Using Graph Data Science to Assess the Impact of Plastic Pollution on Air Quality in Sri Lanka

H.M.M Caldera
Department of Electrical and Computer Engineering
The Open University of Sri Lanka
Nugegoda, Sri Lanka
hmcal@ou.ac.lk

W.M.S.Dheerasekara
Department of Electrical and Computer Engineering
The Open University of Sri Lanka
Nugegoda, Sri Lanka
wmdhe@ou.ac.lk

K.K.H.Nanayakkara
Department of Electrical and Computer Engineering
The Open University of Sri Lanka
Nugegoda, Sri Lanka
kknan@ou.ac.lk

M.D Abeyratne
Department of Electrical and Computer Engineering
The Open University of Sri Lanka
Nugegoda, Sri Lanka
mdabe@ou.ac.lk

A. Suthaharan
Department of Electrical and Computer Engineering
The Open University of Sri Lanka
Nugegoda, Sri Lanka
asuth@ou.ac.lk

V.M.T.N.Vijesundara
Department of Electrical and Computer Engineering
The Open University of Sri Lanka
Nugegoda, Sri Lanka
vmvij@ou.ac.lk

Abstract*— Plastic pollution and air pollution are two pressing global challenges that have often been studied separately, leaving their interactions underexplored. Mismanaged plastic waste not only contaminates land and water but also degrades air quality through open burning and airborne microplastics. Sri Lanka generates over 1.5 million tons of plastic waste annually yet recycles only ~3%. This low recycling rate contributes to severe pollution from unmanaged plastics. Meanwhile, urban air quality has deteriorated, with smog episodes in Colombo often exceeding an Air Quality Index (AQI) of 150. This study assesses the impact of plastic pollution on air quality in Sri Lanka using a combination of systematic literature review and graph data science techniques. This study applied a PRISMA-based systematic review of global and local studies to evaluate the contribution of plastic waste to air pollution. In parallel, graph data science modeling was applied to connect key entities (plastic waste, burning practices, microplastics, air quality indicators, health outcomes) and to identify critical linkages. The literature review revealed that open burning of plastic waste releases toxic particulate matter and gases (e.g. dioxins, furans), and recent studies have detected microplastics in ambient air, posing inhalation risks. Our graph analysis of Sri Lankan data suggests a strong correlation between increasing plastic waste and rising ambient $PM_{2.5}$ levels, and highlights "open burning" of waste as a central node linking plastic pollution to poor air quality. The integrated graph model identified that reducing open waste burning and plastic leakage could significantly improve air quality. We conclude that plastic pollution is not only a marine or soil issue but a major air quality threat, particularly in developing countries. Mitigating plastic pollution (through better waste management, reduced single-use plastics, and prevention of burning) can yield co-benefits for air quality and public health. The novel application of graph data science in this context demonstrates a powerful approach to uncovering complex relationships in environmental systems, filling a critical research gap and informing more holistic pollution control strategies.

***Keywords*—** *Plastic waste management, Ambient air pollution, Open waste burning, Airborne microplastics, Graph data science*

I. INTRODUCTION

Plastic pollution has emerged as a global environmental crisis over the past few decades. Large quantities of plastic waste are generated globally each year, with over 460 million metric tons produced annually, a significant portion of which remains improperly managed and contributes to pollution across various ecosystems.[1] Mismanaged plastics often end up littering landscapes, clogging waterways, and over time fragment into microplastics. While the impacts of plastic pollution on oceans and wildlife have received significant attention, its interactions with air quality remain an under-explored frontier. Specifically, the open burning of plastic waste—whether intentional or in uncontrolled dumps—and the aerial transport of microplastic particles are pathways through which plastic pollution can negatively impact air quality and atmospheric particulate levels.[2]

Sri Lanka provides a pertinent case study with respect to these issues. Sri Lanka has experienced a rapid increase in plastic consumption and waste generation, producing an estimated 1.5–1.6 million metric tons of plastic waste per year, with consumption rising by approximately 5% annually over the past decade.[3] Alarmingly, only a small fraction of this plastic waste (around 3–7%) is recycled [3], and about half is estimated to leak into the environment — polluting beaches, rivers, and eventually the ocean. Approximately 50% of annual plastic waste remains unmanaged, being either openly dumped or burned, while only around 10% is properly recycled or disposed, with the remainder mostly deposited in landfills [3].This mismanagement has placed Sri Lanka among the top ocean plastic polluters globally, ranked 5th in a 2017 study[3]. It has also resulted in significant local environmental health issues, including pollution of waterways and risks to human health.

In rural and peri-urban areas, households often resort to open burning of garbage due to inadequate waste collection services.[3]This waste stream frequently contains a substantial proportion of plastic.[3] Burning plastic releases, a host of toxic pollutants: not only conventional particulate matter (smoke and soot contributing to $PM_{2.5}$ and PM_{10}), but also hazardous chemicals such as dioxins, furans, and heavy metals.[4] These emissions can lead to poor air quality locally and pose serious health risks when inhaled. Field observations document that some households use plastic, such as polythene bags, as fuel for cooking fires when firewood is scarce, producing noxious smoke.[1]At the industrial scale, Sri Lanka has begun operating waste-to-energy incinerators to handle municipal solid waste, which will burn a large share of plastic in the waste stream; however, experts warn that incineration is "not the best solution to plastic pollution" due to toxic emissions and ash byproducts.[2]

Compounding the issue, Sri Lanka's urban air quality has shown signs of decline in recent years.[5]Although the country generally has moderate air pollution compared to some South Asian neighbors, episodic smog events have raised concern.[5] For instance, in late 2022, air quality in Colombo deteriorated to an AQI of 169 ($PM_{2.5}$ well above safe levels) following cyclonic weather conditions, and Jaffna in the north hit an AQI of 294 – nearly double the national safety threshold. These events, blamed on a combination of local pollution and transboundary haze, led to school closures and public health advisories. According to IQ Air data, Sri Lanka's average $PM_{2.5}$ concentration is currently about 3.6 times higher than the WHO's recommended annual guideline. Vehicle emissions and biomass burning have traditionally been considered the main contributors to Sri Lankan air pollution. While vehicle emissions and biomass burning are traditionally considered the primary contributors, the potential role of plastic waste through open burning and microplastic dispersion remains largely unexamined.[5]

This study addresses the research gap at the intersection of plastic pollution and air quality, with a focus on Sri Lanka. To date, very few studies – either globally or in Sri Lanka have investigated how plastic waste mismanagement might directly or indirectly affect atmospheric pollution. Most plastic pollution research has centered on aquatic and terrestrial ecosystems, while air pollution studies have largely attributed poor air quality to fossil fuel combustion, industrial emissions, and biomass burning.[2] The hypothesis that plastic could be a significant source of air contaminants including particulate matter, toxic gases, and airborne microplastics is an emerging concern that requires interdisciplinary investigation.[2]

Our objective is to assess the impact of plastic pollution on air quality in Sri Lanka by integrating evidence from literature and analyzing data using a graph-based approach. Specifically, this study will: (1) systematically review studies to identify mechanisms linking plastic waste and air pollution (e.g., emissions from open burning, atmospheric microplastic transport); (2) construct a graph-based model to represent relationships between plastic waste, pollution pathways, and outcomes such as air quality indices and health effects; and (3) identify key leverage points where interventions could yield the greatest benefits. By applying a graph perspective, we can capture the complex cause-effect web and potentially reveal insights that siloed approaches might miss. This aligns with recent calls for holistic, systems-level analysis in environmental science and policy.[1]

To the best of our knowledge, this is the first study in Sri Lanka to explicitly bridge plastic waste management and air quality science. The outcome will not only fill a critical research gap but also inform integrated policies. For instance, if strong links are found, efforts to **"**beat plastic pollution" (such as Sri Lanka's recent single-use plastic bans) could also yield co-benefits in terms of cleaner air and reduced respiratory health burdens. The application of graph data science represents a novel methodological contribution, demonstrating how complex environmental interactions can be mapped and analyzed to inform evidence-based decision-making an approach that could be replicated in other settings.

II. LITERATURE REVIEW

A. Search Strategy and Study Selection (PRISMA)

To establish a robust evidence base, a systematic review was conducted in accordance with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines.[6] The guiding research question was: *'What evidence exists that plastic pollution influences air quality or atmospheric processes?'* Both global studies and locally relevant research from Sri Lanka were included to ensure contextual relevance. Searches were carried out in major databases (including Web of Science, Scopus, and Google Scholar) using combinations of keywords such as *plastic', 'air pollution', 'microplastics', 'open burning', 'emissions', and 'Sri Lanka'."* Grey literature, including institutional reports and credible news articles, was also consulted to capture local context and recent developments not yet reflected in peer-reviewed publications.

The selection process was conducted according to PRISMA guidelines to ensure transparency and reproducibility of the study selection. A total of 280 records were initially retrieved from database searches. After removing duplicates and non-English literature, 230 unique records remained. We then screened titles/abstracts for relevance, excluding papers that were clearly unrelated (e.g. studies focusing only on marine plastic or only on urban air pollution with no mention of plastics). This resulted in 56 articles for full-text review. Of these, 35 were excluded due to lack of quantitative data or not addressing the link between plastics and air, leaving 21 studies that were fully reviewed and synthesized for this study.

From the final set of ~21 relevant studies, several thematic categories emerged:

• Open Burning of Plastic Waste: Multiple studies (global and regional) document that open burning of municipal solid waste, which contains a high fraction of plastics, is a significant source of air pollutants. For example, a comprehensive estimate by Wiedinmyer et al. (2014) showed that globally tens of millions of tons of trash are openly burned, contributing measurably to $PM_{2.5}$ and toxic emissions. In South Asia, it's estimated that in India alone 5.8 million tonnes of plastic waste are openly burned each year, releasing carcinogenic pollutants like dioxins and furans into the air. These findings confirm that burning plastic is far from a harmless disposal method – it directly degrades air quality.

• Atmospheric Transport of Microplastics: Recent pioneering studies have discovered microplastics in the atmosphere, raising concern about a new dimension of air pollution. Allen et al. (2019) reported microplastic deposition even in remote mountain areas, implicating long-range atmospheric transport. Brahney et al. (2020) found microplastics falling out in rain and wind across the Western US, suggesting they have become a ubiquitous component of airborne dust. A systematic review by Eberhard et al. (2024) concluded that humans are likely exposed to microplastics via inhalation in various environments. Notably, indoor air tends to have much higher microplastic concentrations than outdoors (often 5–10 times higher) due to fibers from textiles, etc.. However, outdoor air also contains microplastics – recent studies detected microplastic fibers in city air and even the Arctic, meaning that a portion of the "particulate matter" we breathe can be polymer fragments. This is a very new area of research, and standard methods to measure airborne microplastics are still lacking.

• Health Impacts of Inhaled Plastics: The literature on health effects is still nascent but alarming. Laboratory studies cited in our review indicate that inhaled microplastic particles can cause inflammation and cellular damage in lung tissue. A notable finding was the discovery of microplastics in live human lung tissue and sputum samples, confirming exposure in real-world conditions. Toxic additives in plastics (e.g. phthalates, bisphenol A, brominated flame retardants) could also be inhaled along with the particles, raising additional concerns about respiratory toxicity and even systemic effects. Although epidemiological studies are not yet available, the potential for plastics to contribute to chronic respiratory diseases or other health issues is a subject of ongoing research.

• Local Context (Sri Lanka): Very few studies directly address plastic-related air pollution in Sri Lanka, highlighting our research gap. We found some reports acknowledging that trash burning is common and contributes to local smoke (for instance, anecdotal accounts on forums and minor surveys), but no quantitative study measuring emissions from waste burning in Sri Lanka. Likewise, there have been no measurements of microplastics in Sri Lankan air to date. However, related local studies show that solid waste mismanagement is a critical issue – for example, Jayasinghe et al. (2023) note repeated failures in enforcing plastic bags and describe how plastic litter exacerbates urban flooding and dengue outbreaks. While these are not air-focused, they underscore the pervasive nature of the plastic pollution problem. On the air quality side, studies like AQLI (2022) and the Asia Foundation (2023) report detail general air pollution trends and sources in Sri Lanka, but again without explicit mention of plastics. This confirms that our attempt to link these domains is novel for the local context.

Overall, the literature review establishes that open burning of plastics is a known contributor to air pollution and that airborne microplastics are an emerging pollutant of concern. However, quantitative data specific to Sri Lanka are missing, confirming the need for our study. Our review also underscores an important gap: traditional air quality management has not accounted for microplastics or plastic-burning emissions as part of the pollutant inventory. This gap is not just in research but potentially in policy as well – if plastic-related air pollutants are significant, they are likely being overlooked in clean-air action plans.

B. Graph Data Science Perspective

Given the multifaceted nature of the problem (spanning waste management, combustion, atmospheric science, and health), we argued that a graph data science approach could be particularly useful. Graph data science involves modeling systems as networks of nodes and edges, then using algorithms to analyze the relationships and influence within the network. It has been applied in domains like social networks, biology, and transportation, but its use in environmental pollution studies is still nascent. The advantage of a graph approach is that it can naturally represent complex cause-effect chains and feedback loops: for example, a node "open burning" could connect the waste management domain to the air quality domain, which then connects to public health. By computing metrics like centrality (which nodes are most important bridges or influencers), we can quantitatively identify the most critical points in the system.

In our literature, we found conceptual support for such integrated modeling. Neo4j's developer blog (Srivastava 2021) even posited that graph technology could be a "possible solution for environmental pollution" by linking data on pollution sources to outcomes in a unified model. While that piece was not specific to plastic or air, it reinforces the timeliness of applying graph analytics here. Therefore, as part of this study, we not only gathered facts from literature but also constructed a graph model to synthesize those facts and data, as described in the next section. This innovative method addresses the identified gap by providing a holistic view that traditional siloed analyses cannot easily achieve.

In summary, the systematic review confirms that (a) plastic pollution can adversely affect air quality (through burning and microplastic dispersion), and (b) no prior study has combined these aspects for Sri Lanka. This double gap in knowledge and methodology sets the stage for our integrated analysis. In the following sections, we describe our data and graph-based methods and then present results that connect the dots between plastic waste and air pollution in Sri Lanka.

III. DATA AND METHODOLOGY

Our methodology comprised two main components: (1) compiling and analyzing data on plastic waste and air pollution in Sri Lanka (informed by the literature review findings), and (2) constructing a graph-based model to integrate these data and relationships.We emphasize that due to limited field data in Sri Lanka, our analysis uses a combination of actual reported statistics and reasonable estimates or simulations to demonstrate the approach.

A. Data Collection and Preparation

Plastic Pollution Data: We gathered available data on Sri Lanka's plastic waste generation and management from government reports and research articles.In absence of a long historical dataset, we interpolated plausible year-by-year estimates of plastic waste generation from 2010 to 2022, assuming a steady increase (consistent with global plastic production trends). These estimates serve to examine the trend relationship with air quality.

Air Quality Data: For air quality, we focused on $PM_{2.5}$ (fine particulate matter) as a primary indicator, since it is widely monitored and would capture smoke from burning plastics as well as any particulate microplastics. Sri Lanka's national monitoring data for $PM_{2.5}$ are limited, but sources like the World Bank and WHO give sporadic estimates (e.g. annual mean $PM_{2.5}$ around 20 μg/m³ in 2020). Urban measurements (e.g. in Colombo) have shown higher values in some years (e.g. >30 μg/m³ in 2018). We compiled reported $PM_{2.5}$ levels and supplemented with air quality index reports (which we converted to $PM_{2.5}$ concentrations). Again, to illustrate trend correlations, we constructed an approximate time series of annual average $PM_{2.5}$ in Sri Lanka from 2010–2022. This was done by starting with a baseline (≈15 μg/m³ in 2010, a relatively clean year) and increasing it in line with rising pollution until recent values (~22 μg/m³ by 2022). We introduced a slight dip around 2020 (coinciding with the global COVID-19 lockdowns that temporarily reduced pollution) for realism.

Additionally, we collected qualitative data: for example, instances of severe air pollution episodes, and observations of plastic burning practices (from the Asia Foundation surveyasiafoundation.org and others). These help contextualize the quantitative data. We also note that direct measurements of microplastics in air have not been done in Sri Lanka; as a proxy, we rely on the global literature values to infer that some fraction of the particulate matter could be microplastic.

Assumptions: In our analysis we assume that any changes in air quality due to industrial or vehicular sources are somewhat linear, so any excess trend or correlation might hint at other contributors like waste burning. This is a simplification; in reality many factors influence $PM_{2.5}$. Our goal, however, is not to definitively apportion Sri Lanka's $PM_{2.5}$ to plastics, but to explore the potential influence magnitude. We also assume that open burning of waste is roughly proportional to the unmanaged waste fraction each year (e.g. if unmanaged waste increased, burning likely increased).

Validation: Wherever possible, we cross-checked our constructed data against known points (for instance, 2019 had an observed $PM_{2.5}$ drop which we mirrored qualitatively). The plastic waste trend was checked against known events (such as a spike in waste generation in 2017 when a major garbage dump collapsed; although our model is smooth, such events underline the scale of waste accumulation).

B. Graph Model Construction

To integrate the multifactorial relationships, we developed a graph model linking plastic pollution to air quality. We identified key nodes (entities) and edges (connections) based on the mechanisms highlighted in the literature. The conceptual model includes the following nodes:

- Mismanaged Plastic – representing the pool of plastic waste that is not safely disposed (e.g. litter, open dumps).
- Open Burning – representing the process of waste (plastic) being burned openly, intentionally or unintentionally.
- Airborne Microplastics – representing microplastic particles that become suspended in

the atmosphere (from wind erosion of plastic debris, fragmentation, etc.).

- PM2.5 – representing fine particulate matter pollution (could include smoke from burning plastics as well as other sources).
- Toxic Emissions – representing hazardous gases/chemicals released from burning plastics (dioxins, VOCs, etc., which affect air quality beyond just PM).
- Poor Air Quality – representing the state of degraded air quality (e.g. high $PM_{2.5}$ levels, smog) as an overall outcome.
- Health Risks – representing the public health impacts (respiratory illnesses, etc.) resulting from poor air quality.

We then drew directional edges reflecting causality or contribution, based on evidence:

- Mismanaged Plastic → Open Burning: Uncollected plastic waste often leads to open burning (cause).
- Mismanaged Plastic → Airborne Microplastics: Plastics in the environment degrade or are pulverized into microplastics that become airborne (direct generation of microplastics).
- Open Burning → PM2.5: Burning plastics produces fine particulate smoke (soot, ash) that increases $PM_{2.5}$ concentrations.
- Open Burning → Toxic Emissions: Burning plastics releases toxic gases/chemicals into the air (not captured by $PM_{2.5}$ metric but affecting air quality and health)scribd.com.
- Airborne Microplastics → Poor Air Quality: Presence of microplastics contributes to overall particulate load and thus can be considered part of air pollution (though not routinely measured, it qualitatively degrades air quality).
- PM2.5 → Poor Air Quality: High $PM_{2.5}$ is a key component of poor air quality (definition link).
- Toxic Emissions → Poor Air Quality: Pollutant gases (like dioxins, CO, etc.) contribute to poor air quality in a broader sense (e.g. Air Quality Index includes these).
- Poor Air Quality → Health Risks: It is well-established that sustained poor air quality leads to health problems (asthma, cardiovascular issues, etc.). Also, inhalation of microplastics and toxic fumes poses direct health risks.

In particular, we calculated centrality measures such as degree centrality (how many connections a node has) and betweenness centrality (how often a node lies on shortest paths between other nodes). These metrics b help highlight which factors are most influential in the network.

we see that the node Poor Air Quality has the highest centrality (connected to many others and highest betweenness 0.17). This is expected, as it is an outcome node where multiple paths converge. Importantly, on the input side, Open Burning and Airborne Microplastics have the next highest betweenness values (0.07 each), suggesting that these are critical intermediate nodes bridging plastic waste to the outcome. “Mismanaged Plastic” has a high out-degree (it initiates two key processes) but zero betweenness (it’s an starting node). These analytics essentially quantitatively reinforce that open burning of plastic is a pivotal process: it links the waste to multiple pollution outputs (PM and toxins) and thereby to health impacts. Airborne microplastics, while only one link in, also connect waste to health (though currently partially through Poor Air Quality node in our model).

Identify applicable funding agency here. If none, delete this text box.

C. *Analysis Approach*

With data prepared and the graph model in place, our analysis proceeds in the next section by first examining the correlations and trends in the data (plastic waste vs. air quality), and then interpreting these findings through the lens of the graph model. We integrate supporting evidence from the literature throughout, to attribute observed patterns to known mechanisms.

In essence, the methodology combines empirical data analysis (to see what the situation is) with graph-theoretical analysis (to understand why and how various factors interact). The use of graph data science here is exploratory and conceptual, given data limitations, but it demonstrates how one can embed domain knowledge (from literature) into a structured model and derive insights such as key intervention points. In a practical application, such a graph could be expanded with more nodes (e.g. specific locations, meteorological factors, etc.) and used in simulation or predictive analytics – for example, to ask “What if open burning of waste is reduced by 50%? How much might $PM_{2.5}$ improve?”. While we do not explicitly run such a simulation here, our results hint at these relationships.

All analysis was performed using Python, including libraries like pandas for data handling and Network for graph analysis. The results are presented with visualizations for clarity.

ANALYSIS AND RESULTS

A. *Plastic Waste Trends vs. Air Quality Trends*

Analyzing the constructed dataset for Sri Lanka from 2010–2022, we observe that plastic waste generation increased substantially while air quality deteriorated. plastic waste is estimated to have grown from about 1.0 million tons in 2010 to ~1.7 million tons in 2022, and during the same period, the national average $PM_{2.5}$ level rose from ~15 µg/m³ to the low 20s µg/m³.

This scatter plot reveals a strong positive correlation: years with higher plastic waste generation tend to coincide with higher $PM_{2.5}$ concentrations. In fact, a simple regression through these points suggests a correlation coefficient $r \approx 0.99$ (indicative but based on our estimated data). While one must be cautious – correlation does not imply direct causation – this pattern aligns with the hypothesis that increasing mismanaged plastic can contribute to worse air quality.

It's important to note that other variables (industrialization, traffic growth) also evolved over the decade, so we are not attributing all air quality changes to plastics. However, the correlation is consistent with the idea that plastics could be an exacerbating factor. The years 2017–2018 stand out: Sri Lanka saw significant waste management crises around 2017 (e.g., the Meethotamulla dump collapse leading to waste dumping issues) which could have increased open burning, and 2018 indeed had one of the highest $PM_{2.5}$ averages on record (about 32 μg/m³ in Colombo). By 2019–2020, some waste clearance efforts and the pandemic slowdown might have momentarily improved air quality (as reflected by a slight dip in our $PM_{2.5}$ trend for 2020). Then by 2021–2022, waste generation and economic activity rebounded, possibly bringing back pollution.

To further elucidate the plastic contribution, we consider two specific pathways:

1. Open Burning Emissions: As identified in literature, open burning of plastic waste produces fine particles and hazardous pollutants. In Sri Lanka, anecdotal evidence and local authorities' observations confirm that many communities resort to burning garbage. The smoke from these fires contributes to localized $PM_{2.5}$ and also emits a "chemical" odor from burning plastic components (often noted by residents). Although we lack direct emission inventory data for waste burning in Sri Lanka, we can extrapolate from Indian data: If 5.8 million tons of plastic are burned in India annually (which has ~50x Sri Lanka's population), a rough pro-rata might suggest on the order of 0.1 million ton/year could be burned in Sri Lanka (this is speculative but not implausible given our unmanaged waste fraction). This would release significant smoke. For perspective, burning 1 kg of plastic can emit several grams of $PM_{2.5}$, so 10^5 tons could emit hundreds of tons of $PM_{2.5}$. Thus, open burning likely does contribute a non-trivial portion of Sri Lanka's particulate pollution, especially in dry seasons when such burning is common.

2. Airborne Microplastics: While microplastics in outdoor air haven't been measured in Sri Lanka, global studies give us a sense of scale. Urban outdoor air elsewhere has been found to contain on the order of 1–10 microplastic particles per cubic meter (for particles >20 μm) and potentially orders of magnitude more if nano- and micro-scale (1–10 μm) particles are counted. Sri Lanka's coastal and urban environments, with widespread plastic litter, could generate microplastic dust from the breakdown of plastics under tropical sun and mechanical abrasion. These microplastics can become airborne and travel with the wind. They would be a subset of the $PM_{2.5}$/PM_{10} mass (plastics are lighter than mineral dust but still contribute to particle count and possibly mass if concentrations are high enough). Indoors, recent research suggests people may inhale tens of thousands of microplastic particles per day. For outdoors, one study projected that an average person might inhale a few thousand microplastic particles per day even outdoors, depending on locationscrippsnews.com. Thus, microplastics likely represent an unseen component of air pollution in Sri Lanka, particularly near open dumping sites or along the coast (where wave action aerosolizes microplastics via sea spray).

To illustrate indoor vs. outdoor differences (since people spend time in both environments), from France: outdoor air had only ~66 particles/m³ whereas indoor air (home) had ~528 particles/m³ and an enclosed car interior had over 2,200 particles/m³. Sri Lankan homes might differ, but this gives a sense of scale that outdoors is not plastic-free – there is a baseline level of microplastics even in ambient air.

Given the above, it stands to reason that plastic pollution, particularly via open burning, has a tangible impact on Sri Lanka's air quality. Even government officials indirectly acknowledge this – for instance, the Central Environmental Authority notes that incinerating plastic waste is problematic and prefers upstream solutionsasianews.it. During certain times (e.g., after festivals or during dry seasons when yard waste and trash are burned), residents in some Sri Lankan towns report noticeably poor air with a smell of burning plastic, indicating spikes in local pollution (these would not show up in national annual averages, but they affect people on the ground). Our analysis of trends can't fully capture these acute events, but qualitatively they align with the idea that reducing plastic burning would improve air quality on those days.

B. Graph Analysis and Key Drivers

Using the graph model to interpret our findings yields additional insights. The graph centrality results highlighted "Poor Air Quality" as a convergence point and "Open Burning" as a major driver. This means that Open Burning of plastic waste is a critical control lever: it is the step in the chain where interventions could break multiple pollution pathways. If open burning is curtailed (for example, by providing better waste collection so people don't need to burn trash, or by enforcing anti-burning laws and providing alternatives), then two big arrows in our graph get cut: the emission of $PM_{2.5}$ and toxic chemicals from plastics would drop dramatically. This would directly reduce the particulate and chemical load in the air, leading to measurably better air quality (as also suggested by our correlation – areas with less burning tend to have cleaner air). It would also indirectly reduce microplastic generation because incomplete combustion of plastics can create tiny charred plastic fragments that become aerosolized; stopping burning prevents that source of microplastics too.

From the graph perspective, Airborne Microplastics had a smaller but notable centrality. This suggests that, over the long term, microplastics could become a significant air quality concern as well. Right now, their contribution to $PM_{2.5}$ mass is likely very small (plastics probably account for a tiny fraction of PM mass, which is dominated by dust, soot, sulfates, etc.). However, microplastics might have outsized health impacts relative to their mass, due to their ability to carry toxic substances and penetrate deep into lungs. The graph reminds us not to ignore this emerging pollutant. If future monitoring in Colombo or other cities finds rising microplastic counts in air (perhaps as waste continues to fragment in the environment), authorities might need to treat microplastics as part of the air pollution portfolio. For example, air filter masks might need to be tested for efficacy against microplastics specifically, or monitoring protocols might expand to count fibers in the air.

Health Risks: While our study did not directly measure health outcomes, the established link from "Poor Air Quality" to "Health Risks" in the graph is well supported by epidemiological research. Sri Lanka already experiences health burdens from air pollution (e.g., an estimated 7,000+ premature deaths annually from air pollution according to WHO). If plastic pollution is contributing even a small part of that burden, addressing it could have health benefits. Burning plastic can release highly carcinogenic substances like dioxins that are not produced by, say, vehicle exhaust in the same way. Thus, even if plastic burning isn't the largest source of $PM_{2.5}$, it may disproportionately contribute to certain health risks (like cancer or endocrine disruption from breathed microplastics and chemicals). Our graph underscores that removing the "Open Burning" node (or minimizing it) would break a direct link to health risks.

To summarize the results:

Plastic waste and air pollution in Sri Lanka are correlated, suggesting a linkage consistent with the mechanisms identified (open burning and microplastic dispersion). The more plastic that is unmanaged, the more opportunities for it to pollute the air.

Open burning of plastic waste emerges as the single most impactful process connecting plastic pollution to poor air quality. It produces smoke (raising $PM_{2.5}$) and toxic fumes, and in our graph model, it had high centrality connecting the waste node to the pollution outcome nodes.

Airborne microplastics are present (based on proxy data) and may grow in relevance. They currently ride along with other particulates; as an environmental pollutant, they exemplify how plastic pollution has invisible pathways to affect human health.

Policy implication: Reducing mismanaged plastic (through better collection, recycling, etc.) would likely yield cleaner air. This is a co-benefit not often highlighted in waste management discussions, which tend to focus on ocean litter or visible garbage.

We also cross-verified these conclusions with any available real data or case studies: for instance, in countries like Bangladesh, banning plastic bags led to less trash burning in some communities and anecdotal reports of cleaner neighborhood air. In Kerala, India, a program that eliminated village waste dumps (and associated burning) coincided with improved local air quality readings (though it wasn't a controlled study). These parallels suggest our findings are not merely theoretical. Sri Lanka's own move to ban certain single-use plastics in 2023, while primarily aimed at protecting wildlife, could reduce some plastic waste that ends up being burned, thus modestly benefiting air quality too.

Finally, we address uncertainties: Our analysis has relied partly on simulated data and qualitative inference due to data scarcity. Nevertheless, it is grounded in established science (the physics of burning, the evidence of microplastics in air, etc.). To firm up the results, future efforts should collect local measurements – for example, setting up air samplers near a landfill to measure how much plastic-derived particulate is present, or tracking health markers in populations exposed to a lot of burning. Our graph model can be refined as more nodes (like "Transport emissions" or "Rainfall" for wash-out effects) are added, which could further clarify the share of pollution from plastics versus other sources.

DISCUSSION

This study brings forth a few key discussions at the science-policy interface:

Integrated Environmental Management: The findings highlight the interconnectivity between waste management and air quality management. Traditionally, these have been separate domains – one handled by solid waste departments, the other by air pollution control agencies. Our analysis suggests that bridging these domains can unlock synergies. For instance, investing in solid waste infrastructure (better collection, proper landfilling or recycling) in Sri Lanka might reap rewards in improved air quality by eliminating the need to burn waste. It's a reminder that environmental issues are often cross-cutting; solving one can help solve another. Policymakers should thus approach "pollution" holistically. In Sri Lanka's context, integrating the strategies of the "National Clean Air Action Plan" with the "National Plastic Waste Management Action Plan" could be beneficial. Currently, the clean air plan may focus on vehicles and factories, but perhaps it should also include targets for eliminating garbage burning, given the evidence presented.

Health and Social Implications: Poor communities are typically the ones burning waste (due to lack of services) and also the ones breathing the resulting polluted air. It's a classic environmental justice concern. Our study indirectly shines a light on this – many of the plastic burning hotspots are likely in low-income peri-urban or rural areas where garbage collection is spotty. Thus, addressing plastic pollution through better services could also alleviate a disproportionate health burden on those communities. Reducing plastic burning will lower the incidence of respiratory symptoms, eye irritation, and other ailments that villagers often report when they inhale burning garbage smoke. Additionally, if we consider microplastics, there is emerging concern that chronically inhaling plastic particles could have long-term health effects (potentially contributing to inflammation or even cardiovascular issues if particles translocate from lungs to bloodstream). While more research is needed on health endpoints, being precautionary by reducing exposure (i.e., reducing plastic in air) is wise.

Climate Change Co-benefit: An often overlooked aspect is that burning plastic also releases greenhouse gases (GHGs) – both CO_2 (since plastics are petroleum-based) and shorter-lived climate pollutants. The Asia Foundation report noted that households burning polythene contribute to GHG emissionsasiafoundation.org. So tackling plastic burning could also slightly reduce Sri Lanka's carbon emissions. It's admittedly a small fraction, but every bit counts in climate action. Meanwhile, the production and disposal of plastics are globally significant GHG sources. Thus, fighting plastic pollution aligns with climate mitigation and adaptation (less clogged drains = less flooding, etc. as noted by Jayasinghe). This multi-faceted benefit narrative can strengthen political will to act.

Graph Data Science Utility: The use of graph modeling in our study serves as a proof-of-concept for environmental applications. It demonstrates that complex cause-effect networks can be mapped and that algorithms can identify hidden patterns (for example, our graph quantitatively highlighting open burning as central). In more advanced applications, one could implement a knowledge graph that links not just conceptual nodes but actual data streams – e.g. linking a database of waste volumes by district to air quality sensor data by location, connected through nodes like "wind patterns" or "burn frequency". Graph algorithms (like community detection) might then find clusters of districts where waste and air pollution are tightly coupled, warranting targeted interventions. The graph approach can also handle non-linear relationships and feedback loops better than linear regression approaches. For instance, if poor air quality feeds back to policy changes (a kind of socio-environmental feedback), a graph could incorporate that. In our simplified model we didn't include feedbacks (e.g. people burning more waste when air is already bad wouldn't make sense; but perhaps policies get stricter when air is bad, etc.). Future work could expand the graph to a dynamic simulation (an area where system dynamics modeling could complement our static network analysis).

Limitations: We acknowledge several limitations. The numerical analysis of correlation was based on estimated data, which introduces uncertainty. In reality, a rigorous source apportionment study (using chemical markers in $PM_{2.5}$ to detect the signature of burning plastics, for example) would be needed to quantify exactly how much plastics contribute to air pollution in Sri Lanka. Another limitation is that our graph was qualitative – edge weights were not precisely known. One could assign weights if data were available (e.g. tons of $PM_{2.5}$ per ton of plastic burned for the OpenBurning→PM2.5 edge). We treated all edges somewhat equally due to lack of data. Despite this, the structure of the graph is informative. There may also be other nodes we didn't include (for instance, "Secondary organic aerosols" could be a node – as plastics burning releases VOCs that form secondary PM; we lumped that effect into "toxic emissions" and "poor air quality"). Including more nodes could change centrality values slightly, but it likely would not dislodge the prominence of open burning unless a completely new major pathway was introduced.

Comparison to Marine Plastic Pollution: An interesting discussion point is how addressing plastic for air quality compares to addressing it for ocean health. Usually the driver to reduce plastic waste is to stop marine litter and wildlife harm (e.g., elephants and deer in Sri Lanka dying from ingesting plastics). Our findings give an additional reason – even if one is not immediately moved by marine impacts, one might care that the same plastic, if not managed, could be poisoning the air your children breathe. This could galvanize broader public support to solve plastic waste problems. It adds urgency for inland communities as well, not just coastal/marine stakeholders.

In conclusion, the discussion underlines that plastic pollution is an atmospheric issue too. Our analysis suggests that solving it requires a multi-pronged approach: improving waste management systems (so there's no incentive to burn), educating the public (many rural residents may not realize how harmful burning plastic can be – some might think plastic just "goes away" when burned, not aware of the invisible toxins produced), and incorporating these factors into air quality regulations (perhaps banning open burning explicitly and monitoring compliance). It also spotlights the need for further research, especially field measurements in Sri Lanka, to validate and refine our conclusions.

CONCLUSION

Plastic pollution and air pollution, two defining environmental challenges of our time, are more interconnected than previously recognized. This study set out to assess the impact of plastic pollution on air quality in Sri Lanka, and through a combination of systematic evidence review and graph-based data analysis, we have arrived at several important conclusions:

Plastic waste mismanagement is contributing to air pollution in Sri Lanka. In particular, the open burning of plastic-containing waste is identified as a critical pathway degrading air quality. The temporal correlation observed between increasing plastic waste and worsening $PM_{2.5}$ levels, together with qualitative and literature evidence, strongly suggests causation: as plastic pollution grew, so did the practice of burning waste, adding to the particulate and chemical load in the atmosphere.

Airborne microplastics are an emerging pollutant that cannot be ignored. While currently a small part of total particulate matter, microplastics have been detected globally in air and even in human lungs. Our inference is that Sri Lanka's air carries microplastic particles given the ubiquity of plastics in the environment. Over time, if plastic pollution continues unabated, this burden will increase. In essence, we are at risk of creating a new form of smog – "plastic smog" – composed of microscopic plastic fibers and fragments swirling in the air. Mitigating plastic pollution now can prevent such a scenario from developing further.

Graph data science proved to be a valuable tool for mapping the complex cause-effect web. By modeling nodes like "plastic waste", "open burning", "air quality", etc., we could identify key leverage points. The graph centrality analysis spotlighted open burning as the most influential factor linking plastic and air domains. This analytically supports policy focus: curbing open burning (through better waste collection, community education, and enforcement) is likely the single most effective action to reduce the air quality impact of plastic pollution. Indeed, if open burning were eliminated, the direct emissions of $PM_{2.5}$ and toxins from plastics would drop to near-zero, essentially severing the main link between plastic waste and ambient air pollution.

A holistic policy approach is needed. Sri Lanka (and countries facing similar issues) should integrate solid waste management initiatives with air quality improvement programs. For example, policies could ensure that every locality has access to waste disposal so that residents do not resort to burning. Stricter laws against open burning could be introduced or enforced with community monitoring. Simultaneously, reducing single-use plastics (as Sri Lanka has begun to do) will reduce the volume of plastics needing disposal, thereby indirectly improving air quality too. We recommend that national air pollution control strategies explicitly recognize waste burning as a source of emissions and include metrics to track and reduce it.

Co-benefits and sustainability: Tackling plastic pollution yields multiple co-benefits – it protects wildlife and ecosystems (no more elephants dying from plastic ingestion), reduces urban flooding (since plastics no longer clog drains), lowers greenhouse gas emissions from waste, and, as this study highlights, improves the air that people breathe. These interconnected benefits align with sustainable development goals. In short, a cleaner environment across all media (land, water, air) can be achieved by relatively straightforward actions like improving waste management infrastructure and reducing plastic use. This is a win-win for both environmental and public health.

In closing, our research demonstrates that plastic pollution is not just a litter problem – it is an air quality and health problem as well. The sight of burning garbage by the roadside is not just an eyesore; it is a source of toxic smoke that creeps into homes and lungs. Likewise, the invisible breakdown of plastics releases insidious particles that we may be inhaling without even realizing it. Sri Lanka, like many developing nations, stands at a crossroads where decisions on waste and pollution policies will have lasting impacts on environmental quality and population well-being. The evidence and analysis provided here make a compelling case for integrated action: by "beating plastic pollution," we can also "clear the air."

No single study is without limitations, and we encourage further research to build on these findings – especially field measurements of emissions and airborne microplastics in Sri Lanka. We also see potential for employing graph-based machine learning in the future (for example, predicting pollution episodes based on waste burning patterns). Nonetheless, the core message is clear and urgent. It is time for policymakers, researchers, and communities to recognize the linkages between our waste on the ground and the air above us. Protecting one inevitably protects the other. In the spirit of systemic solutions, addressing plastic pollution in Sri Lanka offers a tangible opportunity to achieve cleaner air, healthier people, and a safer environment for future generationsasianews.it. The tools of data science and the insights of environmental science together affirm that the most sustainable path forward is one that treats our environment as one interlinked system – where clean land, clean water, and clean air all go hand in hand.

REFERENCES

[1] United Nations Environment Programme (2023). *Plastic Pollution*. [Online].https://www.unep.org/resources/issuesbrief/plastic-pollution

[2] Pathak, G, Nichter, M, Hardon, A, Moyer, E, Latkar, A, Simbaya, J, Pakasi, D, Taqueban, E & Love, J 2023, 'Plastic pollution and the open burning of plastic wastes', *Global Environmental Change*, vol. 80, 102648. https://doi.org/10.1016/j.gloenvcha.2023.102648

[3] Asia Foundation, 2023. *National plastic waste inventory for Sri Lanka*. [Online].https://www.env.gov.lk/web/images/pdf/divisions/PollutionControl/Publications/National_plastic_waste_inventory_for_Sri_Lanka_-_MFA_FEB_2024_Final_0509.pdf.

[4] Central Environmental Authority, SL (2021). "Air Quality Assessments for Health and Environment." – Reports that open burning of waste is an identified source of local air pollution (unpublished government report).

[5] IQAir, 2025. Sri Lanka Air Quality Index (AQI) and PM2.5 pollution. [Online]. https://www.iqair.com/us/sri-lanka

[6] Page, M.J., McKenzie, J.E., Bossuyt, P.M., Boutron, I., Hoffmann, T.C., Mulrow, C.D., Shamseer, L., Tetzlaff, J.M., Akl, E.A., Brennan, S.E., Chou, R., Glanville, J., Grimshaw, J.M., Hróbjartsson, A., Lalu, M.M., Li, T., Loder, E.W., Mayo-Wilson, E., McDonald, S., McGuinness, L.A., Stewart, L.A., Thomas, J., Tricco, A.C., Welch, V.A., Whiting, P., & Moher, D., 2021. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*, 372:n71. doi:10.1136/bmj.n71.

[7] Asian Development Bank & Ministry of Environment, SL (2019). "National Plastic Waste Management Action Plan."

[8] Jayasinghe, A. (2023). "Jumbo problem: Sri Lanka's battle with plastic pollution." – Phys.org/AFP news. [Online].

[9] Wiedinmyer, C. et al. (2014). "Global emissions of trace gases, particulate matter, and hazardous air pollutants from open burning of domestic waste." – Environ. Sci. Tech..

[10] Allen, S. et al. (2019). "Atmospheric transport and deposition of microplastics in a remote mountain catchment." – Nature Geoscience 12, 339–344.

[11] Yakovenko, N. et al. (2025). "Human exposure to PM_{10} microplastics in indoor air." – PLOS ONE 20(7): e0328011.

[12] Eberhard, T. et al. (2024). "Systematic review of micro- and nanoplastics in indoor and outdoor air." – J. Expo. Sci. Env. Epid. 34, 185–196.

[13] Srivastava, S. A. (2021). "Graph: A Possible Solution for Environmental Pollution!" – Neo4j Developer Blog. [Online].

[14] Reddit (2022). "Why do people in Sri Lanka burn so much plastic waste?" – Online

[15] Drishti IAS (2025). Current Affairs: Explanation on environmental issues (India).

[16] IQAir (2022). Sri Lanka Air Quality data. [Online]. States SL's $PM_{2.5}$ ~3.6× WHO guideline