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COLLABORATIVE DIALOGUE ON SUSTAINABLE URBAN HEALTH SYSTEMS

Urban Plastic Waste and Microplastic Pollution: Emerging Health Risks and Integrated Management Strategies

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Abstract

Plastic pollution, particularly microplastics, is a serious issue in Malaysia due to its hidden health risks and poor waste management. This article focused on current trends, challenges, and impacts of urban plastic waste and microplastics, how different groups like industries, the government, and the public contribute to the problem, and exploring potential solutions. The findings revealed several key themes. First, there is weak enforcement of existing plastic regulations, making it easier for plastics to pollute the environment. Second, most households do not separate waste at the source, which complicates recycling efforts. Third, awareness about the dangers of microplastics is low among the public, leading to less responsible waste disposal. Several barriers to solving this issue were also identified. The infrastructure for waste collection and recycling is inadequate, making proper waste management difficult. There is over-reliance on informal recycling systems that are often not effective or sustainable. Furthermore, current biodegradable plastic options are not a complete solution unless the necessary facilities are available to properly handle them. Many people noted that without proper disposal infrastructure, biodegradable plastics can still end up polluting the environment. Most stakeholders agreed that solving plastic pollution requires a collective effort. Everyone from workers and industries to government agencies and citizens needs to work together. Education and awareness programs were seen as vital to changing behaviours. Additionally, effective communication and public incentives can encourage responsible waste disposal and recycling. The article recommends improving waste laws, offering incentives to motivate proper waste management, and increasing education about the harms of plastic pollution. Overall, these efforts can help create a cleaner, healthier, and more sustainable environment for Malaysia, protecting both the ecosystem and public health.

Keywords: *plastic waste, microplastic, recycling, integrated management*

INTRODUCTION

Plastic waste generation in Malaysia increased significantly due to increasing consumerism. According to Zanuri, N.M. (personal communication, June 19, 2025), recent studies have revealed alarming trends in plastic waste generation across Malaysian cities, with Penang emerging as a critical hotspot. Malaysia generates approximately 1.17 million tonnes of plastic waste annually, with only 24% being recycled (Praveena et al., 2023). Urban centers like Kuala Lumpur, Penang, and Johor Bahru contribute disproportionately, with Penang alone accounting for 11.2% of national plastic waste. Microplastics were found abundant in marine, coastal and estuarine areas. Estuaries area is recognized as pollutant sinks as they can filter riverine input before releasing it into the ocean (López et al., 2021).

Studies have found alarming concentrations of microplastics, including plastic fragments, synthetic fibers, microbeads, and films, which are present in surface water and sediment samples, particularly near densely populated residential zones, industrial discharge points, and commercial areas such as wet markets (Karbalaei et al., 2019; Lim et al., 2022). These particles primarily originate from the breakdown of single-use plastic packaging, synthetic textiles released during washing, and personal care products containing microbeads, all of which enter the river system through open drains, greywater discharge, and stormwater runoff. The absence of efficient solid waste separation at the household level, combined with the increase of plastic waste from informal dumpsites and landfills, further exacerbates the situation. Moreover, flood events and inadequate infrastructure maintenance have accelerated the transport of plastics from urban surfaces into waterways. This continuous input of microplastics not only compromises riverine ecosystems but also poses emerging health risks, as these particles accumulate in aquatic organisms that are part of the human food chain.

This article aims to discuss the growing issue of plastic waste and microplastic pollution in urban areas, highlighting the collaboration between key stakeholders such as local authorities, industry, academia, and civil society. As plastic waste continues to affect our environment and public health, there is an urgent need to explore practical, integrated solutions. Thus, the objectives of this article are as follows: to understand the current trends, challenges, and impacts of urban plastic waste and microplastics (1), to identify emerging health risks linked to microplastic exposure in urban environments (2), and to discuss cross-sector strategies and collaborative actions that can improve plastic waste management.

TRENDS IN PLASTIC WASTE

In developing and middle-income countries, the increase in plastic use and waste production has been driven by rapid urbanization, rising income and evolving consumer lifestyle. Malaysia is among the top plastic consumers in Southeast Asia, with an estimated 1.07 million tonnes of plastic waste generated annually, and nearly half of that comprising single-use plastics (KASA, 2021). Most of this waste comes from urban households, retail packaging, and food delivery services, which saw a spike during the COVID-19 pandemic due to increased dependence on e-commerce and takeaway food (Sharma et al., 2020).

Figure 1 highlights the global plastic production has increased dramatically in the mid-20th century since the massive production of plastic due to rapid urbanization and economic growth (Long et al., 2022). With the size as smaller than five mm in diameter (<5 mm), it means that most microplastics are difficult to identify with the naked eye (Barboza & Gimenez, 2015). Microplastics are present in a variety of products such as cosmetics, synthetic clothing, plastic bags, and bottles. Major production is occurring in Asia which contributes 49% from worldwide output with China being the largest producer (28%) followed by Europe and North America (19%) each (KASA, 2021).

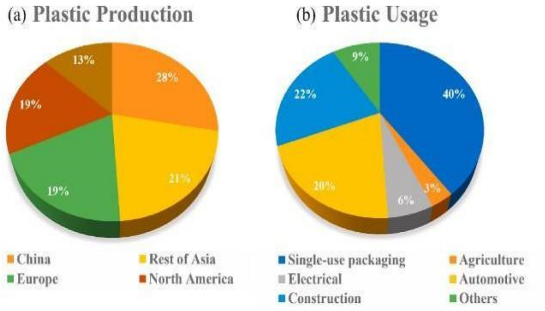

Figure 1. Statistics of (a) worldwide plastic production; (b) plastic usage sectors.

Bahari, A. (personal communication, June 19, 2025) shared that Malaysia's plastics industry has shown consistent growth, with total turnover rising from RM 61.44 billion in 2023 to RM 64.78 billion in 2024. Exports also increased from RM 16.10 billion to RM 17.34 billion during the same period, underscoring the nation's strong position in the regional plastics market. However, this growth has also led to escalating challenges related to plastic waste management. Bahari, A. (personal communication, June 19, 2025) added that approximately 5 million tons of domestic waste are generated annually, with plastic waste accounting for 2 million tons where most of which originates from household sources.

WASTE SEGREGATION AND RECYCLING

Plastic waste segregation and recycling are essential components of sustainable solid waste management, particularly in urbanized and rapidly developing countries like Malaysia. Effective segregation at source, where waste is separated into different categories such as recyclables, organics, and general waste plays a critical role in enhancing recycling rates, reducing landfill use, and minimizing environmental pollution (Nguyen et al., 2021).

Separation at source is always the prime challenge. Behaviour change is needed to enforce the culture. Currently, in Malaysia, waste segregation is mostly done by formal and informal waste facilities. Formal sectors include waste management companies such as SWCorp, SWM, and KDEB, while informal sectors include scavengers and collectors. Sha'aban, A.K. (personal communication, June 19, 2025) observed that waste segregation and recycling may not be regarded as highly valued work, yet the financial returns render it worthwhile. It is a trade secret that is well-kept among waste recyclers. Aluminium is the most expensive recyclable, priced at RM 120 to RM 150 per metric tonne, followed by paper and scrap iron. Plastic, on the other hand, is on par with aluminium since it can be recycled into many products. For example, mixed plastic waste can be recycled into polyester fibre and HDPE pellets and sold at higher prices. Malaysian Plastic Manufacturer Association (MPMA) is encouraging better infrastructure to support recycling, such as expanding Material Recovery Facilities (MRFs), creating more drop-off and collection points, and investing in modern sorting technologies.

Lee, L.S., (personal communication, June 19, 2025) highlights that while the recycling business is a good option for

waste segregation, it depends on who is operating them. If the business is left entirely on scavengers and informal sectors, most of them are operating without considering the environmental impact. Segregation of waste needs a collaboration with many stakeholders (Figure 2). When it comes to the waste business, there is no effort in integrating collection, disposal, and treatment under one scheme. All these elements must be integrated first before enforcing the law of making separation of waste at source mandatory. Infrastructure alone is not enough as public participation is needed. Waste that is sent to recycling facilities needs to be washed beforehand to prevent contamination that can damage recycling equipment, reduce the value of recyclables, and compromise the quality of the final product. Bahari, A. (personal communication, June 19, 2025) emphasizes that the culture of separation of waste at source needs some time, but it is not an excuse as it can be started as small as at home.

Figure 2. Plastic waste recycling process.

OVERCOMING THE CHALLENGES IN PLASTIC WASTE MANAGEMENT

One of the key programs identified is Operation Clean Sweep (OCS). This will prevent plastic spills during transport and manufacturing. Sha'aban, A.K. (personal communication, June 19, 2025), shared their Plastics Neutrality Masterplan 2024– 2030 helps a "circular economy". This is where plastic is reused instead of wasted through tax benefits, research on recyclable materials, and enforcement of stronger rules for producers. Lee, L.S. (personal communication, June 19, 2025) added that businesses must take full accountability towards their packaging waste by following Extended Producer Responsibility (EPR) practices, which matches the national policy suggestions (Abu Bakar, Mohamed, & Kishita, 2025). However, one significant issue is that these plans are not always backed by enforceable laws (Kamaruddin et al., 2022). Bahari, A. (personal communication, June 19, 2025), said they are working with other agencies to come up with better design regulation and framework so that plastic products are easier to recycle. This idea fits well with the concept of "Design for Disassembly," where products are built to be taken apart and recycled more easily (Zainu & Songip, 2021).

Researchers are also playing a part in countering this challenge. Researchers are contributing to the effort to overcome the obstacle as well. Zanuri, N.M. (personal communication, June 19, 2025) highlights the active effort in studying microplastics that end up in oceans and seafood. This will further help industries find cleaner ways to produce goods. In fact, microplastics were recently found in fish caught off Malaysia's east coast, showing that this is also a food safety issue (Nawawi et al., 2024). Environmental groups agree that a change in behaviour is needed. Zaki, M.R.M (personal communication, June 19, 2025) emphasizes that the issue is not just about plastics. However, it is about the behaviour of people, on how they use and throw it away. Weng, D.X. (personal communication, June 19, 2025), explained that people respond better when there are rewards. She gave an example: aluminum cans are rarely littered because they can be sold. If plastic bottles had a return value like RM0.20 each, there would be more people who would recycle them.

In rural and low-income areas, lots of people want to do better but lack alternatives. That is why improving infrastructure and making sustainable options affordable is so important to overcome this microplastic challenge (Kamaruddin et al., 2022). Although Malaysia has plans in place, such as the Zero Single-Use Plastics Roadmap and the Plastics Sustainability Roadmap, many of the stricter initiatives, such as banning plastics and mandating EPR, will not be implemented before 2030. Pemandu Associates (2024) in their articles highlighted the urgent need for stricter laws. They cited Japan's model, which requires corporations to adhere to tougher guidelines for product design, recycling, and plastic consumption.

According to Dyjack, D. T. (personal communication, June 19, 2025) environmental public health practice in the United States has undergone a transition for the past few years. Employing the metaphor of an isthmus, he describes this transition as movement from a traditional compliance-based approach to conformance-based approach by the year 2025. Conformance refers to situations where the absence of enforceable regulations, where a professional judgment becomes important. In the issue of microplastics, regulatory standards have not yet been established. Thus, the judgement and expertise of environmental public health professionals are important in addressing this issue.

CURRENT RESEARCH ON MICROPLASTICS

A study conducted by Tan & Mohd Zanuri (2023) showed Seberang Perai has the highest microplastics waste compared to other areas, and this may be due urbanization and industrialization. Zaki et al. (2021) also showed an increase of microplastics in Klang River, Malaysia due to urbanization. In addition, agricultural soil in the Klang Valley also detected microplastics with concentrations from 1.5-6.0 particles/kg, which has potential as a source of microplastics pollution other than water (Praveena et al., 2023; Noor et al., 2024). A study on four species of marine fish in Northwest Peninsular of Malaysia showed 100% of the samples contained microplastics which have size <5 mm. Most microplastics found in fish guts were fragment type and the content differed between species and *Sardinella fimbriata* (Tamban) was the highest (Foo et al., 2022).

Figure 3 illustrates that there were four (4) morphological shapes of microplastics; fibre, fragment, bead, and film (Zaki et al., 2024). The most common type of microplastics dominant was fibres and foam (polystyrene) (Zaki et al., 2021; Tan & Mohd Zanuri, 2023). Furthermore, primary polymers compositions of microplastics were polypropylene (PP), polyethylene (PE) and polyester (Zaki et al., 2021). In terms of size of microplastics, most studies stated the size of it was between 300 – 1000 µm, while small microplastic (<300µm) were dominated (Zaki et al., 2023). Microplastics such as foam and fibre will undergo substantial mechanical and oxidative degradation. Besides, tidal influence and prolonged exposure to sunlight were factors that enhance degradation of plastics to microplastics (Tan & Mohd Zanuri, 2023).

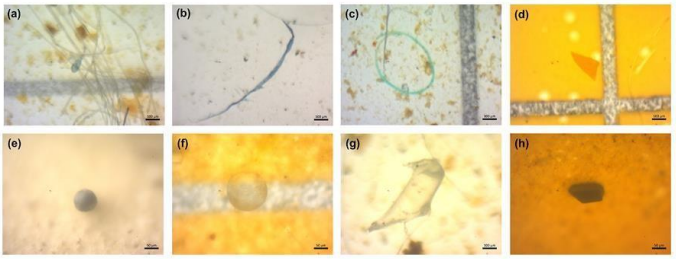

Figure 3. Microscopic images captured by stereomicroscopy show suspected microplastics from the surface of water, consisting of fibers (a− c), film (d), beads (e,f), and fragments (g,h) (Zaki et al., 2024).

In a study by Praveena et al. (2022), Fourier Transform Infrared Spectroscopy (FTIR) was employed to identify the polymer types of microplastic particles in bottled water samples. The analysis revealed the presence of polyethylene terephthalate (PET) and polypropylene (PP) as the predominant polymers, based on characteristic peaks observed at 630–850 cm^{-1} (C–CH_3 stretching), 1000–1300 cm^{-1} (C=O stretching), 1760–1670 cm^{-1} (C=O stretching vibration), and 2760–2970 cm^{-1} (CH_2 /CH_3 stretching). The detection of PET and PP suggests that the microplastics likely originated from packaging materials such as bottle bodies and caps.

Praveena et al. (2022), also estimated the daily intake (EDI) of microplastics through bottled water consumption for both adults and children, using low (8 particles/L) and high (22 particles/L) concentration scenarios. For adults, the estimated daily intake (EDI) ranged from 0.068 to 0.19 particles/kg/day, while for children, it ranged from 0.089 to 0.25 particles/kg/day. These values were calculated based on ingestion rates adapted from (Vieux et al., 2020). Although the EDI values are relatively low, the presence of microplastics in bottled water remains a concern, as leaching of plastic additives such as plasticizers, stabilizers, pigments may pose health risks through inflammatory or toxicological effects.

HEALTH IMPLICATIONS OF MICROPLASTIC EXPOSURE

This emerging contaminant has been detected and prevalent in various components of an ecosystem including water, sediment and biota. Recent studies confirm microplastics are pervasive across Malaysia's urban environments, with airborne particles (50-200 MPs/m³) in cities, contaminated drinking water (4-50 MPs/L), and seafood (72% of sampled fish containing microplastics). Zanuri, N.M. (personal communication, June 19, 2025) revealed that most dangerous microplastics are <10µm, which can cross biological barriers and carry adsorbed toxins like heavy metals and polychlorinated biphenyls (PCBs). These particles become concentrated in the food chain starting from plankton to fish and lastly to humans. It has emerged as an environmental pollutant and can enter the human body via ingestion, inhalation and dermal contact which gives implication to human health.

Microplastics were present in human tissues including placenta, blood, gastrointestinal tract, lungs and reproductive organs due to their diverse sizes, types shaped and surface (Luo et al., 2025). However, toxic effects and their mechanisms have not been fully understood. Prata et al. (2020) highlighted health impacts due to microplastics were cardiovascular risk, obesity, diabetes, prostate, and breast cancer as well as neurodevelopmental disease. Besides, contamination of microplastics in the female reproductive system affects the development of the fetus (Ali-Hassanzadeh et al., 2025). In Penang, it was found that mackerel showed 4 times higher microplastics loads than their prey (Foo et al., 2022). Health risks include intestinal inflammation from ingestion, lung damage from inhalation, and potential DNA damage from chronic exposure. Though most studies are still in early stages, microplastics may cause inflammation, oxidative stress, gut disruption, and hormone-related issues due to leached chemicals like bisphenol A (BPA) (Papp et al., 2022; Grzelak, 2024; Kibria, 2024).

POLICIES AND STAKEHOLDER ACTIONS FOR SUSTAINABLE PLASTIC WASTE MANAGEMENT

MPMA plays a key role in supporting national policies to align with desired objectives. Working closely with various authorities, they actively participate in the development and implementation of regulations that promote good waste management and recycling. Malaysia is also involved in the ongoing negotiations of the Global Plastics Agreement, demonstrating their commitment to addressing global environmental challenges.

In Malaysia, significant progress has been made in improving its waste management system. Key regulatory measures include the mandatory implementation of Extended Producer Responsibility (EPR), source segregation (SAS), and the use of Material Flow Analysis (MFA). This is essential to track accurate recycling rates and ensure that targets for waste reduction and resource recovery are met. Further efforts are aimed at supporting the governance of the informal recycling sector, ensuring better organization and efficiency in recycling practices. In addition, Malaysia is moving towards halal standards for recycled plastic products and mandating product labelling to indicate recyclability. Plans are also underway to expand chemical recycling infrastructure and standardize certification and ratings for recycled content.

Sha'aban, A.K. (personal communication, June 19, 2025) emphasised that the most pressing issue in waste management today is source segregation. He added that it is important to enforce laws that mandate this practice. A replicable model such as the one already in place in Ara Damansara, Kuala Lumpur, where every Wednesday is set aside for recycling collection, a collaboration initiative by Nestle and MBPJ could serve as a benchmark (Satu Arah Untuk Ara, n. d). In this sentiment, Lee, L.S. (personal communication, June 19, 2025) also added that it is important for all stakeholders to work together to enforce existing laws that mandate source segregation. He also supported concerted efforts to resolve the issue of plastic waste, starting with strict and sustained enforcement. Bahari, A. (personal communication, June 19, 2025) further added that instilling a community culture of waste management would take time, but it was a necessary step. In line with Malaysia's National Blue Economy Action Plan, the country has made significant efforts towards a sensible and responsible approach to managing plastic waste. As part of this initiative, the EPR program ensures that manufacturers are responsible throughout the entire life cycle of their products, from production from the factory to recycling and disposal.

To make the EPR programme a success, Malaysia collaborated with key organisations, such as the Design Council of Malaysia (MDM) and the Standards and Industrial Research Institute of Malaysia (SIRIM), to create an integrated framework for the industry sector. This framework guides manufacturers in producing products that comply with the right standards, promote recycling, and reduce environmental impact. The basic component adopted in this regulatory framework is Act 672: Solid Waste Management and Public Cleansing Act 2007. This Act regulates the management of scheduled waste and public cleaning activities, setting guidelines and standards to ensure proper segregation, recycling, and disposal of waste. The

enforcement of this Act reinforces Malaysia's commitment to best waste management, as well as providing a legal foundation that encourages innovation in product design and waste reduction efforts from industry.

To effectively handle the issue of microplastics, Dyjack, D. T. (personal communication, June 19, 2025) proposed four (4) key actions can be practiced by environmental public health professionals to address this challenge effectively; (1) identify high-risk populations include those live in near to waterways, coastal areas and individuals with high seafood consumption which have potential contains microplastics; (2) translate science into actionable insights, by explaining the health implications of microplastics and highlighting on the need for monitoring and mitigation of microplastics; (3) collaborate with other agencies and policymakers to develop evidence-informed policies for mitigating the risks and (4) serve as effective and trusted risk communicator in communities to encourage informed dialogue and advocacy. These actions, he emphasized, can and should be implemented immediately by professionals to address the risks of microplastics.

CONCLUSION

Microplastic pollution in Malaysia is a big problem caused by poor waste management, low recycling, and a lack of public awareness. The discussion showed that everyone agrees microplastics harm not just the environment, but also human health. This is especially alarming for urban areas with high waste. It affects people's well-being, ecosystems, and Malaysia's reputation. Thorough research is needed to discover where the microplastics come from in rivers and food, and to check how well public education efforts work. Practical steps such as better waste separation, financial rewards for recycling, and stricter laws on company responsibility for waste are recommended. Education should reach schools, media, and communities to promote healthier, sustainable living. Solving this issue needs collaborative efforts from the government, industry, and people, all working together with clear, achievable goals to create a cleaner, healthier future for Malaysia.

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