# Environmental Risks of Plastisphere Viruses: Carrier Effects, Virus–Host Interactions, and Mechanisms of Resistance Dissemination

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**Abstract.** Once microplastics enter environmental systems, they rapidly develop plastisphere biofilms that provide a distinct interface for viral attachment, enrichment, and transport. Compared with bacterial communities in the plastisphere, the occurrence and ecological roles of viruses have received much less systematic attention. This review therefore examines the basis of viral enrichment in the plastisphere, the characteristics of plastisphere viral communities, and their major environmental risks. Current evidence suggests that plastisphere viruses may contribute to pathogen transmission, resistance dissemination, and ecological functional disturbance through a progression from surface retention to virus–host interaction within biofilms. However, most available evidence still relies on metagenomic association analyses, whereas direct validation through infection assays, host tracking, and functional experiments remains limited.

## 1 Introduction

Microplastics are now widely distributed across marine, riverine, lacustrine, soil, and atmospheric environments. Once plastic particles enter environmental systems, their surfaces are rapidly colonized by bacteria, fungi, algae, and other microorganisms, leading to the formation of biofilms and, ultimately, a plastisphere microecological interface distinct from the surrounding medium [1-3]. Existing research has mainly focused on bacterial communities in the plastisphere, biofilm succession, pathogen enrichment, and pollutant adsorption, whereas the composition, sources, and roles of viruses in the plastisphere have long lacked systematic discussion [1, 4, 5]. In recent years, metagenomic and viromic studies have identified diverse viral communities on microplastic surfaces and revealed their associations with host microbial communities, antibiotic resistance genes, and virulence factors [6-8]. These findings indicate that the plastisphere may serve not only as a site for viral enrichment and transport, but also as a setting where virus–host interactions shape resistance dissemination and local ecological processes [6-11]. Against this background, the present review summarizes the basis of viral enrichment in the plastisphere, the characteristics of plastisphere viral communities, their major environmental risks, and the main gaps in current research.

## 2 The Plastisphere as a Distinct Interface for Viral Enrichment and Transmission

### 2.1 Plastic surface properties and biofilm formation

The hydrophobicity, roughness, specific surface area, and aging status of plastic surfaces strongly influence the initial attachment of microorganisms, and different polymers therefore support different biofilm structures [3, 5, 12, 13]. Ultraviolet aging, freeze–thaw cycles, and biological ingestion can alter surface functional groups and microtopography, which in turn affects interfacial interactions between plastic particles, microorganisms, and viruses [7, 13, 14]. Once biofilms form, the extracellular polymeric matrix can improve water retention, nutrient accumulation, and microscale heterogeneity, while also providing a relatively stable space for host microbes to aggregate [5, 12]. Together, these features create the basic conditions that allow the plastisphere to retain and continuously adsorb viruses.

### 2.2 Viral adsorption, enrichment, and prolonged persistence on microplastics

Experimental work has shown that microplastics can adsorb viruses efficiently, and that this process is jointly influenced by particle size, surface charge, functional groups, and surrounding ionic conditions [3]. Some materials show stronger adsorption after aging, suggesting that changes in surface condition can directly affect viral

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attachment behavior [3, 14]. Studies of hospital wastewater have also detected nucleic acids from several pathogenic viruses on microplastic surfaces, which suggests that microplastics may act as a reservoir-like interface for viral retention and may extend the time viruses remain in the environment while preserving their potential infectivity [6]. For this reason, the plastisphere should not be viewed merely as a passive attachment surface. It is better understood as an important physical interface for viral enrichment and environmental transport.

By accumulating viable viruses and host microorganisms, this interface does more than just transport. Microplastics capture up to 98.6% of nearby viruses, and surface groups strengthen this electrostatic bond. They also shield viruses from UV radiation, keeping them infectious much longer. My observations indicate that weathered plastics provide even stronger protection in open water, establishing the biological foundation for the complex community interactions detailed next.

## 3 Characteristics of Plastisphere Viral Communities and Their Interactions with Hosts

### 3.1 Diversity and distribution of plastisphere viruses

Watershed-scale studies have shown that microplastic surfaces collected from different regions, polymer types, and environmental settings can harbor markedly different viral assemblages, indicating strong spatial heterogeneity in plastisphere viral communities [2]. Viromic analyses further suggest that plastisphere viruses are not simply a direct copy of the viral communities in surrounding waters. Rather, they appear to be shaped by a combination of plastic surface properties, host sources, and environmental pressures [2, 8, 15-18]. These differences also imply that the risks associated with plastisphere viruses are highly context-dependent. Exposure pathways and ecological consequences may vary substantially across environmental settings.

### 3.2 Virus–host interactions and ecological network features

Available studies indicate stable associations between plastisphere viruses and host groups such as Proteobacteria, Firmicutes, and Actinobacteriota [8]. Within biofilm systems, viruses are embedded in a microecological structure formed jointly by host microbial communities, metabolic networks, and defense systems, and they may influence community relationships through host lysis, metabolic reprogramming, and genetic exchange [7, 8]. Research on marine biofilms has also shown that viruses and hosts can form complex many-to-many relationships, accompanied by changes in auxiliary metabolic genes and antiviral defense systems [7]. These observations suggest that plastisphere viruses may contribute to the reorganization of biofilm networks and may, in turn, affect community stability and functional expression.

These viral-host dynamics within the biofilm act as a primary engine for environmental risk. Viruses here target specific hosts like Proteobacteria and Cyanobacteria, operating independently of the broader bacterial community. They frequently share metal resistance genes. In my work, I see these targeted interactions peak as the biofilm matures, directly translating localized enrichment into the broader risks of resistance dissemination and ecological disturbance.

## 4 Major Environmental Risks of Plastisphere Viruses

### 4.1 Risks of pathogen enrichment and transmission

The first major risk of plastisphere viruses lies in the retention and transmission of pathogens. Studies of hospital wastewater have detected multiple pathogenic viral signals on microplastic surfaces, suggesting that plastic particles may participate in the persistence and movement of pathogens within wastewater systems [6]. Research on plastispheres in both atmospheric and aquatic environments also suggests that particle transport can broaden the potential range of exposure, allowing the plastisphere to act as a link between pollution sources and receiving environments [2, 3, 6, 19]. This risk deserves particular attention in urban watersheds, wastewater effluents, and coastal waters that are strongly influenced by human activity.

### 4.2 Risk associated with dissemination of resistance genes and virulence factors

A second major concern is the role of plastisphere viruses in resistance dissemination. Studies have identified antibiotic resistance genes and metal resistance genes in both microplastic-associated viral metagenomes and host genomes, pointing to genetic links between viruses and hosts that are relevant to resistance spread [8]. At the same time, plastisphere biofilms are characterized by high cell density, frequent contact, and active exchange of genetic material, conditions that are favorable for horizontal gene transfer [9, 10]. Research in rivers, farmlands, and on different plastic types has likewise shown that microplastic surfaces are often associated with the enrichment of resistant pathogens, virulence factors, and resistance-related microbial assemblages [4, 11, 20].

Instead of a generalized spread, viruses use distinct pathways within this dense "microniche." The thick biofilm matrix is crucial; it shields extracellular DNA from enzymatic degradation in the water. When viral lysis occurs, it releases genetic material into this protective layer, allowing nearby microbes to assimilate traits through natural transformation. I've found this "sticky" protection essential for maintaining a steady supply of resistance genes, accelerating their horizontal spread.

### 4.3 Risks of ecological functional disturbance

A third category of risk involves ecological functions. Existing studies have shown that virus-mediated changes in plastisphere function are associated with processes such as denitrification and methanogenesis, which suggests that viruses may influence biofilm functions by altering host composition and metabolic potential [7]. In addition, plastic biofilms themselves have already been linked to nitrogen cycling, dissolved organic matter turnover, and local carbon metabolic processes [13]. On this basis, if viruses continue to shape host regulation and gene exchange, they may further alter metabolic partitioning and biogeochemical processes within the plastisphere. Compared with pathogen transmission, this functional disturbance is less visible but highly dynamic. Biological factors, like snail ingestion, trigger major shifts. Digestion alters the plastic surface, which changes how viruses influence local metabolism, disrupting vital nitrogen and carbon cycles. My tests show that even a single passage through a gut makes the plastisphere far more biologically reactive, meaning its ecological significance should definitely not be underestimated.

## 5 Conclusion and Outlook

Current evidence shows that the plastisphere provides a distinct interface for viral attachment, enrichment, and transport (Fig.1). Once retained within plastisphere biofilms, viruses may enter a second stage in which they interact with host communities, biofilm structure, and resistance-related genetic processes [2, 3, 6-10]. In this sense, the environmental significance of plastisphere viruses should be understood as a progression from physical enrichment to biological interaction and, ultimately, to broader ecological and health-related consequences. Based on the evidence available so far, these consequences can be grouped into three main aspects: pathogen transmission, the spread of resistance and virulence factors, and disturbance of ecological functions [4, 6-11, 14, 19, 20]. Plastisphere viruses should therefore be included in ecological risk assessment frameworks for microplastics.

At the same time, research on plastisphere viruses remains limited. Most conclusions still rely mainly on metagenomic and correlation-based analyses, while infection experiments, host validation, and activity measurements are still lacking [2, 7, 8]. Current work also focuses largely on aquatic environments, and more studies are needed in soils, the atmosphere, wastewater systems, and food-web transfer scenarios [4,15]. In addition, there is still no consistent understanding of how plastic type, aging status, and environmental factors affect viral adsorption and ecological effects, and evaluation indicators for plastisphere viral risks remain underdeveloped. Future work should combine viromics with cultivation-based verification and functional experiments so that the actual environmental effects and risk boundaries of plastisphere viruses can be defined more clearly.

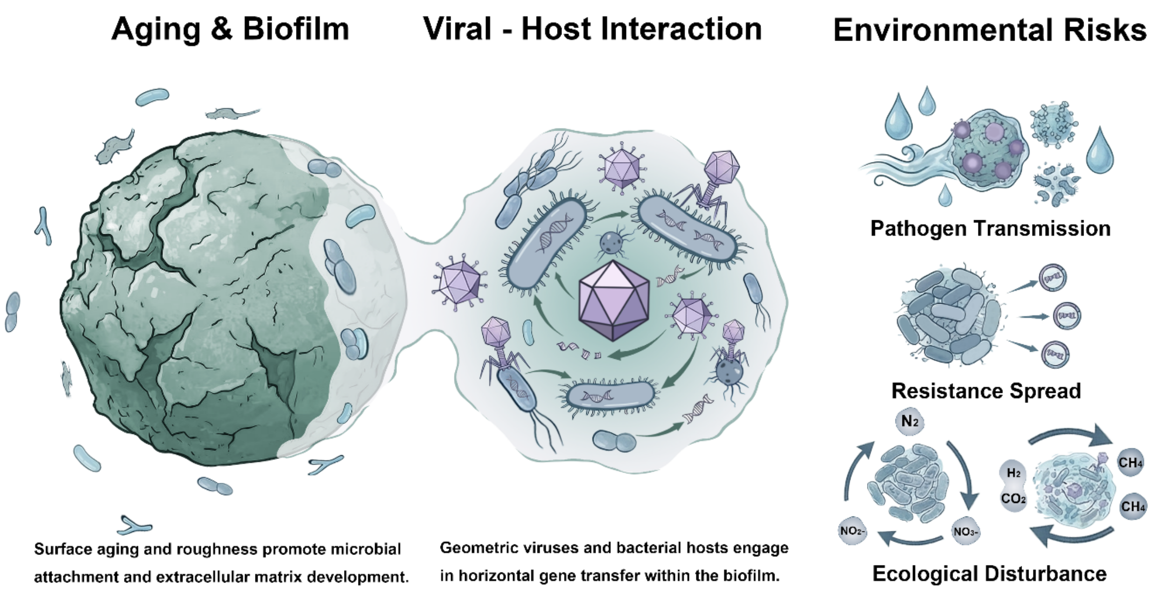


**Fig. 1.** Plastisphere Virus Enrichment and Risks

## References

1. E.R. Zettler, T.J. Mincer, L.A. Amaral-Zettler, Life in the "Plastisphere": Microbial Communities on Plastic Marine Debris, Environmental Science & Technology, 47 (2013) 7137-7146. https://doi.org/10.1021/es401288x
2. R. Li, L. Zhu, L. Cui, Y.-G. Zhu, Viral diversity and potential environmental risk in microplastic at watershed scale: Evidence from metagenomic analysis of plastisphere, Environment International, 161 (2022) 107146.

https://doi.org/10.1016/j.envint.2022.107146

3. J. Lu, Z. Yu, L. Ngiam, J. Guo, Microplastics as potential carriers of viruses could prolong virus survival and infectivity, Water Research, 225 (2022) 119115.
https://www.sciencedirect.com/science/article/pii/S0043135422010612
4. M.J. Ormsby, L. Woodford, R. Fellows, H.L. White, R.S. Quilliam, Rapid colonisation of environmental plastic waste by pathogenic bacteria drives adaptive phenotypic changes, Journal of Hazardous Materials, 480 (2024) 136359.
https://www.sciencedirect.com/science/article/pii/S0304389424029388
5. X. Zhai, X.-H. Zhang, M. Yu, Microbial colonization and degradation of marine microplastics in the plastisphere: A review, Frontiers in Microbiology, Volume 14 - 2023 (2023).
https://www.frontiersin.org/journals/microbiology/articles/10.3389/fmicb.2023.1127308
6. Y.S. Ibrahim, T.J. Yi, T.T. Chin, S.T. Anuar, L.Y. Yeh, S.S. Azmi, N.S. Roslan, W.M.A.W.M. Khalik, S.Z. Abidin, K.M. Kalkausar Ku Yusof, M.H. Barawi, W.A. Wan Mahari, W.S. Kuan, L.A. Lai, T. Brentnall, Microplastics as the potential reservoir and carrier of viral pathogens detected from hospital sewage, Environmental Research, 286 (2025) 122944.
https://doi.org/10.1016/j.envres.2025.122944
7. Z. Shi, W. Zeng, W. Zhuang, F. Yao, D. Sun, Z. Liu, J. Zhang, Ingestion and digestion by the freshwater snail Pomacea canaliculata drive microplastic surface transformations and virus-mediated plastisphere functional shifts, Water Research, 290 (2026) 124926.
https://doi.org/10.1016/j.watres.2025.124926
8. R. Li, X.-L. An, Y. Wang, Z. Yang, J.-Q. Su, J. Cooper, Y.-G. Zhu, Viral metagenome reveals microbial hosts and the associated antibiotic resistome on microplastics, Nature Water, 2 (2024) 553-565.
https://doi.org/10.1038/s44221-024-00249-y
9. H. Wang, K. Xu, J. Wang, C. Feng, Y. Chen, J. Shi, Y. Ding, C. Deng, X. Liu, Microplastic biofilm: An important microniche that may accelerate the spread of antibiotic resistance genes via natural transformation, Journal of Hazardous Materials, 459 (2023) 132085.
https://www.sciencedirect.com/science/article/pii/S0304389423013687
10. L. Zhu, R. Li, K. Yang, F. Xu, C. Lin, Q. Chen, D. Zhu, Q. Sun, Y.-G. Zhu, L. Cui, Quantifying health risks of plastisphere antibiotic resistome and deciphering driving mechanisms in an urbanizing watershed, Water Research, 245 (2023) 120574.
https://www.sciencedirect.com/science/article/pii/S004313542301014X
11. I. Silva, E.T. Rodrigues, M. Tacão, I. Henriques, Microplastics accumulate priority antibiotic-resistant pathogens: Evidence from the riverine plastisphere, Environmental Pollution, 332 (2023) 121995.
https://www.sciencedirect.com/science/article/pii/S0269749123009971
12. P. Sooriyakumar, N. Bolan, M. Kumar, L. Singh, Y. Yu, Y. Li, C. Weralupitiya, M. Vithanage, S. Ramanayaka, B. Sarkar, F. Wang, D.B. Gleeson, D. Zhang, M.B. Kirkham, J. Rinklebe, K.H. M Siddique, Biofilm formation and its implications on the properties and fate of microplastics in aquatic environments: A review, Journal of Hazardous Materials Advances, 6 (2022) 100077.
https://www.sciencedirect.com/science/article/pii/S277241662200033X
13. J.M. Kingsbury, O. Laroche, X. Pochon, A. Zaiko, G. Lear, L. Weaver, S. Gaw, H. Masterton, F. Doake, F. Audrézet, J. Wallbank, S.D.M. Maday, J.H. Bridson, R. Abbel, L. Donaldson, R. Risani, B. Theobald, R. Dunlop, G.L. Northcott, O. Pantos, Plastic physico-chemical properties shape the early marine plastisphere, Environmental Pollution, 390 (2026) 127532.
https://www.sciencedirect.com/science/article/pii/S0269749125019062
14. J.H. Lim, J.W. Kang, Assessing biofilm formation and resistance of vibrio parahaemolyticus on UV-aged microplastics in aquatic environments, Water Res, 254 (2024) 121379.
10.1016/j.watres.2024.121379
15. W. Zhang, G. Bhagwat, T. Palanisami, S. Liang, W. Wan, Y. Yang, Lacustrine plastisphere: Distinct succession and assembly processes of prokaryotic and eukaryotic communities and role of site, time, and polymer types, Water Research, 248 (2024) 120875.
https://doi.org/10.1016/j.watres.2023.120875
16. W. Zhang, S. Liang, H.P. Grossart, J.A. Christie-Oleza, G.M. Gadd, Y. Yang, Convergence effect during spatiotemporal succession of lacustrine plastisphere: loss of priority effects and turnover of microbial species, ISME communications, 4 (2024) ycae056.
10.1093/ismeco/ycae056
17. V. Nava, K. Attermeyer, J. Schelker, J. Kalem, F. Dory, I. Gandolfi, R. Ambrosini, A. Kruszelnicki, C. Gwinnett, B. Leoni, Temporal succession outweighs substrate characteristics in shaping riverine plastisphere biofilm on textiles, Environmental Pollution, 396 (2026) 127881.
https://doi.org/10.1016/j.envpol.2026.127881
18. P. Yan, S. Zhuang, M. Li, J. Zhang, S. Wu, H. Xie, H. Wu, Combined environmental pressure induces unique assembly patterns of micro-plastisphere biofilm microbial communities in constructed wetlands, Water Research, 260 (2024) 121958.
https://doi.org/10.1016/j.watres.2024.121958
19. W. Rao, Y. Fan, M. Chen, X. Qian, L. Zhang, New insights into the microbial succession and health risks

of atmospheric plastispheres, Environmental Research, 296 (2026) 124011.

https://doi.org/10.1016/j.envres.2026.124011

20. F. Li, H. Shen, R. Pang, X. Wang, B. Xie, M. Zhan, Y. Su, Biodegradable and non-biodegradable plastics foster unique regimes of antibiotic resistance and virulence factors in aquatic plastispheres, Biocontaminant, 2 (2026) e001.

http://www.maxapress.com/article/doi/10.48130/biocontam-0025-0026