# Supporting information

## Microplastics in the Arctic: A critical review of transport pathways, climate feedbacks, and governance frameworks

**Table S1** Direct and indirect influences of climate change on the fate and presence of pollutants in the Arctic (Hung et al., 2022).

| Influence of climate change | Contaminant-related processes potentially affected |
|---|---|
| Direct influences | |
| Increased ambient temperatures (sea, land, atmosphere) | Pollutant re-mobilization<br>Long-range transport<br>Transformation pathways |
| Ocean acidification | Transformation conditions |
| Changing weather patterns (e.g. precipitation, seasonal characteristics, frequency of extreme events) | Long-range atmospheric transport<br>Deposition and precipitation event frequency |
| Sea level rise | Transfer between terrestrial and marine environments<br>Marine transport pathways |
| Loss of cryosphere | Translocation, re-mobilization, and redistribution of contaminants |
| Different radiation characteristics [black carbon (BC), cloud condensation nuclei (CCN)] | Photochemistry and transformation pathways |
| Altered carbon cycling and sequestration | Biotic and abiotic transformation |
| Water mass transport changes (e.g. changing ocean currents) | Long-range oceanic transport |
| Increased dust aerosol loadings | Additional advective transport and particle-mediated transport |
| Indirect influences | |
| Food web composition change (e.g. invading species) | Bioaccumulation and transformation |
| Re-mobilization of pollutants | Re-emission from sediment, ice surfaces, and soils |
| Land degradation (e.g. increased erosion) and fooding | Re-mobilization and re-emission<br>Transfer between terrestrial and marine environments |
| Biodiversity loss | Bioaccumulation and transformation |
| Behavioral pattern changes (e.g. animal migration) | Contaminant exposure<br>Bioaccumulation<br>Biovector-based transport of pollutants |
| Human socio-economic development | New pollutant sources<br>New exposure routes |
| New economic opportunities in the Arctic | New pollutant sources<br>Re-mobilization |
| Increased agricultural disease and pests | Pesticide and pest control agent use |
| Increased frequency of boreal forest fires | Pollutant re-mobilization and redistribution |
| Effects on the oceanic biological pump | Ocean sequestration of pollutants |

**Table S2.** Microplastics can affect greenhouse gas emissions by influencing microorganisms (Li et al., 2024).

| MP category | Ecological setting | Particle range | Applied dosage | Microbial community response and GHG impact | Reference |
|---|---|---|---|---|---|
| PET | Freshwater Sediments | Various Sizes | 0.5% (w/w) | Changes in nitrogen-related microbes result in altered nitrous oxide emissions. | (Zhang et al., 2022) |
| PE | Fertile Soil | Medium-Size Particles | 1% (w/w) | Microplastics notably increase nitrous oxide release from soil microbes. | (Zhang et al., 2023) |
| PE | Fertile Soil | Small & Medium Particles | 5% (w/w) | Microbial composition in the soil shifts selectively in the presence of MPs. | (Ren et al., 2020) |
| PS | Mud | Micro to Nanoscale Particles | 1.6% (w/w) | Microbial carbon metabolism is impacted due to suppressed thermal adaptability. | (Wang et al., 2022) |
| PA | Soil | Small Particles | 0.3% and 1% (w/w) | MPs boost soil carbon fixation by enhancing genes linked to carbon capture processes. | (Sun et al., 2023) |
| PE | Paddy Field Soil | Medium-Size Particles | 1% (w/w) | Methane emissions and gene markers related to methane production decrease under acidic conditions. | (Zhang et al., 2023) |
| PE, PS, Polybutylene, PLA | Soil | Medium Particles | 1% (w/w) | Microbial networks display higher complexity in response to biodegradable MPs exposure. | (Su et al., 2022) |

| | | | | | |
|---|---|---|---|---|---|
| PVC, PP, PE | Soil | Moderate Particles | 0.25%, 2%, and 7% (w/w) | Overall microbial community structure and lipid profiles are significantly modified. | (Chen et al., 2023) |
| PVC and PET | Freshwater Environments | Larger Plastic Pieces | - | Microbial communities expand with ecological implications due to MPs presence. | (Miao et al., 2021) |
| LDPE | Soil | Small & Medium Particles | 0.5% (w/w) | MPs suppress gut microbiota functions in earthworms, reducing carbon and nitrogen cycling genes. | (Gao et al., 2022) |

**References**


Chen X, Xie Y, Wang J, Shi Z, Zhang J, Wei H, Ma Y (2023). Presence of different microplastics promotes greenhouse gas emissions and alters the microbial community composition of farmland soil. Science of the Total Environment, 879: 162967

Gao B, Li Y, Zheng N, Liu C, Ren H, Yao H (2022). Interactive effects of microplastics, biochar, and earthworms on CO2 and N2O emissions and microbial functional genes in vegetable-growing soil. Environmental Research, 213: 113728

Hung H, Halsall C, Ball H, Bidleman T, Dachs J, De Silva A, Hermanson M, Kallenborn R, Muir D, Sühring R, Wang X, Wilson S (2022). Climate change influence on the levels and trends of persistent organic pollutants (POPs) and chemicals of emerging Arctic concern (CEACs) in the Arctic physical environment – a review. Environmental Science: Processes & Impacts, 24(10): 1577-1615

Li K, Du L, Qin C, Bolan N, Wang H, Wang H (2024). Microplastic pollution as an environmental risk exacerbating the greenhouse effect and climate change: a review. Carbon Research, 3(1): 9

Miao L, Yu Y, Adyel T M, Wang C, Liu Z, Liu S, Huang L, You G, Meng M, Qu H, Hou J (2021). Distinct microbial metabolic activities of biofilms colonizing microplastics in three freshwater ecosystems. Journal of Hazardous Materials, 403: 123577

Ren X, Tang J, Liu X, Liu Q (2020). Effects of microplastics on greenhouse gas emissions and the microbial community in fertilized soil. Environmental Pollution, 256: 113347

Su X, Yuan J, Lu Z, Xu J, He Y (2022). An enlarging ecological risk: Review on co-occurrence and migration of microplastics and microplastic-carrying organic pollutants in natural and constructed wetlands. Science of the Total Environment, 837: 155772

Sun X, Tao R, Xu D, Qu M, Zheng M, Zhang M, Mei Y (2023). Role of polyamide microplastic in altering microbial consortium and carbon and nitrogen cycles in a simulated agricultural soil microcosm. Chemosphere, 312: 137155

Wang C, Wei W, Chen Z, Wang Y, Chen X, Ni B-J (2022). Polystyrene microplastics and nanoplastics distinctively affect anaerobic sludge treatment for hydrogen and methane production. Science of the Total Environment, 850: 158085

Zhang W, Liu X, Liu L, Lu H, Wang L, Tang J (2022). Effects of microplastics on greenhouse gas emissions and microbial communities in sediment of freshwater systems. Journal of Hazardous Materials, 435: 129030

Zhang Z, Yang Z, Yue H, Xiao M, Ge T, Li Y, Yu Y, Yao H (2023). Discrepant impact of polyethylene microplastics on methane emissions from different paddy soils. Applied Soil Ecology, 181: 104650