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Assessment of Human Activities as Drivers of Microplastic Pollution in Rural and Urban Water Bodies

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Article Info

Abstract

Microplastic contamination of inland waters is increasingly understood as a consequence of ordinary human production, consumption, disposal, and land-management practices. This article assesses how domestic waste handling, wastewater discharge, textile use, agricultural plastics, traffic-related deposition, recreation, and the fragmentation of larger plastic litter shape microplastic loads in rural and urban water bodies. It integrates current conceptual evidence with primary findings reported in Hamza Khalil's thesis on twelve water sites in Tehsil Pattoki, Punjab, Pakistan. The thesis used filtration, sodium-chloride density separation, drying, and stereomicroscopic observation at 40× magnification. Site-level reconstruction from the thesis tables identified microplastics at four locations: an urban swimming pool (6 MPs/L), an urban canal (10 MPs/L), a rural standing surface-water site (12 MPs/L), and an urban standing swamp-water site (15 MPs/L); eight filtration-plant, drinking-water, drain/nullah, and tap-water samples recorded zero particles. The overall mean was 3.583 MPs/L. When site values are paired with the distribution-area labels in the sampling table, the six urban sites total 31 MPs/L (mean 5.17), while the six rural sites total 12 MPs/L (mean 2.00). The thesis reports no statistically significant group difference ($F = 0.93$, $p = 0.35$), so the observed contrast must be interpreted cautiously. Results nevertheless suggest that open, stagnant, recreational, and canal waters are more exposed to direct human inputs than protected groundwater-derived supplies. The article argues that source control, drainage management, wastewater improvement, agricultural plastic recovery, and harmonized monitoring are more effective than downstream cleanup alone.

Keywords: microplastics, human activities, rural water bodies, urban water bodies, wastewater, agricultural runoff, plastic waste management, Tehsil Pattoki

INTRODUCTION

Plastics have become indispensable to packaging, clothing, construction, transport, agriculture, electronics, personal-care products, and household consumption because they are inexpensive, durable, lightweight, and versatile. These same characteristics make discarded plastics persistent environmental contaminants. Once released, large items are weakened by ultraviolet radiation, abrasion, temperature change, and biological activity and fragment into particles smaller than 5 mm. Primary microplastics are manufactured at small sizes, whereas secondary microplastics originate through the breakdown of larger materials. Both forms can travel through drains, wastewater, surface runoff, wind, irrigation networks, and river systems, allowing pollution generated by people in one location to appear in water bodies far downstream (Wang et al., 2019; Zhang et al., 2021). The rural–urban distinction is useful but should not be treated as a simple contrast between polluted cities and pristine countryside. Urban environments concentrate population, paved surfaces, traffic, laundering, industry, sewage flows, litter, and recreational activity. Rural catchments may have fewer people but can receive plastic mulch fragments, fertilizer and pesticide packaging, greenhouse films, irrigation-pipe residues, synthetic fibers in household wastewater, and urban waste transported through canals or drains. Hydrology, water-body openness, retention time, waste collection, sanitation coverage, and proximity to emission points may therefore explain contamination better than administrative labels alone. This article uses the Pattoki thesis as a local case study to examine human activities as drivers of microplastic pollution. The purpose is not to claim causation from a small observational dataset; rather, it is to connect measured site patterns with plausible source pathways documented in the literature, identify uncertainties, and develop practical priorities for rural and urban water governance. The analysis retains the thesis's reported measurements while correcting an apparent group-label inconsistency through transparent reconstruction from its site-classification and site-concentration tables.

Human Activities and Microplastic Source Pathways:

Human activity produces microplastics through both direct release and the gradual fragmentation of larger plastic waste. Mismanaged bags, bottles, food wrappers, disposable containers, and packaging accumulate along roads, markets, drainage channels, canals, ponds, and vacant land. Rainfall and street washing mobilize this litter into water, while sunlight and mechanical abrasion generate smaller fragments. Poor collection systems increase the residence time of plastics in exposed environments and repeatedly feed particles into water bodies. Accordingly, litter is not only a visible solid-waste problem; it is a continuing reservoir from which secondary microplastics are produced. Wastewater is another major pathway. Domestic laundering sheds synthetic fibers, personal-care products can contribute small polymer particles, and household dust containing synthetic material enters drains during cleaning. Where wastewater treatment is absent, incomplete, or bypassed, these particles pass directly to canals, streams, ponds, and low-lying stagnant water. Even effective treatment transfers much of the captured load to sewage sludge, which can reintroduce particles to land when applied as fertilizer. Fibers are frequently dominant in freshwater studies, reinforcing the importance of clothing, washing, and sewage pathways (Ding et al., 2019; Mahbub & Shams, 2022). Urban traffic and commercial activity contribute tire-wear particles, road-marking residues, synthetic dust, and packaging fragments that wash from impermeable surfaces during storms. Swimming pools and recreational waters receive fibers from swimwear, towels, cleaning materials, cosmetics, and nearby litter. Rural activities contribute through mulch films, nursery materials, irrigation pipes, feed and seed sacks, fertilizer packaging, and informal burning or burial of farm plastics. Weathered agricultural plastics can fragment in soil and move with wind erosion, field drainage, and irrigation return flows. Thus, differences in land use alter both the source mixture and the transport route, while connected waterways blur the geographic origin of pollution.

Rural–Urban Patterns and Exposure Conditions:

Urban water bodies are often located near dense emission networks. Impervious surfaces shorten the time between plastic release and arrival in drains; high population density increases consumption and waste generation; and open sewers or combined drainage systems convey particles efficiently. Stagnant urban waters can act as sinks because low flow promotes deposition and repeated local inputs accumulate. Conversely, rapidly flowing channels may dilute concentrations at a given moment while exporting large particle loads downstream. A single grab sample therefore reflects both emissions and short-term hydrological conditions. Rural systems exhibit different but equally important pressures. Agricultural land may receive plastic residues directly, and canals connect settlements, farms, roads, and markets. Standing ponds and surface-water depressions trap material carried by runoff and wind. Lower formal waste-collection coverage can encourage open dumping and burning, leaving partially degraded residues available for transport. Yet protected groundwater, filtered supplies, and covered tap-water systems may show low detectable loads because their pathways are less exposed to surface litter. These differences demonstrate why water-source type should be evaluated alongside rural or urban classification. Human exposure can occur through drinking water, consumption of aquatic organisms, food prepared with contaminated water, and inhalation or ingestion of deposited particles. Ecological receptors encounter microplastics through direct ingestion and trophic transfer. Experimental studies report physical obstruction, oxidative stress, altered immune responses, microbiome disruption, and other effects, although laboratory doses and particle types do not always match environmental exposures (de Sá et al., 2018; Kim et al., 2021). Risk assessment therefore requires not only particle counts but also size, polymer, shape, additives, associated contaminants, and realistic exposure duration.

Evidence from Tehsil Pattoki Water Bodies:

Khalil’s thesis sampled twelve water locations in Tehsil Pattoki on 12 June 2022. The sites represented filtration-plant water, drinking water, swimming-pool water, drain/nullah water, canal water, standing surface water, standing swamp water, and tap water. Samples were filtered; retained material was dried and mixed with 5 M sodium chloride for density separation; the light fraction was filtered and observed with a stereomicroscope at 40×. Particles were characterized by size, color, and shape, and the reported types included microfibers, microbeads, and microfragments. This approach provided a useful local screening survey but did not include polymer confirmation by FTIR or Raman spectroscopy, field blanks, laboratory blanks, or repeated seasonal sampling in the reported method. The site-level results were highly uneven. Four samples contained detected particles: S-3 swimming-pool water (6 MPs/L), S-6 canal water (10 MPs/L), S-9 standing surface water (12 MPs/L), and S-10 standing swamp water (15 MPs/L). The remaining eight sites recorded zero. The overall mean was 3.583 MPs/L, while the standard deviation was approximately 5.41 MPs/L, indicating strong site-to-site dispersion. The highest values occurred in exposed recreational, flowing surface, or stagnant waters rather than filtration-plant, drinking, or tap-water samples. This pattern is consistent with greater contact with litter, runoff, wastewater, atmospheric deposition, and repeated local use, but the observational design cannot identify which activity produced any individual particle. The thesis contains an internal labeling inconsistency. Its sampling table classifies S-1, S-2, S-3, S-4, S-6, and S-10 as urban and S-5, S-7, S-8, S-9, S-11, and S-12 as rural. Those classifications produce an urban total of 31 MPs/L and rural total of 12 MPs/L. A later rural–urban table places the same site sets under reversed headings, while narrative passages alternately state that urban and rural areas were more polluted. The present article uses the original site classifications because they are tied to location metadata. The thesis’s ANOVA result ($F[1,10] = 0.93$, $p = 0.35$) indicates that the group difference was not statistically significant. With only six sites per group, many zero values, and no temporal replication, the data support a descriptive site pattern rather than a general conclusion that all urban waters are more polluted than rural waters.

Ecological and Public-Health Significance:

Microplastics can be mistaken for food by zooplankton, invertebrates, fish, and other organisms. Ingestion may reduce feeding, damage tissues, alter energy allocation, and facilitate movement of particles through food webs. Particle surfaces can carry additives, metals, or organic contaminants, and biofilms may change particle behavior and biological interactions. Evidence of trophic transfer and experimental toxicity justifies precaution, but environmental risk varies substantially with dose, size, morphology, polymer chemistry, and co-contaminants (Botterell et al., 2019; Nelms et al., 2018). For people, the presence of particles in freshwater is a concern because water connects environmental contamination with food preparation, irrigation, livestock, fisheries, and drinking-water systems. However, particle detection alone does not establish a quantified health effect. The Pattoki results are especially limited for health inference because visual microscopy cannot confirm polymer identity or reliably characterize the smallest particles. The zero values should therefore be interpreted as "not detected by the applied method," not proof that the water was entirely free of microplastics. Stronger exposure assessment requires contamination controls, validated recovery tests, spectroscopic confirmation, smaller detection limits, and sufficient sample volume. The local pattern nevertheless provides a useful precautionary signal. Open standing waters recorded the two highest concentrations and may expose wildlife continuously. The canal can transport particles across urban and agricultural landscapes, redistributing pollution rather than retaining it at the emission point. The swimming-pool finding suggests that direct recreational use and maintenance materials merit attention. By contrast, the non-detects in protected supplies indicate that barriers such as source protection and filtration may reduce exposure, although this hypothesis should be tested through repeated and methodologically controlled sampling.

Prevention, Governance, and Research Priorities:

Effective control begins upstream. Municipalities should improve routine waste collection, install litter interception at drains, prevent dumping around canals and ponds, and maintain storm-water channels before seasonal rainfall. Wastewater strategies should combine expanded treatment with technologies capable of retaining fine particles and safe management of captured sludge. Public campaigns are most useful when paired with practical infrastructure, enforcement, and producer responsibility for high-leakage packaging. Recreational facilities can adopt fiber-reducing filtration, proper backwash management, and low-shedding cleaning materials. Rural interventions should establish collection and take-back systems for mulch, fertilizer bags, irrigation plastics, and livestock-feed packaging. Farmers need affordable alternatives to burning or abandoning films, while extension services can promote durable materials, retrieval after harvest, and controlled storage. Canal authorities should identify accumulation zones and coordinate cleanup with upstream municipalities. Because particles cross administrative boundaries, watershed-based governance is preferable to isolated rural and urban programs. Future studies in Pattoki should repeat sampling across dry and wet seasons, collect multiple replicates per site, standardize water volume and mesh size, use field and procedural blanks, and confirm polymers using FTIR or Raman spectroscopy. Researchers should record rainfall, flow, nearby population, land use, wastewater outlets, solid-waste sites, and agricultural plastic use so statistical models can test drivers rather than merely compare labels. Reporting should retain an auditable site codebook to prevent group-label errors. These improvements would allow the preliminary thesis findings to become a stronger basis for source apportionment, ecological risk assessment, and targeted policy.

Summary:

Human activities drive microplastic pollution through a linked chain of plastic production, everyday use, waste leakage, wastewater discharge, surface runoff, atmospheric deposition, agricultural inputs, and environmental fragmentation. Urban settings typically intensify sewage, traffic, consumption, recreation,

and storm-drain pathways, while rural settings add agricultural films, packaging, irrigation networks, weaker collection services, and contaminated inflows from upstream settlements. The resulting concentration in a water body depends not only on whether it is rural or urban but also on whether the source is open or protected, flowing or stagnant, connected to drainage, and repeatedly exposed to direct human use. The Pattoki thesis offers valuable site-level evidence. Across twelve samples, the mean concentration was 3.583 MPs/L; particles were detected in a swimming pool, canal, standing surface water, and standing swamp water, with a maximum of 15 MPs/L. Reconstructing the data from site metadata yields 31 MPs/L across six urban sites and 12 MPs/L across six rural sites, but the reported difference was not statistically significant ($p = 0.35$). Because the thesis contains reversed group labels in one table and contradictory narrative statements, its strongest conclusion concerns the higher loads in exposed surface waters, not a universal rural–urban ranking. Prevention should focus on the activities that release particles: improved solid-waste and wastewater services, drain and canal interception, recovery of agricultural plastics, better recreational-water filtration, and shared watershed governance. Monitoring must also improve through seasonal replication, contamination controls, polymer confirmation, and consistent site classification. These measures would turn a preliminary local survey into actionable evidence and reduce contamination before particles become dispersed, biologically available, and costly to remove.

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