Cholera Endemic Regions

For much of low-income countries, the convergence of climate change, poor waste management, and high cholera burden creates a perfect storm. Rising temperatures, frequent flooding, and widespread plastic pollution provide conditions highly favourable to *V. cholerae*. Fish camps and aquaculture systems, already implicated in outbreaks (Kobayashi et al., 2010), may act as hotspots where MPs sustain *V. cholerae* reservoirs. Despite this, few longitudinal field studies in African contexts have systematically examined the intersection of MPs, pathogen persistence, and outbreak dynamics. This gap is particularly concerning given the increasing visibility of plastic pollution in rivers and lakes, and city drainages. Research is urgently needed to quantify MP burdens in cholera-prone water systems and to link these with epidemiological data.

Conclusions

Microplastics are no longer merely inert pollutants; they are active ecological agents capable of reshaping pathogen ecology and epidemiology. By providing protective surfaces, amplifying the effects of warming and eutrophication, and priming *V. cholerae* for enhanced virulence, MPs may be silent drivers of cholera persistence and outbreaks. Compounding this is their role as reservoirs and exchange hubs for AMR genes, which could make future cholera epidemics more difficult to treat. Addressing these risks requires integrated One Health strategies that combine plastic pollution control, cholera surveillance, aquaculture management, and antimicrobial stewardship. Without such coordinated interventions, MPs will remain invisible amplifiers of pathogen persistence and resistance in aquatic ecosystems, silently shaping the future trajectory of cholera in vulnerable regions.

Conflict of Interest: The author declares no conflict of interest.

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