



UNIVERSITI PUTRA MALAYSIA

***OCCURRENCE AND DISTRIBUTION OF MICROPLASTICS IN URBAN
SOIL FROM CYBERJAYA, SELANGOR***

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SOIL FROM CYBERJAYA, SELANGOR**

BY
NIK MUNIRAH BINTI NIK MOHD ZAIDI

**Thesis submitted in fulfilment of the requirement for the degree of Bachelor of
Science in Environmental and Occupational Health with Honours from the
Faculty of Medicine and Health Sciences, Universiti Putra Malaysia**

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ABSTRACT

OCCURRENCE AND DISTRIBUTION OF MICROPLASTICS IN URBAN SOIL FROM CYBERJAYA, SELANGOR

NIK MUNIRAH BINTI NIK MOHD ZAIDI

Background: Microplastics are widely acknowledged as one of the most severe environmental threats, and it have been widely reported in marine environments for the past decades. Microplastics pollution of marine originates mostly from terrestrial sources; hence evidence of MPs in this system cannot be ignored. Nonetheless, there is inadequate information on Malaysia's prevalence of microplastics in urban soil. **Objective:** This study aims to provide information on microplastics pollution in the urban area (Cyberjaya, Selangor). **Methodology:** A total of 25 urban surface soil samples consisting of five (5) land use: construction area (CU: n=2), commercial area (CO: n=11), residential area (RA, n=4), roadway (RW: n=6), and vacant land (VL: n=2) were collected from the urban area of Cyberjaya, Selangor in September 2021. Microplastics were detected in the soil samples using NaCl hypersaline solution. Microscopic imaging and Fourier-transform infrared spectroscopy (FTIR) were used to identify the extracted particles' morphological properties (size, color, shape, and polymer composition). **Result and Discussion:** All soil samples identified yielded particles ranging from 0.30 to 1.15 particle/g. It was CO (6.61 particle/g) that had the highest concentration, followed by RW (3.46 particle/g), RA (2.11 particle/g) and CU (1.37 particle/g), and VL (0.65 particle/g). Particle size with a range from 0 μm to 4543.47 μm was identified. The shortest microplastics particle was from the commercial area (0 μm), and the longest came from vacant land (793.775 μm). Furthermore, various colors were observed in the urban soil samples, with black (32%) being the most prevalent and followed by red (21.40%), grey (20.90%), green (11.35%), transparent (9.67%), blue (2.79%), yellow (1.12%), purple (0.56%), and white (0.19%). The most common particle extracted was fibre (52%), followed by fragment (37%), film (22%), pellet (6.7%), and foam (1.3%). Plastic polymers discovered in the recovered particles from urban soil included polycarbonate (PC), polystyrene (PS), and polyvinyl chloride (PVC), indicating that the particles originated from potential sources such as debris from littering behavior, tire and road wear, abrasion of road marking, construction materials, shoe sole wear and tear or atmospheric transport. **Conclusion:** Urban soil samples from Cyberjaya, Selangor, Malaysia, were found to contain microplastics. More research is needed to understand better how human activities and environmental factors may influence microplastics accumulation in urban soil. Toxicological tests are necessary to further understand microplastics toxicity to the environment.

Keywords: Microplastics, land use, urban soil, Cyberjaya

ABSTRAK

KEJADIAN DAN PENGEDARAN MIKROPLASTIK DI TANAH BANDAR DARI CYBERJAYA, SELANGOR

NIK MUNIRAH BINTI NIK MOHD ZAIDI

Latar Belakang: Mikroplastik diakui secara meluas sebagai salah satu ancaman alam sekitar yang paling teruk. Mikroplastik telah dilaporkan secara meluas dalam persekitaran marin sejak beberapa dekad yang lalu. Namun begitu, terdapat maklumat yang tidak mencukupi tentang kelaziman mikroplastik di Malaysia di dalam tanah bandar. **Objektif:** Kajian ini bertujuan untuk memberi kefahaman tentang pencemaran mikroplastik di kawasan bandar (Cyberjaya, Selangor). **Metodologi:** Sebanyak 25 sampel tanah permukaan bandar yang terdiri daripada lima (5) guna tanah: kawasan pembinaan (CU: n=2), kawasan komersial (CO: n=11), kawasan kediaman (RA, n=4), jalan raya (RW: n=6) dan tanah kosong (VL: n=2) telah dikutip dari kawasan bandar Cyberjaya, Selangor pada September 2021. Mikroplastik dikesan dalam sampel tanah menggunakan larutan hipersaline NaCl. Pengimejan mikroskopik dan spektroskopi inframerah-transformasi Fourier (FTIR) digunakan untuk mengenal pasti sifat morfologi zarah yang diekstrak (saiz, warna, bentuk dan komposisi polimer). **Keputusan dan Perbincangan:** Semua sampel tanah mengenal pasti zarah terhasil antara 0.30 hingga 1.15 zarah/g. Ia adalah CO (6.61 zarah/g) yang mempunyai kepekatan tertinggi, diikuti oleh RW (3.46 zarah/g), RA (2.11/zarah/g) dan CU (1.37 zarah/g), dan VL (0.65 zarah/g). Saiz zarah dengan julat dari 0 μm hingga 4543.47 μm telah dikenalpasti. Zarah mikroplastik terpendek adalah dari kawasan komersial (586.082 μm), dan yang terpanjang datang dari tanah kosong (793.775 μm). Tambahan pula, pelbagai warna diperhatikan dalam sampel tanah bandar, dengan warna hitam (32%) paling lazim dan diikuti oleh merah (21.40%), kelabu (20.90%), hijau (11.35%), lutsinar (9.67%), biru (2.79%), kuning (1.12%), ungu (0.56%), dan putih (0.19%). Zarah yang paling biasa diekstrak ialah serat (52%), diikuti oleh serpihan (37%), filem (22%), pelet (6.7%), dan buih (1.3%). Polimer plastik yang ditemui dalam zarah pulih dari tanah bandar termasuk polikarbonat (PC), polistirena (PS), dan polivinil klorida (PVC), menunjukkan bahawa zarah itu berasal daripada sumber yang berpotensi seperti serpihan daripada tingkah laku membuang sampah, tayar dan haus jalan, lelasan penandaan jalan, bahan binaan, haus dan lusuh tapak kasut atau pengangkutan atmosfera. **Kesimpulan:** Sampel tanah bandar dari Cyberjaya, Selangor, Malaysia, didapati mengandungi mikroplastik. Lebih banyak penyelidikan diperlukan untuk memahami dengan lebih baik bagaimana aktiviti manusia dan faktor persekitaran boleh mempengaruhi pengumpulan mikroplastik di tanah bandar. Ujian toksikologi adalah perlu untuk memahami ketoksikan mikroplastik kepada alam sekitar dengan lebih lanjut

Kata Kunci: Mikroplastik, guna tanah, tanah bandar, Cyberjaya

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LIST OF ABBREVIATIONS

Danish EPA	Danish Environmental Protection Agency
EPS	Expanded Polystyrene
FTIR	Fourier-transform infrared spectroscopy
GIS	Geographic information system
LC	Land cover
LU	Land use
HVAC	Heating, ventilation, and air conditioning
MPs	Microplastics
MSC	Multimedia Super Corridor
NaCl	Sodium Chloride
OECD	Organisation for Economic Co-operation and Development
PA6	Polyamide 6
PAHs	Polycyclic aromatic hydrocarbons
PE	Polyethylene
PET	Polyethylene terephthalate
PP	Polypropylene
PS	Polystyrene
PVC	Polyvinyl chloride
RS	Remote sensing
SIS	Styrene-isoprene
SBR	Styrene-butadiene
SERAS	Scientific Engineering Response and Analytical Services
US EPA	United States Environmental Protection Agency
UV	Ultraviolet

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Over decades, most Asian countries, including Malaysia, have been undergoing rapid changes in urbanization due to modernity. As of 2010, Malaysia has a population of 28.3 million, up from 23.3 million in 2000. In 2011, in line with Malaysia's rapid development, the proportion of the people living in cities climbed to 71.0% in 2010 from 62.0% in 2000. Aside from Wilayah Persekutuan Kuala Lumpur and Wilayah Persekutuan Putrajaya, which have reached 100% urbanization, the other states with a high level of urbanisation are Selangor (91.4%) and Pulau Pinang (90.8%). On the other hand, the states with the lowest levels of urbanization were Kelantan (42.4%), Pahang (50.5%), and Perlis (51.4%) (Department of Statistics Malaysia, 2011).

Urbanization is a dynamic socio-economic process that changes the built environment and shifts spatial population distribution from rural to urban areas (United Nations Department of Economic and Social Affairs, 2019). Meanwhile, urban areas can be defined as gazetted areas and their adjacent built-up areas with a total population of 10,000 or further at the time of the 2010 Census, or the identified particular development area with a population of at least 10,000 and at least 60% of the population (15 years old and above) engaged in non-agricultural activities (Department of Statistics Malaysia, 2021). OECD (2020) states that the degree of urbanisation is principally determined by population size and density thresholds applied to a grid of cells measuring one by one km. Grid cells are classified into urban regions, towns and semi-dense areas, and rural areas. Much of contemporary

urbanization has been characterized as urban sprawl, relatively extensive land acquisition for urban purposes that have negative environmental consequences (Nuissl & Siedentop, 2021). Rapid urbanization has resulted in significant changes in land usage, particularly in developing countries (Wu et al., 2011). Due to the high density of human activity, the urban area is considered a potential source of microplastics (MPs). Microplastics in urban areas can be generated in various ways, including tire wear, garbage and sewage treatment, construction, industrial activity, domestic laundry, and other processes (Qiu et al., 2020). Macroplastics derived from these sources may degrade into smaller debris due to physical abrasion, solar exposure, or biological deterioration (Thomas et al., 2020).

On top of that, direct exposure to higher oxygen levels and higher temperatures caused topsoil to likely form a significant degradative environment. Microbial populations in the soil and terrestrial species may aid in the biodegradation of fragile polymers (Hurley & Nizzetto, 2018). Additionally, cities need to develop supporting infrastructure, especially in road and public transportation networks. Every year, over 240,000 km of metropolitan highways and nearly 915,000 km of country roads must be constructed (Autodesk Inc, 2020). Urbanization also results in an increase in urban population, which inevitably raises transportation needs, putting a strain on the environment (Arvin et al., 2015). As the urban population proliferated, there would be an increase in demand for mobility and hence an increase in motor vehicle ownership, leading to traffic congestion (Alam & Ahmed, 2013).

1.2 Problem Statement

Cyberjaya has a reasonably large student population, owing to its four institutions and two colleges with over 800 businesses, including 40 international enterprises, making it an area with high population density and diverse activities. With

several commercial and residential buildings taking shape, the city's economic activity has risen significantly, making it an interesting location for domestic and international corporate endeavors to reside (Cyberview Sdn Bhd, 2017). As of 2016, Cyberjaya consists of many land-use types which were potential for the emission of microplastics such as housing area, light industrial area, a mixed development of housing and commercial area, transportation area, and others (Majlis Perbandaran Sepang, 2017). Rafique et al. (2020) study conducted on the soil from the urban center concluded that microplastics in soils are because of human activity. The concentration of various microplastics forms also appeared to be related to land use prevalent local human activities. A prior study from Corradini et al. (2021) also reveals that the risk of microplastics pollution is higher in managed lands than in natural, unmanaged lands, and according to Hurley & Nizzetto (2018), it is highly likely that microplastics sources for soil may outnumber major inputs to freshwater or marine habitats. Thus, the issue of human influence appears because a variety of human activities will be available in a specific area, which may result in the presence of microplastics in urban soil.

The majority of the studies have focused on microplastics in marine and freshwater ecosystems, with very little information available concerning microplastics in soils (Abbasi et al., 2019; Rafique et al., 2020; Xu et al., 2020). Currently, almost 96% of microplastics studies are focused on maritime systems. Since most marine microplastics pollution is recognized to originate from terrestrial sources, evidence of MPs in the terrestrial system cannot be forgotten (Xu et al., 2020). However, studies investigating microplastics in the terrestrial environment across diverse land use contexts are still lacking (Corradini et al., 2021). Microplastics concentrations in different soils and land-use systems worldwide should be measured to establish the

severity of the MPs problem (Scheurer & Bigalke, 2018). Even microplastics studies in Malaysia mainly involve marine (Khalik et al., 2018), freshwater (Tee et al., 2020) and mangrove ecosystems (Barasarathi et al., 2014), while research concerning urban soil were more concentrated on heavy metals (Praveena et al., 2015), polycyclic aromatic hydrocarbons (Mohd Radzi et al., 2016), and leachate containing heavy metals from landfill site (Ismail et al., 2015). Nonetheless, there is insufficient evidence available on microplastics pollution in the terrestrial environment, prominently in soil samples from Malaysia.

1.3 Study Justification

This research aims to add to the body of knowledge by providing information on the microplastics pollution in soils under different land uses in the urban area of Cyberjaya, Selangor. Microplastics pollution study in the soil is necessary as the soil appears to be a significant long-term repository for microplastic debris. Once accumulated in the soil, microplastics can be absorbed by plants and passed through the food chain, and this includes contaminants that are adsorbent to microplastics. Urban and agricultural soils, especially are potentially exposed to microplastics pollution due to their constant exposure and contact with artificial activities, and hence with microplastic input methods. (Yang et al., 2021). Therefore, this study will determine whether land use consists of construction, commercial, residential, roadway, and vacant land with different types of human activities have the potential for the deposition and degradation of the microplastics. Additionally, this study will offer information on the microplastics generated from the different types of land use, particularly their size, color, shape, and polymer types.

Besides, this study will be able to close the gap of knowledge between microplastics studies in Malaysia, especially in the terrestrial environment. Since

many microplastics research in Malaysia has focused on marine and freshwater, this study could provide insight and information on microplastics occurrence in urban soil in Malaysia. In addition, this study will also provide information on potential microplastics pollution mitigation in the urban soil from Cyberjaya, Selangor, to be implemented by the policymaker.



1.4 Research Question

This study seeks to address various research concerns, including the following:

- i. Is there any occurrence of microplastics in urban soil from Cyberjaya based on land use types?
- ii. What is the association between microplastics occurrence in urban soil and land use?
- iii. What is the hotspot area for microplastics pollution in Cyberjaya?

1.5 Research Objective

1.5.1 General Objective

- To provide information on microplastics pollution in the urban area (Cyberjaya, Selangor).

1.5.2 Specific Objective

- 1) To determine the occurrence of microplastics in urban soil from Cyberjaya based on types of land use.
- 2) To identify the microplastics particles extracted from the urban soil samples
- 3) To compare the association between microplastics occurrence in urban soil and land use.

1.6 Research Hypothesis

- i. There will be an association between microplastics occurrence in urban soil and land use.

1.7 Conceptual Definition

i. Microplastics

According to United Nations Environment Programme & Caribbean Environment Programme (2015), microplastics are tiny particles of plastic, typically less than (5mm) in diameter, formed during the breakdown of macroplastics.

ii. Urban soil

Urban soil refers to soils in densely populated areas with a predominantly constructed environment. Human-transported materials may considerably transform these soils, slightly altered or intact "native" soils (United States Department of Agriculture, 2019)

iii. Land use

The phrase "land usage" refers to the human application of various land. It is a term that refers to the economic and cultural activities (for example, agricultural, residential, industrial, mining, and recreational uses) that take place in a particular location (United States Environmental Protection Agency, 2021).

iv. Surface soil

Surface soils are classed as those located between the ground surface and a depth of 15 to 30 cm below the ground surface. The most frequently used interval is between 0 and 15 cm (US Environmental Protection Agency, 2020).

1.8 Operational Definition

i. Microplastics

There are no standardized analytical procedures for the extraction, identification, characterization, and quantification of microplastics. Since study approaches vary, it isn't easy to compare the findings of several studies (He et al., 2019). However, the technique used in this study to extract microplastics is density separation because it is the most often used method for pre concentrating or isolating microplastics from the soil. Density separation uses plastic particles' buoyancy in liquids with a higher density than plastics (Thomas et al., 2020). A previous study from Li et al. (2019) stated that the most frequently applied flotation solution in extraction is a saturated solution of NaCl, ZnCl₂, or NaI.

ii. Urban soil

Urban soil measurement can be conducted through the assessment of urban soil quality by measuring soil quality indicators related to soil functions such as physical indicators (e.g., bulk density), chemical indicators (e.g., pH, electrical conductivity), biological indicators (e.g., basal respiration), and soil metals (e.g., zinc, arsenic, lead) (Tresch et al., 2018).

iii. Land use

Classification of land use (LU) and land cover (LC) can be done by utilizing Geographic information system (GIS) and Remote Sensing (RS) data. With the application of RS and GIS, land use and land cover mapping have provided a valuable and detailed method for recovering the selection of areas intended for urban, agricultural, or industrial regions within a region (Kamarudin et al., 2018)

iv. Surface soil

Spades, shovels, and scoops can be used to collect surface soil. Surface dirt can be removed to the desired depth with a garden spade, and the sample collected with a stainless steel or plastic scoop (US Environmental Protection Agency, 2004). The unit of measurement used in measuring soil depth is centimeter (cm) and millimeter (mm) (Kosmas et al., 1999).

1.9 Conceptual Framework

Figure 1.1 shows all the variables to be included in this study. Pollution of any contaminants can expose and affect human health in two ways, either occupational or environmental. However, this study will be the focus on environmental exposure. Soil is one of the elements that can measure any contamination, and urban soil, precisely soil samples from Cyberjaya, Selangor, is chosen to be assessed for this study. Soil can have different types of land use depending on the human activities at a specific location. Types of land use selected for this study are construction, commercial, residential, roadway and vacant land. Hence, urban soil chosen from different land-use types is the independent variable in this study.

Soil has its layers and classification, and it should be sampled at a depth that reflects the type of exposures predicted at the site (United States Environmental Protection Agency, 1996). Contaminants that are persistent in the near-surface environment can be investigated using surface soil samples (US EPA, 2000). Thus, the sample soil investigated in this study is surface soil. Two types of pollutants in the ground are organic and inorganic pollutants; microplastics are categorized under organic pollutants. The

dependent variable in this study will be the microplastics occurrence. This study will be further investigate total particles and plastic polymers in soil.



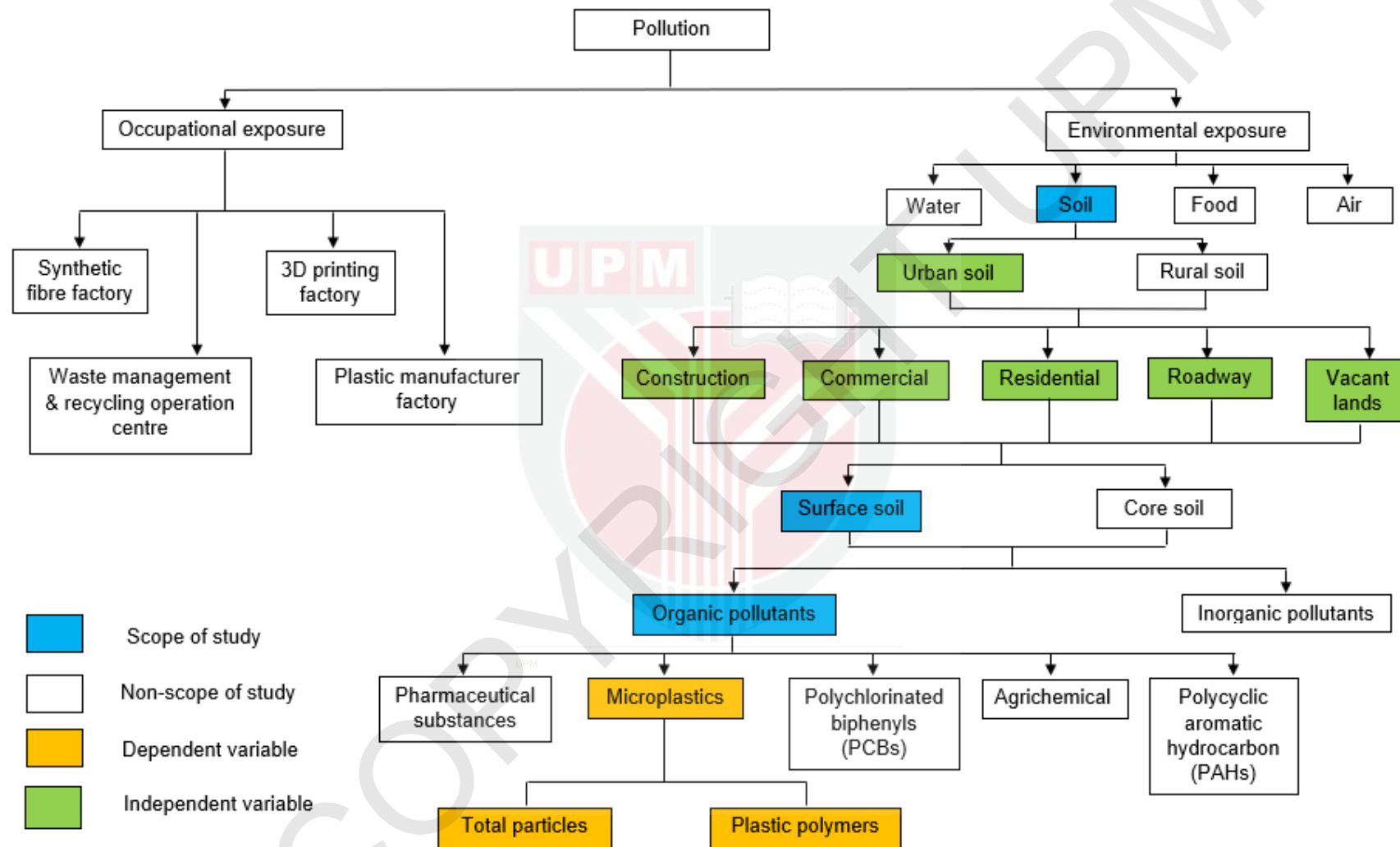


Figure 1.1 Conceptual Framework

CHAPTER 2

LITERATURE REVIEW

2.1 Microplastics Pollution in Urban Areas

. Primary and secondary microplastics are the two main categories of microplastics. Plastic microbeads and nanoparticles were the most common primary microplastics used in several industrial operations for a range of uses like industrial detergents and cosmetics (Qi et al., 2020). Primary microplastics were produced directly from home products, including facial cleansers, toothpaste, and exfoliating lotions. Plastic raw materials for plastic production were a crucial source of primary microplastics (Da Costa et al., 2020). Furthermore, paints, blasting abrasives, and rubber granules were significant contributors to the emission of primary microplastics (Lassen et al., 2015). Inadequate handling, unintentional loss, processing facility runoff, and industrial leftovers can lead to primary microplastics build-up (Da Costa et al., 2020).

Secondary microplastics typically consisted of more oversized plastic items that degraded in the environment (e.g., plastic film residues, household garbage) (Qi et al., 2020). Tires, textiles, paints, road markings, plastic building materials, footwear, culinary utensils, and other usage emit secondary microplastics, according to Lassen et al. (2015). The breakdown of larger polymers into microplastics occurs via various mechanisms, including mechanical such as erosion and abrasion, UV irradiation, contact with a chemical that causes corrosion and photo-oxidation, and biological processes (Qi et al., 2020; Rahman et al., 2021). Nevertheless, this degradation can occur before these materials enter the environment, like synthetic fibres discharged during washing cycles or with tire wear and tear, producing minute polymeric pieces (Da Costa et al., 2020). Given that most of humankind lives on land

and that most human activities take place on land, it is inevitable that the bulk of plastic litter, including macroplastics, microplastics, and nanoplastics, is discharged directly into lands (Peng et al., 2020).

Road tire wear particles can be distributed in the environment in many ways. Small particles are usually released into the air and dispersed. Still, big particles settle on the road surface, where some are retained, and others are carried away by rainfall runoff into soils, sewers, or surface waterways (Kole et al., 2017). Tires generated between 4,200 and 6,600 tonnes of particles per year, making them the single most significant source of microplastics in the environment (Lassen et al., 2015). Kole et al. (2017) study stated that 5871 tonnes (67 %) of the 8768 tonnes of tires wear and tear ending up in the environment are predicted to end up in the soil. Abrasion of road markings is another source of microplastics on roads. These are a mixture of thermoplastic and polymer paints. Although road markings are primarily composed of fillers, they often contain thermoplastic elastomers between 1 and 5% (Sundt et al., 2014). With more traffic, it is conceivable that paint on road markers may wear off and become coarser. Road marking paints likely to deteriorate over time due to the correlation between traffic density and microplastics (Kitahara & Nakata, 2020).

As has become evident, plastics are necessary for a modern building, but their use poses significant environmental and societal challenges. Plastics are necessary for a modern building construction where it utilizes plastics as damp proofing materials, insulation, moisture and, floor coverings, pipes, window frames, ducts, and cables, as well as various elements and components for HVAC, electrical, and plumbing system (Häkkinen et al., 2019). According to Lassen et al. (2015), these materials were susceptible to corrosion and weathering. Around 40% of plastic consumption was for packing, while 20% was for building and construction. Apart from the potential

environmental loss of plastic raw materials, the usage of plastics can result in the release of macroplastics (particularly packaging goods) and abrasive microplastics from plastic objects (particularly building materials).

During usage, environmental emissions may occur due to outsole abrasion or when shoes are discarded at the end of their useful life. Footwear is an example of a complex product with up to 250 components. The components are made of leather, fabric, rubber, and plastic (Ingre-Khans et al., 2010). Based on the Danish Environmental Protection Agency (Danish EPA) report, shoe sole abrasion accounted for 100 to 1000 tonnes in Denmark alone in 2015 (Lassen et al., 2015). A German study found that shoe sole wear and tear (109 g per person per year) was the country's seventh-largest contributor to microplastics. These findings suggest that sole shoe abrasion may be a significant source of microplastics in high-traffic areas of the natural environment (Forster et al., 2020).

Plastic inputs to soils can also come from other sources, such as trash near highways and trails or illegal waste dumping. Littering near roads or trails is normal (Bläsing & Amelung, 2018). Additionally, a lack of land-based infrastructure to collect litter, along with a lack of awareness among major stakeholders and the general population, are significant reasons why the litter issue happens to be worsening globally (United Nations Environment Programme, 2005). Therefore, plastic wastes that have been improperly managed are frequently found scattered around roadways, in soils, and unauthorized disposal sites. (K. Zhang et al., 2018). Plastic trash has been discovered accumulating in various environmental areas across the world, where it is subjected to gradual disintegration caused mainly through UV light and mechanical abrasion (Wanget al., 2020). Littering behaviors include pedestrians throwing rubbish on the streets, vehicles discarding garbage out of their windows, laziness, e.g.,

individuals who don't even care to clean up litter that falls outside of waste bins, and a disposable attitude, counting on garbage collection (Magnusson et al., 2016).



Source:

<https://www.voicesuamoto.com.br/216885/>

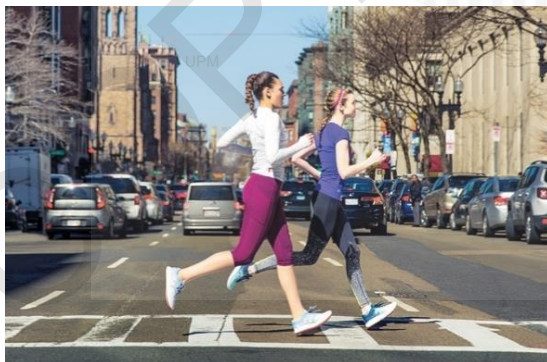


Source:

https://www.horiba.com/en_en/science-in-action/where-do-microplastics-come-from/



Source: <https://www.acplasticsinc.com/informationcenter/r/applications-of-plastic-construction-materials>



Source:

<https://www.bostonmagazine.com/health/2017/03/26/why-boston-best-running-city/>



Source: <https://www.thebulletin.be/higher-fines-littering-brussels>

Figure 2.1 Potential sources of microplastics

2.2 Occurrence of Microplastics in Urban Soil

Table 2.1 below summarises previous studies that have been conducted in the urban area and includes details on the microplastics' size, color, shape, and types of plastics polymers. It also provides the potential sources of microplastics emission available in each study

Table 2.1 Summary of past studies reporting the occurrence of microplastics in urban soil

Urban area	Size	Color	Shape	Plastic polymers found	Sources	References
Tehran, Iran	250 to 500 μm (33.7%),	Black (29.9%), yellow (26.4%), transparent (17.3%), blue (12.6%), red (10.2%), green (3.6%).	Fibrous (16.9–44.3%, 33.5 on average), Granule (54.5–82.2%, 65.9 on average).	-	-	Dehghani et al. (2017)
Baoding, China	Range: 0 to 35 μm <10 μm ($\geq 26.3\%$), 20–25 μm (17.83%), 25–35 μm (9.3%,)	-	-	Polypropylene (PP), polyvinyl chloride (PVC), polyethylene terephthalate (PET), polyamide 6 (PA6) PET and PA6 (30.2%)	Industry of shoes and clothing, as well as non-ferrous metals-related businesses such as car parts and electronic device manufacturing	Du et al. (2020)
Lahore, Pakistan	300–5000 μm (41.16%), 50–150 μm (30.67%),	Yellow, transparent, white	Fibres, fragments, or sheets (99%), Foams or beads (1%)	-	Lack of awareness on single-use plastics, people's behavior (littering), degradation of discarded solid waste and	Rafique et al. (2020)

	150–300 μm (28.17%)				raw plastic pellets, solid trash dumping, abrasion of tires, wind transfer, aerial deposition	
Yeoju, Korea	994 (> 5 mm), 488 (1–5 mm), 3013 (< 1 mm)	Black (65.5%), white (12.3%), yellow (8.8%), blue (8.1%), green (2.2%), transparent (1.7%), red (1.5%)	Fragments (66.1%), film (19.2%), fibres (14.6%), spheres (0.2%).	Styrene-butadiene rubber (SBR), and styrene-isoprene-styrene (SIS) (43%), polypropylene (PP) (22%), polyethylene terephthalate (PE) (20%), expanded polystyrene (EPS) (12%), polystyrene (PS) (1.7%), polyethylene terephthalate (PET) (1.7%)	Tire dust and road paint, materials used for asphalt, paint on roads and buildings, and traffic safety facilities	Choi et al. (2021)
Central valley, Chile	Average area 0.076 \pm 0.292 mm ² , median area of 0.012 mm ² .	-	Fibres (68%), films (23%), fragments (7%) pellets (2%)	Acrylates, polyurethane, and varnish, polyethylene, polypropylene (PP), nitrile rubber, polystyrene (PS.)	Only mentioned microplastics increased due to human interventions. No potential sources were identified.	Corradini et al. (2021)
Victoria, Australia	0.08 to 4.7 mm (mean size of 1.2 mm), < 1 mm (30.0-62.0%), <3 mm (95%)	-	Fibres (45.7-100%), fragments (0-45.7%), pellets (<5%)	Polyester, polypropylene and rayon (63.4%)	Transport, littering, construction works that lead to demolition waste and littering, abrasive vehicle emission, wind patterns, and rainfall	Su et al. (2020)

Asaluyeh County, Iran	<100 mm (75%), 500-1000 mm (1 microplastics)	White-transparent (66%) was the most prevalent color	Microplastics: Spherules (74%), films (14%) Microrubbers: Fragments (61%), fibres (36%),	-	Industrial sources, synthetic textiles, decomposing litter, waste disposal, agricultural practices, clothing, household soft furnishing, vehicle interiors, industrial processes, and procedures	Abbasi et al. (2019)
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2.2.1 Size

Table 2.1 shows studies have been conducted related to microplastics in urban soil. The critical requirement for identifying whether a suspicious particle is microplastic is its morphological features (such as surface texture, color, and shape) (Wang et al., 2020). Dehghani et al. (2017) set up their study to have the size of the microplastics range from less than 100 to 5 mm and obtained plastic particles with a length of 250 to 500 μm accounted for 33.7% of total plastics, followed by microplastics with a size larger than 1000 μm , which accounted for 25.7% of total microplastics in dust samples with a range of variation from 15.4 to 30.4%. In Baoding city of China, the particle size of the collected microplastics ranged from 0 to 35 μm , with <10 μm microplastics accounting for more than 26.3% of the total, whereas 20–25 μm (17.83%) and 25–35 μm (9.3%) microplastics were relatively tiny (Du et al., 2020).

A study in Lahore, Pakistan obtained that the overwhelming range of size 41.16% were prominent size microplastics (300–5000 μm), followed by fine size microplastics (50–150 μm ; 30.67%) and medium-size microplastics (150–300 μm ; 28.17%) (Rafique et al., 2020). 994 mesoplastics (> 5 mm), 488 large microplastics (1–5 mm), and 3013 tiny microplastics (1 mm) were found in 100 soils of Yeosu City, Korea (Choi et al., 2021). A study by Corradini et al. (2021) stated that the average area of the particles found is $0.076 \pm 0.292 \text{ mm}^2$, with a median area of 0.012 mm^2 . Plus, the area of the outstanding particle was 2.036 mm^2 , but these massive particles were an anomaly; the second-largest particle had an area a tenth of this size (0.290 mm^2). The shortest fibre measured 0.3 mm in length, and in unmanaged fields, microplastics as small as 300 m for fibres and 80 m for various shapes are found.

Furthermore, a previous study from Su et al. (2020) discovered that microplastics ranged in size from 0.08 to 4.7 mm in all samples, with a mean of 1.2 mm. Excluding the one sampling site in their study, microplastics <1 mm were widespread, accounting for 30.0-62.0% of microplastics identified from each site, while microplastics <3mm recorded for 95% of total counts. On top of that, Abbasi et al. (2019) observed that 75% of particles are in the <100 µm group, with decreasing percentages appearing as particle size increases. About 98% of particles were in the lowest size category among spherules, with just one microplastics between 500 and 1000 µm and one over 1000 µm. The other shape categories had a more typical distribution, with the most significant microplastics found in the 100-250 µm range. This distribution was also found in all form kinds of micro rubber except spherules, where just one particle was observed in the lowest size categorization. Microrubbers is another type of microplastics, distinct from other microplastic types due to their particular physical and deformation features as well as their unique appearance, application and origins.

2.2.2 Colours

In previous studies, researchers found microplastics in the soil come in a wide range of colors. Colors have been frequently incorporated into the manufacturing of commercial plastics to increase their attractiveness (Yang et al., 2021). These plastics' shape, size, and content might vary depending on the product (Cole et al., 2011). On average, black (29.9%), yellow (26.4%), and transparent microplastics (17.3%) are all higher in percentage than blue (12.6%), red (10.2% %), and green microplastics (3.6%). In addition, brown, orange, and pink microplastics can be observed (Dehghani et al., 2017). The detected microplastic's visual features revealed sharply colored, glossy, smooth, and threadlike fibres. The fragments' surfaces were also sharp in color and shiny, although they appeared to be fading. The foams found in the soil samples

had a spongy or foamy look and were yellow or white. Sheets were glossy, smooth, and brightly colored plastic flakes with a thin layer; nevertheless, translucent sheets were also discovered. During the analysis, transparent or white beads with a smooth and shiny surface were found (Rafique et al., 2020).

There were also noticeable differences in the abundance of color found in different types of land use of Yeosu, Korea, which involved forest, urban (traffic and residence), and agricultural area: red (1.5%), transparent (1.7%), green (2.2%), blue (8.1%), yellow (8.8%), white (12.3%), and black (65.5%). 70% of the fragment, fibre, and film microplastics were primarily black, whereas spherical-shaped microplastics were more colorful: white (50%); black (25%); transparent (12.5%); yellow (12%). In high-traffic areas, black and yellow predominate, most likely due to tire dust and road paint (Choi et al., 2021). Another study was conducted where authors defined microplastics as objects with gleaming surfaces, vibrant colors, and sharp geometrical shapes. Particles with smooth sides and bright colors were assumed to be made of synthetic fibre (Corradini et al., 2021). Regarding the color categorization of microplastics, white-transparent was the most prevalent (about 66%), with the remaining colors being relatively evenly distributed. This percentage distribution was consistent in the spherule and fibre categories. Still, in the film microplastics category, white-transparent particles accounted for over 90% of the total population. In contrast, in the fragment category, white-transparent particles accounted for only about 45% of the total, followed by red-pink and blue-green MPs accounting for about 20% each. Micro rubber is defined as black in color (Abbasi et al., 2019).

2.2.3 Shapes

Dehghani et al. (2017) study observed the most prevalent microplastics were fibrous (16.9–44.3%, 33.5 on average) and granule microplastics (54.5–82.2%, 65.9

on average). Additionally, pellets and spherules were encountered. 99% of the microplastics particles found were in the form of fibres, fragments, or sheets, with the remaining 1% being foams or beads (Rafique et al., 2020). Meanwhile, 66.1% of shapes were in the form of fragments, followed by 19.2% for film, 14.6% for fibres, and 3% for spheres (0.2%) was found by Choi et al. (2021). Furthermore, the most frequent microplastic form (68%) was fibre, followed by films (23%). Pellets and fragments were less commonly seen (2% and 7%, respectively) (Corradini et al., 2021). Fibres were the most common form, comprising 45.7-100% of all shapes, continued by fragments (0-45.7%). Only three locations were found with pellets, accounting for 5% of the total count (Su et al., 2020). Spherules (74%) and films (14%) monopolised microplastics, but fragments and fibres can also be detected among the samples (Abbasi et al., 2019).

2.2.4 Types of Polymers

Few types of microplastics were immediately identified by Du et al. (2020): polypropylene (PP), polyethylene terephthalate (PET), polyvinyl chloride (PVC), and poly (amide 6) (PA6). PET and PA6 accounted for the highest proportions of both, accounting for up to 30.2%. A previous study from Choi et al. (2021) stated that there were more microplastics (1108 pieces kg⁻¹), primarily black styrene-butadiene rubber (SBR) fragments linked with tire dust. Microplastics from upland, greenhouse, and orchard sites included polyethylene (PE) and polypropylene (PP), while SBR-derived microplastics were discovered in all agricultural soils. Synthetic rubbers such as SBR and styrene-isoprene-styrene (SIS) (43%) were the most prevalent, followed by polypropylene (PP) at 22%, polyethylene (PE) at 20%, expanded polystyrene (EPS) (12%), polystyrene (PS) (1.7%) and polyethylene terephthalate (PET) (1.7%). According to the findings, plastic polymers are often detected in the study area,

including acrylates, polyurethanes, and varnishes. The second most widely used polymers were polyethylene and polypropylene, followed by nitrile rubber and polystyrene (Corradini et al., 2021). Su et al. (2020) observed that artificial polymers and additives accounted for 58.6% of the 221 identified microplastics; the remainder were non-plastic materials. 63.4% of polymers consisted of polyester, polypropylene, and rayon, whereas the combination of cotton and cellulose accounted for 65.4% of all non-plastic materials.

2.3 Potential Sources of Microplastics in Urban Areas

This study demonstrates that microplastics are a relatively long-lasting consequence of human-induced activities that profoundly alter terrestrial ecosystems. The abundance of microplastics in Baoding city of China contributed by the footwear and clothing sector, and PA6, in particular, generates a significant quantity of plastic waste during the manufacturing and production operations. Related businesses in the non-ferrous metals sector, such as car parts and electronic device manufacturing, require a significant quantity of PET powder in their manufacturing processes. Some PET waste is immediately dumped into the surrounding soil (Du et al., 2020). Due to widespread ignorance about the harmful consequences of single-use plastics, the tendency for people to throw away plastics is increasing. The goods are purchased and discarded in parks. In industrial regions, microplastics were generated by the degradation of discarded solid waste (mostly packaging material) and raw plastic pellets used to manufacture plastic goods. During the soil sampling, solid trash dumping was also seen. Microplastics are also accumulated on roadsides because of tire abrasion, wind transport, and the degradation of macroplastics, mainly due to littering behaviors. Moreover, aerial deposition may occur due to the vast open region (Rafique et al., 2020). Microplastics residues are generated by other materials used in

paint on roads and buildings, asphalt, and traffic safety infrastructure. Because of its abrasion resistance, styrene-butadiene rubber is widely utilized in tire manufacturing. Over half of microplastics found in metropolitan areas were SBR black fragments, suggesting that constant microplastic emission from automobile tires enhanced their prevalence, notably along highways, roadsides, and parking lots. The influence of microplastics on atmospheric fallout on forest soils is measured and shown to be substantial. (Choi et al., 2021).

Corradini et al. (2021) studied distinct land uses characterized by urbanization, agricultural, and mining operations. It involved four different land-use systems with varying management intensities: pastures, croplands, rangelands, and natural grasslands. It explained that even though human interventions enhanced microplastics deposition in soils, microplastics are not frequent in all land uses. Despite indications of microplastic contamination in managed soils, a potential pollution source or a covariable to assess in addition to microplastics were not found. Su et al. (2020) study had the same point of view as others study where anthropogenic activities like transportation and littering are expected to significantly affect their quantity of roadside dust. Construction activities in metropolitan areas can bring additional pollutants, such as demolition debris and litter, from non-resident people. Plus, vehicle abrasive emissions might be a one-of-a-kind source of microplastics contamination in roadside dust which can be deposited on the soil. Wind patterns and rainfall may clarify some of the increases and decreases in microplastic abundance from October to December.

Furthermore, Abbasi et al. (2019) explain that microplastics are almost certainly derived from various sources, including industrial emissions, synthetic textiles, decomposing litter, waste disposal, and agricultural practices. In contrast,

micro rubber is almost certainly derived primarily from vehicle tire wear (and, possibly, footwear), with a distribution that represents traffic density and driving habits. Clothing, soft furnishings for the home, vehicle interiors, and specific industrial processes and procedures are proposed as possible sources.

2.4 Microplastics Past Studies in Malaysia

There is clear evidence of microplastics in Malaysia's marine water (Khalik et al., 2018), mangrove forests (Barasarathi et al., 2011), and freshwater (Tee et al., 2020) in prior research. Several studies have also been conducted to determine the presence of microplastics on beaches (Nurul Nadia, 2019), in bottled water (Wong et al., 2021), and commercial fish (Karbalaee et al., 2019). Besides, other studies are available to identify potential microplastic emissions sources, such as personal care and cosmetic products (Praveena et al., 2018) and laundry water from household washing machines (Praveena, 2021). Johnson et al. (2020) conducted the closest research on microplastics associated with urbanization. However, this study also involved aquatic systems.

Meanwhile, research on urban soil focuses on heavy metals like lead, cadmium, chromium, nickel, and arsenic (Hamid et al., 2019; Praveena et al., 2015) and the level of contamination and risk assessment of polycyclic aromatic hydrocarbons (PAHs) in the soil (Mohd Radzi et al., 2016). Not to mention that leachate from a non-sanitary waste landfill site can cause soil contamination (Ismail et al., 2015). Nonetheless, there is a lack of microplastics research in Malaysia's terrestrial ecosystem.

Table 2.2 Summary of past studies reporting microplastics and urban soils in Malaysia

Scope of the previous study	Reference
Microplastics in marine water	Khalik et al., 2018
Microplastics in mangrove forest	Barasarathi et al., 2011
Microplastics in freshwater	Tee et al., 2020
Macro and microplastics at beaches	Nurul Nadia, 2019
Microplastics in bottled water	Wong et al., 2021
Microplastics in commercial fish	Karbalaei et al., 2019
Microplastics in personal care and cosmetic products	Praveena et al., 2018
Microplastics from laundry water of household washing machines	Praveena, 2021
Degree of urbanization impact on microplastics	Johnson et al., 2020
Heavy metal exposure in urban soil	Hamid et al., 2019 Praveena et al., 2015;
Polycyclic aromatic hydrocarbon (PAHs) contamination level and risk assessment in urban soil	Mohd Radzi et al., 2016
Soil contamination by leachate from the landfill site	Ismail et al., 2015

CHAPTER 3

METHODOLOGY

3.1 Study Design

This research is a cross-sectional study that is able to provide information on microplastics pollution in the urban area, specifically in Cyberjaya, Selangor.

3.2 Study Area

Cyberjaya is Malaysia's first integrated metropolis, technology hub, and the nucleus of Malaysia's Multimedia Super Corridor (MSC) (Cyberview Sdn Bhd, 2021). Cyberjaya is under the district of Sepang, where it is also known as planning blocks 2 (BP 2), and this area is further subdivided into 12 minor planning blocks (BPK), namely Cyber 1, up to Cyber 12 (Majlis Perbandaran Sepang, 2017). Cyberjaya consists of four dynamic zones: North (Global Business District), Downtown (Thriving Commerce District), South (Innovation District), and West (Nurturing Talent for Tech Hub). (Cyberview Sdn Bhd, 2021). The launch location for Cyberjaya was a former palm oil plantation, one of many remnants of Malaysia's agricultural past. Cyberjaya mainly consists of undeveloped land, 2,800 hectares (6,960 acres), and about 40 km south of Kuala Lumpur (Salman, 2018).

3.3 Soil Sampling

A random soil sample was taken from a different region around the Cyberjaya area. Surface soil sample with a depth of 5 until 10 cm had been taken as this is the range in which the majority of microplastic particles are most likely to be found (Möller et al., 2020). Surface soil samples were used in this study to investigate pollutants near the earth's surface. Contaminants discovered in the near-surface environment can travel to great depths, move to groundwater, surface water, the atmosphere, or infiltrate biological systems (Scientific Engineering Response &

Analytical Services (SERAS), 2012). The soil samples were collected using a shovel and wrapped in blank A4 papers.

A total of 25 locations have been selected, and the types of land use for each location are classified by observing the human activities in that area. The construction industry is generally defined by new construction projects, renovations, repairs, and destruction (Jabatan Perangkaan Malaysia, 2011). A commercial building is an area that has been built and developed to benefit both the owner and its users by accounting for numerous factors (Koswara & Pamungkas, 2017). The urban residential area is defined as 1.6 dwelling units per acre based on the average density levels of practical public transportation (Theobald & Merenlender, 2014). Any urban soil close to the road was considered as roadway samples. Meanwhile, vacant lands are classified as undeveloped land/government land or developed but abandoned lots, lots for future development in their original condition or after construction (Jabatan Perancangan Bandar dan Desa, 2016).

The samples taken for each land use were two samples from the construction area (CU: n=2), eleven samples from the commercial area (CO: n=11), four samples from the residential area (RA: n=4), six samples from the roadway area (RW: n=6), and two more samples from vacant land (VL: n=2). Figure 3.1 shows the map of Cyberjaya, and the number of samples collected from each location, while appendix 1 shows the sampling site for each soil sample.

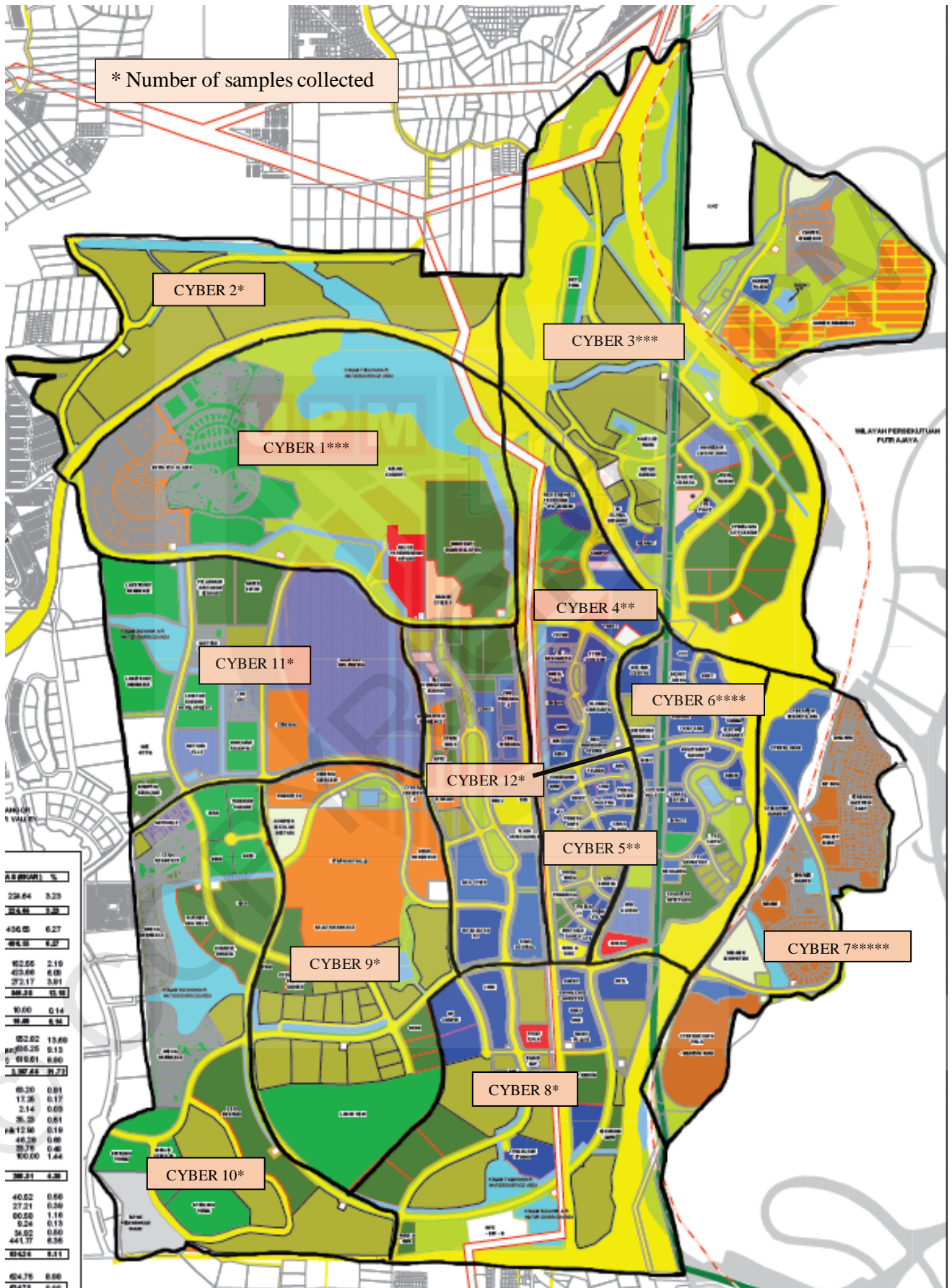


Figure 3.1 Map of Cyberjaya, Selangor

3.4 Sample and Solution Preparation

Air-drying of the soil samples was done to dry the soil samples. The samples were then homogenized using pestle and mortar and sieved with a 2-mm metal mesh. Macroplastics discovered during homogenization were collected and safely kept (Corradini et al., 2019). After homogenization, the urban soil samples were weighed approximately 100 g and placed in the conical flask, covered with aluminum foil. The extraction stage in this study was performed by applying the flotation technique for low-density microplastics in saturated sodium chloride (NaCl) solution. It is ideal for separating low-density polymers such as polyethylene, polypropylene, and polystyrene from soil mineral matrices because they are economical, widely available, and non-toxic to the environment (Thomas et al., 2020).

3.5 Density Separation

A 200 mL of NaCl solution was added into the conical flask containing soil samples for the first batch. The second batch, which also acted as duplicates of each soil sample, was poured with 50 ml of NaCl solution and were labelled as S1.1 until S25.1. The mixture had been stirred well with the spatula sampling spoon. The visible floating plastic particles were taken manually and wrapped in blank A4 paper. Meanwhile, the rest of the particles that settled on the solution's surface were filtered using Whatman no. 42 filter sheets. The filter papers were moved to the petri dish for air drying.

3.6 Identification and Characterization of the Particles

The polymers' size, colors, and shapes from each sample preparation stage were further investigated using the Nikon Eclipse E200LED MV RS combined with BestScope International Limited camera. Then, the images were analyzed using ImageJ 1.51, non-proprietary particle analysis software (Praveena, 2021).

3.7 Identification of the Plastic Polymer

The polymers of retrieved particles were examined using an FTIR spectrometer from Thermo Scientific, Nicolet 6700. A manually controlled FTIR microscope with a single element MCT-A liquid nitrogen-cooled detector was used for speed, point, and shoot analysis. Additionally, spectra of unknown particles in each sample were collected and compared to a spectrum database of synthetic polymers (Thermo Scientific OMNIC Spectra and Essential FTIR ®Spectroscopy Toolbox software) from 500 to 4000 cm⁻¹ (Praveena, 2021).

3.7 Data Analysis

Table 3.1 shows the data analysis used for each specific objective. The Shapiro Wilk test was used to determine the normality and homogeneity of the data. This research utilized ANOVA analysis to compare the association between microplastics in urban soil and land use.

Table 3.1 Data analysis for each specific objective

Specific Objective	Data Analysis
To determine the occurrence of microplastics in urban soil from Cyberjaya based on land use types.	-
To compare the association between microplastics occurrence in urban soil and land use.	ANOVA
To identify microplastics hotspots in Cyberjaya	-

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Occurrence of Microplastics in Urban Soil from Cyberjaya

Table 4.1 shows the number of particles in each sampling location from each land use of urban soil from Cyberjaya.

Table 4.1 Microplastics extracted from the surface of urban soil samples

Land use	Sample	Number of particles (particle/g)	Sum of number of particles for each land use (particle/g)
Construction	S4	0.82	1.37
	S4.1		
	S9	0.55	
	S9.1		
Commercial area	S2	0.87	6.61
	S2.1		
	S3	1.15	
	S3.1		
	S5	0.61	
	S5.1		
	S11	0.44	
	S11.1		
	S12	0.41	
	S12.1		
	S13	0.33	
	S13.1		
	S14	0.60	
	S14.1		
	S16	0.85	
	S16.1		
	S17	0.49	
	S17.1		
	S18	0.50	
	S18.1		
S20	0.36		
S20.1			
Residential area	S6	0.52	2.11
	S6.1		
	S8	0.46	
	S8.1		
	S19	0.54	

	S19.1		
	S21	0.59	
	S21.1		
Roadway	S1	0.66	3.46
	S1.1		
	S7	0.53	
	S7.1		
	S10	0.57	
	S10.1		
	S15	0.83	
	S15.1		
	S22	0.52	
	S22.1		
	S23	0.35	
	S23.1		
	Vacant land	S24	
S24.1			
S25		0.30	
S25.1			

The concentration of the particles ranged between 0.65 to 6.61 particle/g according to the data. The highest concentration of particles was discovered in 6.61 particle/g from the commercial area, and the lowest number of microplastics found was 0.65 particle/g from vacant land. It is relevant that commercial area has a higher concentration of particles, while vacant land has a lower concentration as commercial area comprises many buildings and active human activities that may generate a high number of particles compared to vacant land with fewer buildings and human activities. According to Nkem Ede et al. (2014), there is more usage of plastics in buildings construction now because of the new technologies, better materials, and the need for lightweight, durable materials and insulation. Apart from that, concentrations of microplastics were also associated with human activities. For example, beads are related to plastic manufacturing and cosmetics usage, whereas fragments are associated with the dumping and disintegrating of big plastic trash (Rafique et al., 2020). Many roads in commercial areas can also contribute significantly to the

accumulation of microplastics since plastic was fully utilized in making tires, road constructions, and road markings. Around 5000 tonnes of microplastics each year were estimated to be generated from tires and road markings abrasion (Sundt et al., 2014). Tires are often made from a mixture of natural and synthetic rubbers, whereas synthetic rubbers are petroleum-based polymers (Kole et al., 2017). In India, plastic wastes have been used in road construction. The inclusion of 8% processed plastic was ideal for saving 0.4% as it increases bitumen's stability, strength, life, and other desirable features (Shafiq & Hamid, 2016). As for the road markings, about 98% to 99% of all markings on Danish roads are made with thermoplastic materials (Lassen et al., 2015). Styrene-isoprene-styrene (SIS), ethylene-vinyl acetate (EVA), polyamide (PA), and polyacrylate are the most often used polymers in road markings in Norway (Sundt et al., 2014). It is crucial to identify the accumulation of microplastics since it has been shown to have a detrimental effect on soil structure and water dynamics, as well as the fitness of soil biota such as earthworms, nematodes, and plants (Thomas et al., 2020). Earthworms have been observed to consume microplastics, and the rate of ingestion has been demonstrated to rise dramatically as the microplastics concentration increases. Using INCA-Contaminants model, they found that over 60% of microplastics in soil will eventually migrate into river catchments, contaminating the aquatic environment. Thus, soil serves as both a sink and a source for microplastics in the surrounding ecosystem. (Guo et al., 2020).

4.2 Identification of the Particles Extracted from the Urban Soil Samples

4.2.1 Microplastics Particle Size in Urban Soil from Cyberjaya

In this study, particle size ranged from 0 μm to 4543.465 μm was detected in the urban soil from the Cyberjaya area. The particle size of 0 μm was included too because the actual particle size was less than 0 μm , and it can't be measured through due to the detection limit. Table 4.2 shows the mean for each land use.

Table 4.2 The size of microplastics extracted from all samples

No.	Sample	Mean (μm)	Standard Deviation (μm)	Minimum (μm)	Maximum (μm)	Mean for each land use (μm)
Construction area						
1.	S4	569.536	444.323	80.519	2662.378	662.993
2.	S4.1	755.904	541.141	159.622	2843.327	
3.	S9	552.596	413.464	41.147	1641.889	
4.	S9.1	773.935	783.696	86.216	3166.896	
Commercial area						
1.	S2	354.472	378.773	0	1569.572	586.082
2.	S2.1	234.615	207.225	23.563	1093.313	
3.	S3	544.711	463.512	59.246	1875.245	
4.	S3.1	250.625	282.071	48.94	1470.478	
5.	S11	521.256	284.328	143.693	1172.591	
6.	S11.1	658.89	480.561	118.492	2314.777	
7.	S5	423.325	284.126	59.246	1286.786	
8.	S5.1	125.592	64.376	15.147	286.37	
9.	S12	537.504	350.871	79.487	1497.898	
10.	S12.1	1046.772	880.479	203.212	3932.222	
11.	S13	1002.56	483.286	355.767	2140.793	
12.	S13.1	725.886	393.470	325.774	1589.753	
13.	S14	669.174	406.989	167.573	1634.01	
14.	S14.1	1010.07	1100.441	106.372	4543.465	
15.	S16	315.266	294.231	68.311	1825.805	
16.	S16.1	726.429	665.652	109.244	2545.572	
17.	S17	684.344	893.512	75.216	4436.185	
18.	S17.1	641.307	471.523	161.806	2018.034	
19.	S18	366.624	312.075	71.846	1343.31	
20.	S18.1	659.833	831.851	59.246	3942.134	
21.	S20	707.55	549.726	81.791	2107.54	
22.	S20.1	687.01	537.174	113.872	2172.379	
Residential area						
1.	S6	939.996	660.365	302.097	2704.635	718.316
2.	S6.1	682.947	708.880	145.691	3762.506	
3.	S8	450.728	487.321	71.846	1758.933	

4.	S8.1	783.304	376.843	126.58	1754.702	
5.	S19	752.124	852.697	114.954	3158.454	
6.	S19.1	479.376	307.376	82.295	1117.853	
7.	S21	1063.427	856.710	67.091	3372.801	
8.	S21.1	594.628	453.315	113.69	1810.417	
Roadway						
1.	S1	656.488	507.664	113.69	2646.331	597.420
2.	S1.1	636.051	387.649	136.168	1511.251	
3.	S7	661.707	463.711	115.849	1812.696	
4.	S7.1	348.442	202.358	40.755	818.848	
5.	S10	492.127	442.558	58.191	2068.06	
6.	S10.1	484.418	318.294	81.285	1448.721	
7.	S15	601.695	662.980	92.008	2899.11	
8.	S15.1	472.057	399.307	74.941	1871.553	
9.	S22	752.797	544.766	83.54	2441.748	
10.	S22.1	897.812	893.182	51.409	3437.915	
11.	S23	540.833	257.102	69.212	1042.641	
12.	S23.1	624.607	630.298	184.017	2562.323	
Vacant land						
1.	S24	837.488	729.850	165.216	3181.356	793.775
2.	S24.1	644.316	825.718	89.506	3192.092	
3.	S25	667.876	367.897	254.219	1431.747	
4.	S25.1	1025.42	539.894	305.293	2348.885	

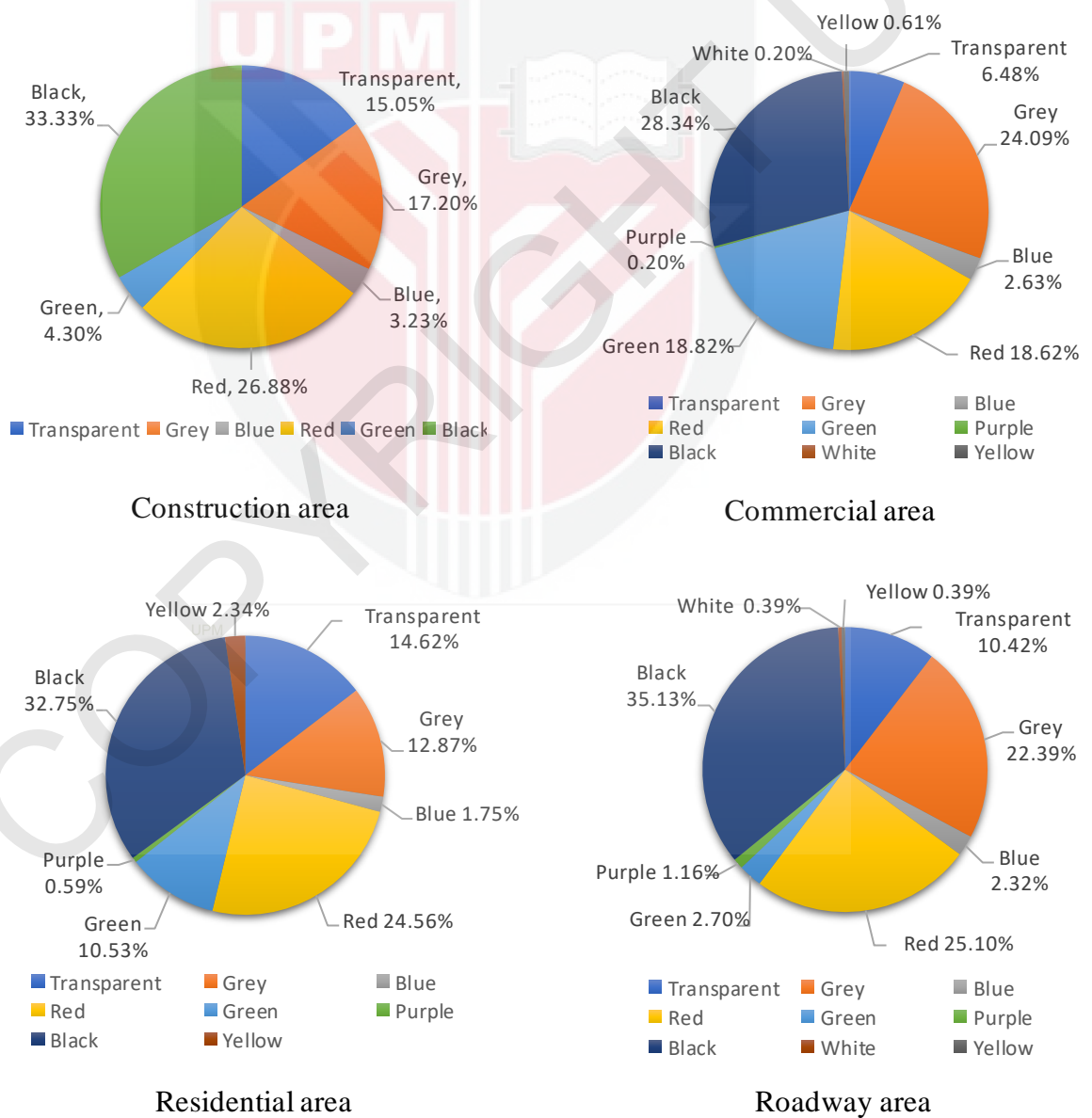
The shortest microplastics particle was from the commercial area (586.082 μm), and the longest came from vacant land (793.775 μm). Microplastics get smaller more often in the commercial area and less often in vacant land as commercial areas are much more influenced by humans and contain various types of activity compared to vacant land, which has less human activity. Rafique et al. (2020) stated that it is difficult to identify any single point source at a sampling site that controls the concentration of MPs; however, there appears to be a link between land usage and MPs size and the association between land use, and the link gets weaker with the decrease in particle size. Du et al., (2020) observed that microplastics in vacant land have bigger particle size because the microplastics in these locations are less impacted by external disturbances, and the microplastics discharged into the environment are continuously collected, making further deterioration more difficult. Apart from that, the size of the microplastics was also affected due to several complicated environmental factors such

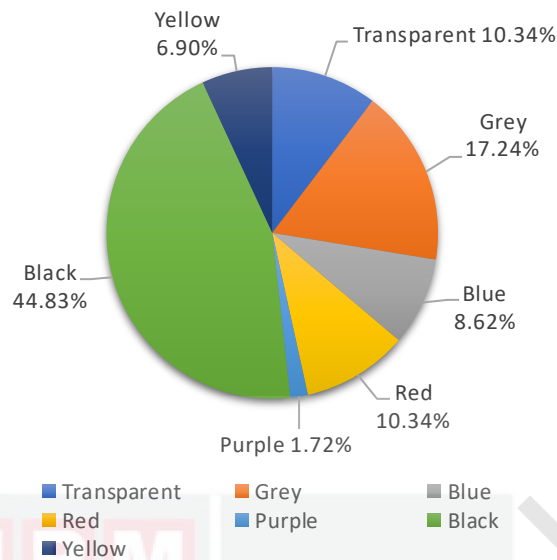
as wind, waves, temperature, and ultraviolet light (Guo et al., 2020; Lwanga et al., 2017). It can be argued that human and environmental factors have a significant influence in defining the dominant size fraction of microplastics in soil (Rafique et al., 2020). Therefore it can be stated that the size of microplastics depends on the intensity of human activity and environmental factors in a given location.

Wind may contribute to the long-distance transport of airborne particles directly to both terrestrial and aquatic environments. The properties of microplastics particles such as size, shape, and polymer types need to be determined as it influence their movement, partitioning, and degradation in soil environments. The migration of microplastics through the food chain alters the biological community dramatically and coupled with the decreasing particle size of microplastics, increased concentrations, and transmission of microplastics in food chains, eventually reaching humans (O'Kelly et al., 2021). Furthermore, fibrous microplastics up to 250 μm in size have been shown to obstruct lung clearance processes. Several health concerns were documented, including diminished lung capacity, coughing, and shortness of breath. On top of that, microplastics can accumulate in the upper respiratory system (nose, mouth, throat) and can enter the gut when ingested. Finer microplastics may be able to diffuse to the cardiovascular system and other organs. Toxic to reproduction, carcinogenic, and mutagenic in nature (Uddin et al., 2022).

4.2.2 Microplastics Color in Urban Soil from Cyberjaya

Nine types of colors (transparent, grey, blue, red, green, purple, black, white, and yellow) were identified in the extracted microplastics from the urban soil samples. 32% of microplastics extracted were black, followed by red (21.40%), grey (20.93%), green (11.35%), transparent (9.67%), blue (2.79%), yellow (1.12%), purple (0.56%), and white (0.19%). Figure 4.1 shows the further proportion of colors among microplastics for each land use.





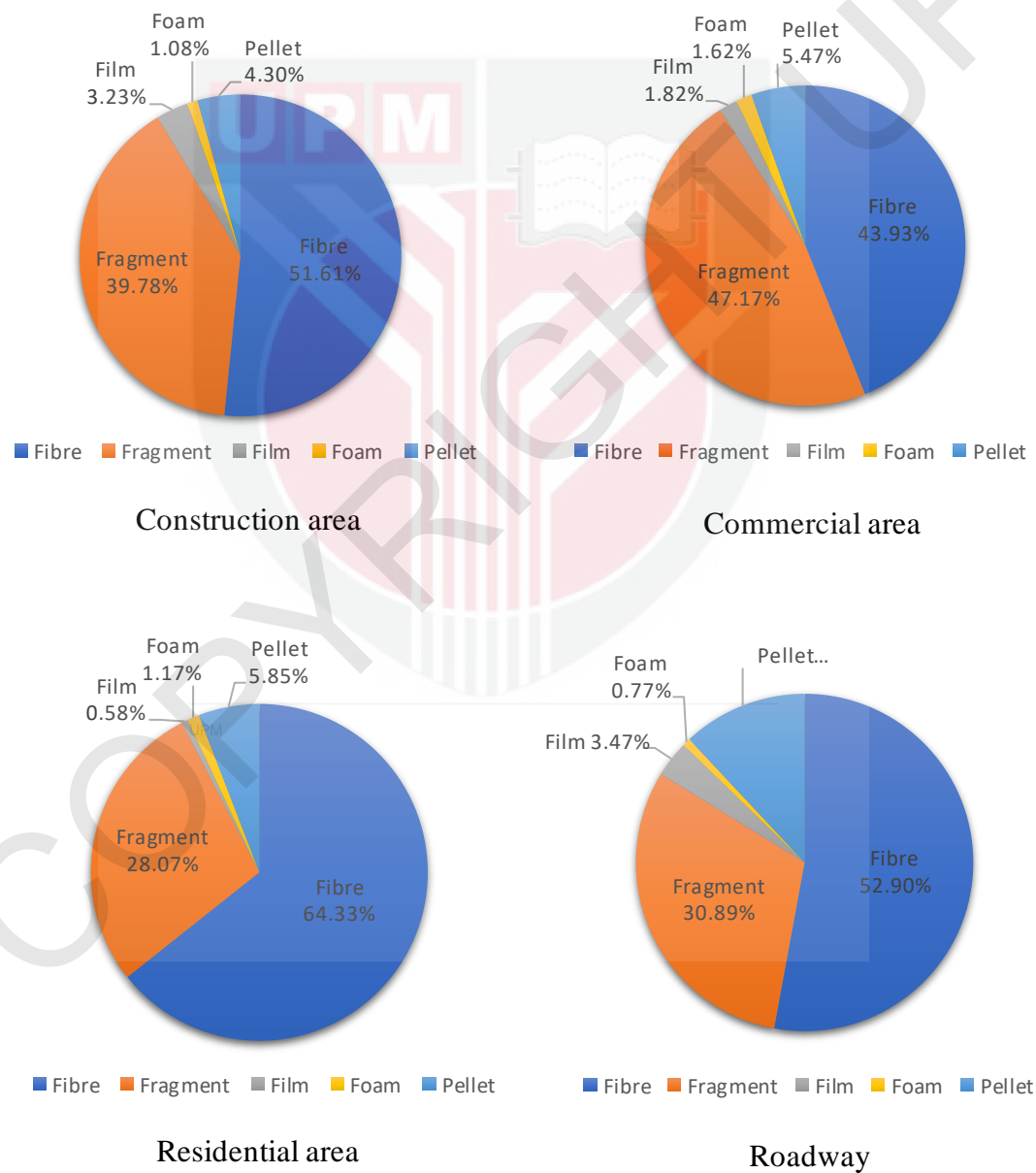
Vacant land

Figure 4.1: The proportion of color among particles extracted from urban soil samples

Distinct colors can provide an overview of the origins of plastic materials; (Khalik et al., 2018). For instance, black microplastic fragments were considered as tire wear particles (Austin D.Gray et al., 2018). Carbon black is applied at a concentration of 22–40% to act as a filler and increase the tire's UV resistance (Kole et al., 2017). Yellow and black colors are also generated from tire dust and road paint (Choi et al., 2020). Moreover, a variety of microplastics colors, including red, blue, grey, orange, yellow, brown, tan, off-white, white, green, and others were found from the atmospheric deposition (Y. Zhang et al., 2020). Colors such as red, blue, purple, transparent, and others also may produce from the debris of the littering activities and other potential sources

4.2.3 Microplastics Shape in Urban Soil from Cyberjaya

Five types of shape (fibre, fragment, film, foam and pellet) were identified in these extracted particles. Fibre shape accounted for the dominant form of the particle extracted (52%), followed by fragment (37%), pellet (6.7%), film (2.04%), and foam (1.3%). Figure 4.2 shows the details on the proportion of shapes among particles extracted from each land use.



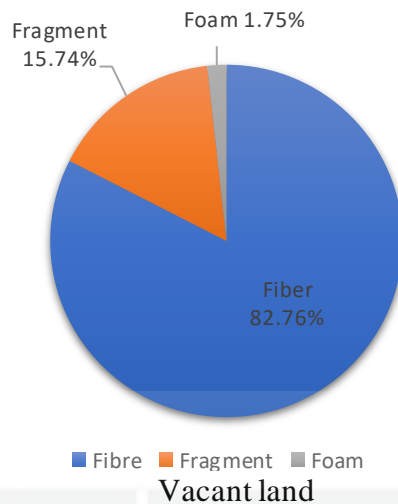


Figure 4.2 The proportion of shapes among particles extracted from each land use

As illustrated in Figure 4.3, there are various probable sources of particles in the urban area. Discarded containers, plastic bottles, and food wrappers were regularly found on the urban soil, which demonstrates that littering is a significant source of microplastics contamination. Based on figures 4.8 - 4.12, the commercial area has a high number of particles in the fragment (64%) compared to the other land-use where fibre was the dominant shape that can be identified. The high formation of the fragment in the commercial area can occur due to the photodegradation of the large plastic debris, which degrades into tiny bits. Most fragments originated from the long-term decomposition of large plastic waste (Said, 2020). As for the fibre, it was commonly released by synthetic clothes, most notably during the laundry process. Even though the microplastics emission from the synthetic fibre is generally known to contaminate the water, atmospheric fallouts could also be listed as a potential route of microplastics pollution in the fibre-shaped. Prior study's findings found that over 90% of microplastics found were fibre in atmospheric fallout (Dris et al., 2015). Another study concluded that the atmospheric compartment should not be overlooked

as a possible source of microplastics because it estimated that 29% of fibre contain plastic polymers (Dris et al., 2016).





Figure 4.3 Potential sources of the particles found in the Cyberjaya area

4.2.4 Microplastics Polymer Types in Urban Soil from Cyberjaya

After visual identification and characterization, only five urban soil samples were chosen due to the financial cost. The polymers of the collected particles were identified using Fourier transform infrared spectrometry. FTIR spectrometry of particles collected from urban soil samples is shown in Table 4.2, and the results are summarized in the following paragraphs.

Table 4.3 The polymer composition of extracted particles from urban soil of Cyberjaya

Sample	Land use	The polymer composition of extracted particles
S11.1	Commercial area	PC
S20.1	Commercial area	PC
S15	Roadway	PS
S25.1	Vacant land	PS
S24	Vacant land	PVC

Three distinct types of polymers with varying chemical compositions have been identified. The FTIR and microscopic images of extracted particles in the samples, along with their polymer types, are shown in Figure 4.4 to Figure 4.8. Polycarbonate (PC) and polystyrene (PS) was the most often found plastic polymer, followed by polyvinyl chloride (PVC).

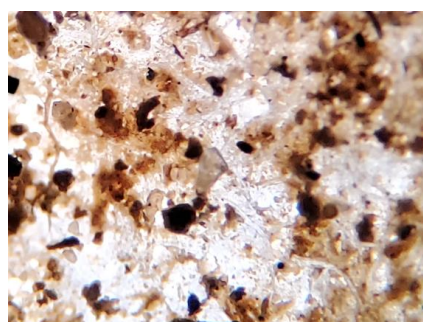
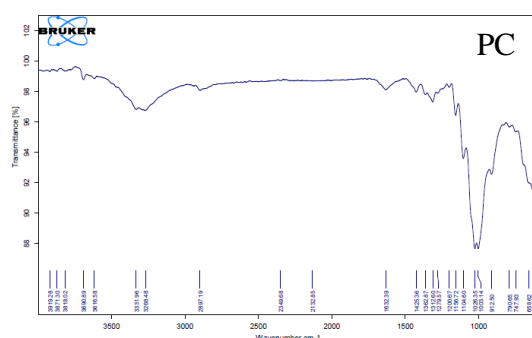


Figure 4.4 FTIR and microscopic images of extracted particles in S11.1

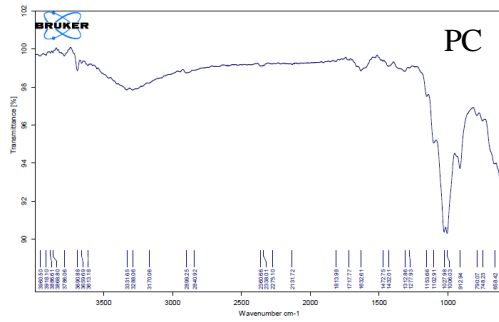


Figure 4.5 FTIR and microscopic images of extracted particles in S20.1

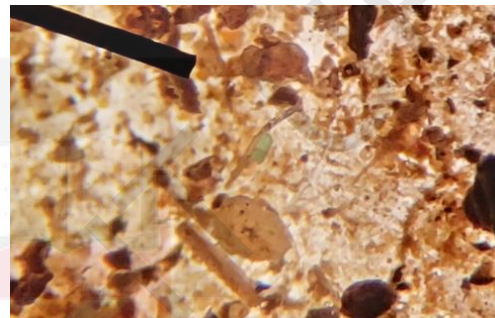
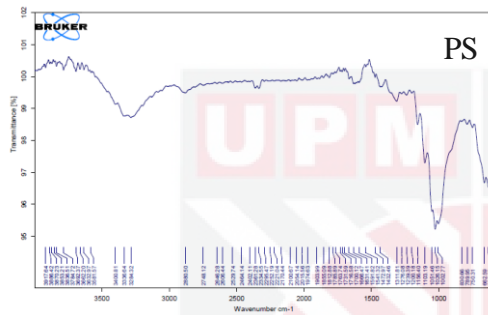


Figure 4.6 FTIR and microscopic images of extracted particles in S15

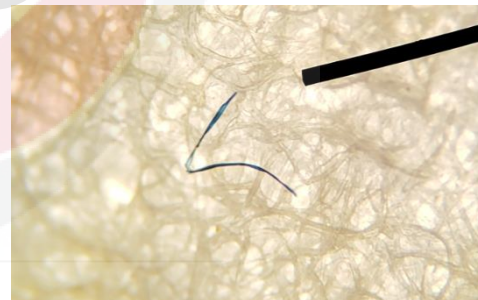
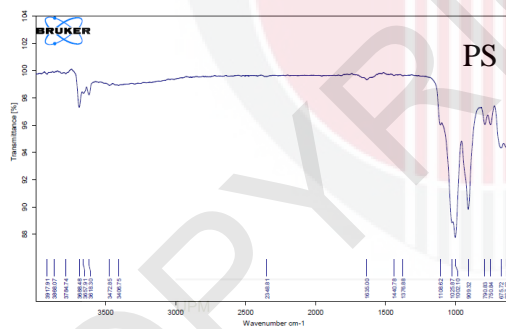


Figure 4.7 FTIR and microscopic images of extracted particles in S25.1

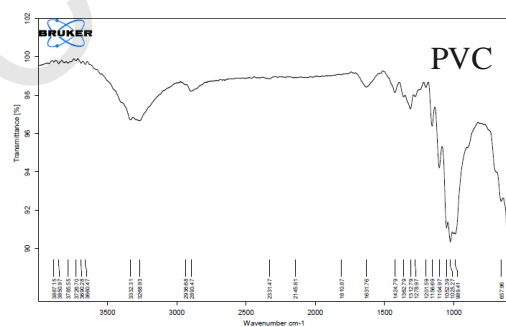


Figure 4.8 FTIR and microscopic images of extracted particles in S24

Polycarbonate (PC) was discovered in both commercial areas, where both areas (S11.1 and S20.1) were near the gas station and food premises, respectively. According to Magnusson et al. (2016), polycarbonate microplastics can be emitted by the roofing sheets. Many gas stations and convenience stores include bullet-proof glass and barricades to protect staff and prevent criminals. Polycarbonate is appropriate for this application because it looks like glass but is more secure (Piedmont Plastics, 2021). Besides, polystyrene (PS) was identified in the roadway and vacant land. Polystyrene is usually observed in plastic cutlery, food containers and utilized for insulation foam (Andrady, 2011; Magnusson et al., 2016). However, polystyrene was also available in road infrastructure in the form of expanded polystyrene (EPS), developed to insulate and mitigate pavement frost damage (Giuliani et al., 2020). Additionally, polyvinylchloride (PVC) was detected in vacant land near the playground space. It was frequently used in packaging, pipes, wire coating, containers, and the breakdown of plastic components (Said, 2020). PVC was also used extensively in playground equipment, where it was used as the coating for its assemblies. PVC-coated steel deck technology was often mixed with plasticizers and phthalates, which pose a more severe health risk (Bachman, 2013; Beckwith, 2014).

4.3 The Association between Microplastics Occurrence in Urban Soil and Land Use

A one-way analysis of variance (ANOVA) between groups was performed to determine the effect of land use types on the microplastics size in urban soil. Skewness, kurtosis, and Shapiro-Wilk statistics all supported the assumption of normality for each of the three conditions. Levene's statistic was significant at $\alpha=0.05$, ($F=1.398$, $Sig.=0.250$), indicating that the assumption of variance homogeneity was not violated. Thus, ANOVA test was selected to assess the association between the

types of land use and size of the microplastics. The ANOVA was not statistically significant, depicting that the particles size from the urban soil were not influenced by the types of land use, $F(4, 45) = 1.286$, $p=0.290$. However, $\eta^2 = 0.103$, is classified as medium, which shows that the independent variable (types of land use) accounts for 10% of the variability in the size of the particles. Table 4.3 shows ANOVA test result used to assess the association between microplastics size in urban soil and land use

Table 4.4 ANOVA test used to assess the association between microplastics size in urban soil and land use

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	228839.094	4	57209.774	1.286	.290
Within Groups	2001499.078	45	44477.757		
Total	2230338.172	49			

Based on the result, land use did not significantly impact the size of the microplastics. Microplastics varied in size, shape, and color according to the type of land use, indicating not just their origin but also their degree of accumulation and deterioration (Choi et al., 2020). Therefore, it is necessary to look at the association between size of the particles and land use. Anthropogenic impacts such as intense urban land use and high population densities are not the only cause that is responsible for the changes in the size of the microplastics, but environmental factors should also be considered to affect the size of it.

Exposure to sunlight over an extended time can cause changes in particles through the photodegradation of plastics. UV light aided by high-temperature changes is typically larger on land than those seen in seawater, which can produce chemical

changes in polymers by oxidizing them, making them brittle and hence more prone to fragmentation. (Cole et al., 2011; Horton et al., 2017). It was anticipated that darker colored plastic materials (for example, black particles) would absorb more sunlight, increase the temperature, and speed up the pace of disintegration (Campanale et al., 2020). On a molecular level, the deterioration of synthetic polymers in the environment is often triggered via photo-oxidation (using ultraviolet light) or hydrolysis, which is then continued by chemical oxidation (using oxygen). The major mechanisms are highly dependent on the type of polymer, as there are various synthetic polymer compositions available such as polypropylene, polyamides, and styrene-butadiene rubber. Following the early interactions, the polymer's molecular weight decreases, and the reacted groups become accessible for microbial breakdown. While photo-oxidation is typically a rapid process, the breakdown pace is also dependent on the number of additives present in a specific polymer that inhibits oxidation reaction, such as antioxidants (Wagner & Lambert, 2018).

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In conclusion, abundance particles have been identified in the selected surface soil samples from the urban area in Cyberjaya, Selangor, comprised of commercial area (6.61 particle/g), which had the highest concentration, followed by roadway (3.46 particle/g), residential area (2.11 particle/g) and construction area (1.37 particle/g), and vacant land (0.65 particle/g). Particle size with a range from 0 μm to 4543.47 μm was identified. The shortest microplastics particle was from the commercial area (586.082 μm), and the longest came from vacant land (793.775 μm). Furthermore, various colors were observed in the urban soil samples, with black (32%) being the most prevalent and followed by red (21.40%), grey (20.90%), green (11.35%), transparent (9.67%), blue (2.79%), yellow (1.12%), purple (0.56%), and white (0.19%). The most common particle extracted was fibre (52%), followed by fragment (37%), film (22%), pellet (6.7%), and foam (1.3%). Polycarbonate (PC), polystyrene (PS), and polyvinyl chloride (PVC) were detected in the extracted particles, indicating that the particles originated from a variety of sources such as debris from littering behavior, tire and road wear, abrasion of road marking, construction materials, shoe sole wear and tear or atmospheric transport.

5.2 Recommendations

Toxicological test on the effect of microplastics in soil is necessary to further understand microplastics' toxicity to the environment. More research is needed to understand better how human activities and environmental factors may influence microplastics accumulation in urban soil. Future studies are recommended to involve a large number of samples as it helps to reduce bias and improve the accuracy of the results. Future research should also consider studying how the age of land use may impact the size of the microplastics.

REFERENCES

- A&C Plastics (2022). Application of Plastic Construction Materials in Building Development. <https://www.acplasticsinc.com/informationcenter/r/applications-of-plastic-construction-materials>
- Abbasi, S., Keshavarzi, B., Moore, F., Turner, A., Kelly, F. J., Dominguez, A. O., & Jaafarzadeh, N. (2019). Distribution and potential health impacts of microplastics and microrubbers in air and street dusts from Asaluyeh County, Iran. *Environmental Pollution*, 244, 153–164. <https://doi.org/10.1016/j.envpol.2018.10.039>
- Alam, M. A., & Ahmed, F. (2013). Urban Transport System and Congestion: A case study of Indian Cities. *Transport and Communications Bulletin for Asia and the Pacific*, 82, 33–43.
- Andrady, A. L. (2011). Microplastics in the marine environment. *Marine Pollution Bulletin*, 62(8), 1596–1605. <https://doi.org/10.1016/j.marpolbul.2011.05.030>
- Arvin, M. B., Pradhan, R. P., & Norman, N. R. (2015). Transportation intensity, urbanization, economic growth, and CO2 emissions in the G-20 countries. *Utilities Policy*, 35, 50–66. <https://doi.org/10.1016/j.jup.2015.07.003>
- Austin D.Gray, Hope Wertz, Rachel R.Leads, & John E.Weinstein. (2018). *Microplastic in two South Carolina Estuaries_ Occurrence, distribution, and composition | Elsevier Enhanced Reader*. <https://doi.org/doi.org/10.1016/j.marpolbul.2018.01.030>
- Autodesk Inc. (2020). *Building for a 10-Billion-Person Planet | Autodesk*. <https://www.autodesk.com/solutions/architecture-engineering-construction/building-future>
- Bachman, K. (2013). *Making Play PVC-free*. <https://www.fmamfg.org/blog/making-play-pvc-free>
- Barasarathi, J., Agamuthu, P., Emenike, C. U., & Fauziah, S. H. (2011). Microplastic abundance in selected mangrove forest in Malaysia. *Proceeding of The ASEAN Conference on Science and Technology 2014, 18-20 August 2014, Bogor, Indonesia, June 2015*, 4.
- Beckwith, J. (2014). *The Technology of Playgrounds*. <https://www.playgroundprofessionals.com/playground/playstructures/technology-playgrounds>
- Bläsing, M., & Amelung, W. (2018). Plastics in soil: Analytical methods and possible sources. *Science of the Total Environment*, 612, 422–435. <https://doi.org/10.1016/j.scitotenv.2017.08.086>
- Campanale, C., Stock, F., Massarelli, C., Kochleus, C., Bagnuolo, G., Reifferscheid, G., & Uricchio, V. F. (2020). Microplastics and their possible sources: The example of Ofanto river in southeast Italy. *Environmental Pollution*, 258, 113284. <https://doi.org/10.1016/j.envpol.2019.113284>
- Choi, Y. R., Kim, Y. N., Yoon, J. H., Dickinson, N., & Kim, K. H. (2021). Plastic contamination of forest, urban, and agricultural soils: a case study of Yeosu City in the Republic of Korea. *Journal of Soils and Sediments*, 21(5), 1962–1973. <https://doi.org/10.1007/s11368-020-02759-0>

- Choi, Y. R., Kim, Y., Yoon, J., Dickinson, N., & Kim, K. (2020). *Plastic contamination of forest, urban, and agricultural soils : a case study of Yeosu City in the Republic of Korea.*
- Cole, M., Lindeque, P., Halsband, C., & Galloway, T. S. (2011). Microplastics as contaminants in the marine environment: A review. *Marine Pollution Bulletin*, 62(12), 2588–2597. <https://doi.org/10.1016/j.marpolbul.2011.09.025>
- Corradini, F., Casado, F., Leiva, V., Huerta-Lwanga, E., & Geissen, V. (2021). Microplastics occurrence and frequency in soils under different land uses on a regional scale. *Science of the Total Environment*, 752, 141917. <https://doi.org/10.1016/j.scitotenv.2020.141917>
- Corradini, F., Meza, P., Eguiluz, R., Casado, F., Huerta-Lwanga, E., & Geissen, V. (2019). Evidence of microplastic accumulation in agricultural soils from sewage sludge disposal. *Science of the Total Environment*, 671, 411–420. <https://doi.org/10.1016/j.scitotenv.2019.03.368>
- Cyberview Sdn Bhd. (2017). *Cyberjaya city centre- redefine you.*
- Cyberview Sdn Bhd. (2021a). *Cyberjaya Malaysia | The Story of a Global Tech Hub.* <https://www.cyberjayamalaysia.com.my/about/the-story>
- Cyberview Sdn Bhd. (2021b). *Cyberview - Tech Hub Developer - Cyberview.* <https://www.cyberview.com.my/business/cyberview-tech-hub-developer/>
- Da Costa, J. P., Rocha-Santos, T., & C. Duarte, A. (2020). *The environmental impacts of plastics and micro-plastics use , waste and pollution : EU and national measures. October.* [https://www.europarl.europa.eu/thinktank/en/document/IPOL_STU\(2020\)658279](https://www.europarl.europa.eu/thinktank/en/document/IPOL_STU(2020)658279)
- Dehghani, S., Moore, F., & Akhbarizadeh, R. (2017). Microplastic pollution in deposited urban dust, Tehran metropolis, Iran. *Environmental Science and Pollution Research*, 24(25), 20360–20371. <https://doi.org/10.1007/s11356-017-9674-1>
- Department of Statistics Malaysia. (2011, July 29). *Populations Distribution and Basic Demographic Characteristics Report 2010.* https://www.dosm.gov.my/v1/index.php?r=column/cthemByCat&cat=117&bul_id=MDMxdHZjWTK1SjFzTzNkRXYzcVZjdz09&menu_id=L0pheU43NWJwRWVVSZklWdzQ4TlhUUT09
- Department of Statistics Malaysia. (2021, October 28). *Population and Housing Census.* https://www.dosm.gov.my/v1/index.php?r=column/cone&menu_id=bDA2VkxRSU40STcxdkZ4OGJ0c1ZVdz09
- Dris, R., Gasperi, J., Rocher, V., Saad, M., Renault, N., & Tassin, B. (2015). Microplastic contamination in an urban area: A case study in Greater Paris. *Environmental Chemistry*, 12(5), 592–599. <https://doi.org/10.1071/EN14167>
- Dris, R., Gasperi, J., Saad, M., Mirande, C., & Tassin, B. (2016). Synthetic fibers in atmospheric fallout: A source of microplastics in the environment? *Marine Pollution Bulletin*, 104(1–2), 290–293. <https://doi.org/10.1016/j.marpolbul.2016.01.006>
- Du, C., Liang, H., Li, Z., & Gong, J. (2020). Pollution characteristics of microplastics in soils in southeastern suburbs of Baoding City, China. *International Journal of Environmental Research and Public Health*, 17(3). <https://doi.org/10.3390/ijerph17030845>
- Forster, N. A., Tighe, M. K., & Wilson, S. C. (2020). Microplastics in soils of wilderness areas:

What is the significance of outdoor clothing and footwear? *Geoderma*, 378(August).
<https://doi.org/10.1016/j.geoderma.2020.114612>

- Giuliani Felice, Autelitano Federico, Garilli Erika, & Montepara Antonio. (2020). *Expanded polystyrene (EPS) in road construction: Twenty years of Italian experiences*.
<https://reader.elsevier.com/reader/sd/pii/S2352146520301952?token=AFE3178EC896802A10B57529CC44ED63C2A870AC1A81514383B3448E6174D91B3E70CAC98DA43C4071CD316ED6D81BF7&originRegion=eu-west-1&originCreation=20211230075701>
- Guo, J. J., Huang, X. P., Xiang, L., Wang, Y. Z., Li, Y. W., Li, H., Cai, Q. Y., Mo, C. H., & Wong, M. H. (2020). Source, migration and toxicology of microplastics in soil. *Environment International*, 137(September 2019), 105263.
<https://doi.org/10.1016/j.envint.2019.105263>
- Häkkinen, T., Kuittinen, M., & Vares, S. (2019). *Plastics in buildings*.
- Hamid, A., Bakar, A. F. A., Ng, T. F., Ghani, A. A., & Zulkifley, M. T. M. (2019). *Distribution and contamination assessment of potentially harmful elements (As, Pb, Ni, Cd) in top soil of Penang Island, Malaysia*.
- He, P., Chen, L., Shao, L., Zhang, H., & Lü, F. (2019). Municipal solid waste (MSW)landfill: A source of microplastics? -Evidence of microplastics in landfill leachate. *Water Research*, 159, 38–45. <https://doi.org/10.1016/j.watres.2019.04.060>
- Horton, A. A., Walton, A., Spurgeon, D. J., Lahive, E., & Svendsen, C. (2017). Microplastics in freshwater and terrestrial environments: Evaluating the current understanding to identify the knowledge gaps and future research priorities. *Science of the Total Environment*, 586, 127–141. <https://doi.org/10.1016/j.scitotenv.2017.01.190>
- Hurley, R. R., & Nizzetto, L. (2018). Fate and occurrence of micro(nano)plastics in soils: Knowledge gaps and possible risks. *Current Opinion in Environmental Science and Health*, 1, 6–11. <https://doi.org/10.1016/j.coesh.2017.10.006>
- Ingre-Khans, E., Rudén, C., & Breitholtz, M. (2010). Chemical risks and consumer products: The toxicity of shoe soles. *Ecotoxicology and Environmental Safety*, 73(7), 1633–1640. <https://doi.org/10.1016/j.ecoenv.2010.06.016>
- Ismail, S., Ishak, C., Samah, M., Hatta, E., & Wahab, A. (2015). Soil Contamination from Non-sanitary Waste Landfill in Langat Water Catchment Area, Malaysia. *Journal of Scientific Research and Reports*, 7(6), 480–493. <https://doi.org/10.9734/jsrr/2015/15102>
- Jabatan Perancangan Bandar dan Desa. (2016). *Sistem Maklumat Guna Tanah Perancangan Bersepadu (i-Plan)*. https://iplan.townplan.gov.my/kamus_data/user_view
- Jabatan Perangkaan Malaysia. (2011). *Banci Ekonomi 2011*. https://www.dosm.gov.my/v1/images/stories/files/questionnaire/BanciBE/pembinaan/Borang_BE2011_PembinaanBM.pdf
- Johnson, G., Hii, W. S., Lihan, S., & Tay, M. G. (2020). Microplastics Determination in the Rivers with Different Urbanisation Variances: A Case Study in Kuching City, Sarawak, Malaysia. *Borneo Journal of Resource Science and Technology*, 10(2), 116–125. <https://doi.org/10.33736/bjrst.2475.2020>
- Kamarudin, M. K. A., Gidado, K. A., Toriman, M. E., Juahir, H., Umar, R., Abd Wahab, N., Ibrahim, S., Awang, S., & Maulud, K. N. A. (2018). Classification of land use/land cover







- changes using GIS and remote sensing technique in Lake Kenyir Basin, Terengganu, Malaysia. *International Journal of Engineering and Technology(UAE)*, 7(3.14 Special Issue 14), 12–15. <https://doi.org/10.14419/ijet.v7i3.14.16854>
- Karbalaei, S., Golieskardi, A., Hamzah, H. B., Abdulwahid, S., Hanachi, P., Walker, T. R., & Karami, A. (2019). Abundance and characteristics of microplastics in commercial marine fish from Malaysia. *Marine Pollution Bulletin*, 148(August), 5–15. <https://doi.org/10.1016/j.marpolbul.2019.07.072>
- Khalik, W. M. A. W. M., Ibrahim, Y. S., Tuan Anuar, S., Govindasamy, S., & Baharuddin, N. F. (2018). Microplastics analysis in Malaysian marine waters: A field study of Kuala Nerus and Kuantan. *Marine Pollution Bulletin*, 135(February), 451–457. <https://doi.org/10.1016/j.marpolbul.2018.07.052>
- Kitahara, K. I., & Nakata, H. (2020). Plastic additives as tracers of microplastic sources in Japanese road dusts. *Science of the Total Environment*, 736, 139694. <https://doi.org/10.1016/j.scitotenv.2020.139694>
- Kole, P. J., Löhr, A. J., Van Belleghem, F. G. A. J., & Ragas, A. M. J. (2017). Wear and tear of tyres: A stealthy source of microplastics in the environment. *International Journal of Environmental Research and Public Health*, 14(10). <https://doi.org/10.3390/ijerph14101265>
- Kosmas, C., Kirkby, M. J., Geeson, N., & (Eds). (1999). *Medalus Project: Mediterranean Desertification and Land Use. Manual on Key Indicators of Desertification and Mapping Environmentally Sensitive Areas* (Issue June 2014). <http://www.kcl.ac.uk/projects/desertlinks/downloads/publicdownloads/ESA Manual.pdf>
- Koswara, A. Y., & Pamungkas, A. (2017). *STRATEGI PENYEDIAAN KAWASAN KOMERSIAL DI LINGKUNGAN KAMPUS ITS SURABAYA*. http://digilib.mercubuana.ac.id/manager/t!@file_artikel_abstrak/Isi_Artikel_233151136978.pdf
- Lassen, C., Hansen, S. F., Magnusson, K., Hartmann, N. B., Rehne Jensen, P., Nielsen, T. G., & Brinch, A. (2015). Microplastics Occurrence, effects and sources of releases. In *Danish Environmental Protection Agency*.
- Li, Q., Wu, J., Zhao, X., Gu, X., & Ji, R. (2019). Separation and identification of microplastics from soil and sewage. *Environmental Pollution*, 254, 113076. <https://doi.org/10.1016/j.envpol.2019.113076>
- Lwanga, E. H., Gertsen, H., Gooren, H., Peters, P., Ploeg, M. Van Der, Besseling, E., Koelmans, A. A., & Geissen, V. (2017). *Incorporation of microplastics from litter into burrows of Lumbricus s Sal a Tam a*. 220, 523–531. <https://doi.org/10.1016/j.envpol.2016.09.096>
- Magnusson, K., Eliasson, K., Fråne, A., Haikonen, K., Hulten, J., Olshammar, M., Stadmark, J., & Voisin, A. (2016). Swedish source and pathways for microplastics to the marine environment - A review of existing data. *IVL Swedish Environmental Research Institute, C 183(C)*, 87.
- Majlis Perbandaran Sepang. (2017). *Cyberjaya Smart & Low Carbon City Action Plan 2025*. 89. <http://smart.mpsepang.gov.my/wp-content/uploads/2017/12/Action-Plan-Cyberjaya-SLC-2025.compressed.pdf>

- Mohd Radzi, N. A. S., Abu Bakar, N. K., Emenike, C. U., & Abas, M. R. (2016). Polycyclic aromatic hydrocarbons (PAHs): contamination level and risk assessment in urban areas, Kuala Lumpur, Malaysia. *Desalination and Water Treatment*, 57(1), 171–190. <https://doi.org/10.1080/19443994.2015.1021103>
- Möller, J. N., Löder, M. G. J., & Laforsch, C. (2020). Finding Microplastics in Soils: A Review of Analytical Methods. *Environmental Science and Technology*, 54(4), 2078–2090. <https://doi.org/10.1021/acs.est.9b04618>
- Nkem Ede, A., Alegiuno, V., & OluwaseunAwoyera, P. (2014). Use of Advanced Plastic Materials in Nigeria: Performance Assessment of Expanded Polystyrene Building Technology System. *American Journal of Engineering Research (AJER)*, 03, 301–308. www.ajer.org
- Nuissl, H., & Siedentop, S. (2021). *Urbanisation and Land Use Change*. Springer International Publishing. https://doi.org/10.1007/978-3-030-50841-8_5
- Nurul Nadia, A. (2019). *Macro and Microplastics Abundance on Beaches of Selected Islands in Peninsular Malaysia*.
- O'Kelly, B. C., El-Zein, A., Liu, X., Patel, A., Fei, X., Sharma, S., Mohammad, A., Goli, V. S. N. S., Wang, J. J., Li, D., Shi, Y., Xiao, L., Kuntikana, G., Shashank, B. S., Sarris, T. S., Hanumantha Rao, B., Mohamed, A. M. O., Paleologos, E. K., Nezhad, M. M., & Singh, D. N. (2021). Microplastics in soils: an environmental geotechnics perspective. In *Environmental Geotechnics*. <https://doi.org/10.1680/jenge.20.00179>
- OECD. (2020). Cities in the world: A New Perspective on Urbanisation. In *OECD Urban Studies/European Union*. <https://read.oecd.org/10.1787/d0efcbda-en?format=pdf>
- Peng, L., Fu, D., Qi, H., Lan, C. Q., Yu, H., & Ge, C. (2020). Micro- and nano-plastics in marine environment: Source, distribution and threats — A review. *Science of the Total Environment*, 698, 134254. <https://doi.org/10.1016/j.scitotenv.2019.134254>
- Piedmont Plastics. (2021). *Polycarbonate and Acrylic Sheet for Bullet-Resistant Glazing*. <https://www.piedmontplastics.com/applications/gas-station-convenience-store-glazing>
- Praveena, S. M. (2021). *Microplastic emissions from household washing machines: preliminary findings from Greater Kuala Lumpur (Malaysia)*. 18518–18522.
- Praveena, S. M., Ismail, S. N. S., & Aris, A. Z. (2015). Health risk assessment of heavy metal exposure in urban soil from Seri Kembangan (Malaysia). *Arabian Journal of Geosciences*, 8(11), 9753–9761. <https://doi.org/10.1007/s12517-015-1895-3>
- Praveena, S. M., Shaifuddin, S. N. M., & Akizuki, S. (2018). Exploration of microplastics from personal care and cosmetic products and its estimated emissions to marine environment: An evidence from Malaysia. *Marine Pollution Bulletin*, 136(August), 135–140. <https://doi.org/10.1016/j.marpolbul.2018.09.012>
- Qi, R., Jones, D. L., Li, Z., Liu, Q., & Yan, C. (2020). Behavior of microplastics and plastic film residues in the soil environment: A critical review. *Science of the Total Environment*, 703, 134722. <https://doi.org/10.1016/j.scitotenv.2019.134722>
- Qiu, R., Song, Y., Zhang, X., Xie, B., & He, D. (2020). Microplastics in Urban Environments: Sources, Pathways, and Distribution. In *Handbook of Environmental Chemistry* (Vol. 95, pp. 41–61). https://doi.org/10.1007/698_2020_447

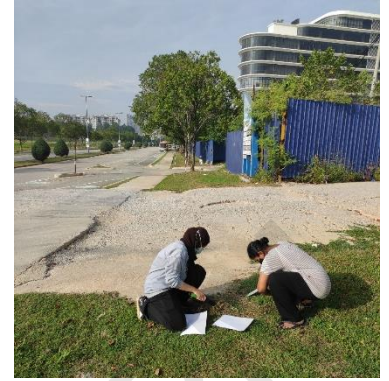
- Rafique, A., Irfan, M., Mumtaz, M., & Qadir, A. (2020). Spatial distribution of microplastics in soil with context to human activities: a case study from the urban center. *Environmental Monitoring and Assessment*, 192(11). <https://doi.org/10.1007/s10661-020-08641-3>
- Rahman, A., Sarkar, A., Yadav, O. P., Achari, G., & Slobodnik, J. (2021). Potential human health risks due to environmental exposure to nano- and microplastics and knowledge gaps: A scoping review. *Science of the Total Environment*, 757, 143872. <https://doi.org/10.1016/j.scitotenv.2020.143872>
- Said, R. A. (2020). *Detection and Chemical Composition of Polysynthetic Plastic Materials along the Coastline of Zanzibar, Tanzania*.
- Salman, A. (2018). *Lessons from Cyberjaya : Malaysia 's Promised Silicon Valley*. July.
- Scheurer, M., & Bigalke, M. (2018). Microplastics in Swiss Floodplain Soils. *Environmental Science and Technology*, 52(6), 3591–3598. <https://doi.org/10.1021/acs.est.7b06003>
- Scientific Engineering Response & Analytical Services (SERAS). (2012). *Standard operating procedures*. 1–13.
- Shafiq, H., & Hamid, A. (2016). *Plastic Roads: A Recent Advancement in Waste Management*. www.ijert.org
- Su, L., Nan, B., Craig, N. J., & Pettigrove, V. (2020). Chemosphere Temporal and spatial variations of microplastics in roadside dust from rural and urban Victoria , Australia : Implications for diffuse pollution. *Chemosphere*, 252, 126567. <https://doi.org/10.1016/j.chemosphere.2020.126567>
- Sundt, P., Schultze, P.-E., & Syversen, F. (2014). Sources of microplastic- pollution to the marine environment. *Mepex, Norwegian Environment Agency*, 1–108.
- Tee, Y. H., Shuaib Ibrahim, Y., & Wan Mohd Khalik, W. M. A. (2020). Microplastic Abundance, Distribution, and Composition in Sungai Dungun, Terengganu, Malaysia. *Sains Malaysiana*, 49(7), 1479–1490. <https://doi.org/10.17576/JSM-2020-4907-01>
- Theobald, D. M., & Merenlender, A. M. (2014). Development and Applications of a Comprehensive Land Use Classification and Map for the US. *Citation: Theobald DM*, 9(4), 94628. <https://doi.org/10.1371/journal.pone.0094628>
- Thomas, D., Schütze, B., & Heinze, W. M. (2020). *Sample Preparation Techniques for the Analysis of Microplastics in Soil — A Review*. 1–28. <https://doi.org/10.3390/su12219074>
- Tresch, S., Moretti, M., Bayon, R. C. Le, Mäder, P., Zanetta, A., Frey, D., Stehle, B., Kuhn, A., Munyangabe, A., & Fliessbach, A. (2018). Urban soil quality assessment—a comprehensive case study dataset of urban garden soils. *Frontiers in Environmental Science*, 6(NOV), 1–5. <https://doi.org/10.3389/fenvs.2018.00136>
- U.S. Environmental Protection Agency. (2004). *Field Sampling Guidance Document #1205: Soil Sampling*. 1–8. https://dehs.umn.edu/sites/dehs.umn.edu/files/19990901_epa_soilsamplingguide.pdf
- U.S. Environmental Protection Agency. (2020). *Operating Procedure of Soil Sampling*. 1–29. <https://www.epa.gov/sites/production/files/2015-06/documents/Soil-Sampling.pdf>
- Uddin, S., Fowler, S. W., Habibi, N., Sajid, S., Dupont, S., & Behbehani, M. (2022). *Indoor Aerosol — Kuwait 's Baseline*. 2–17.

- United Nations Department of Economic and Social Affairs. (2019). World Urbanization Prospects: The 2018 Revision. In *Demographic Research*. <https://population.un.org/wup/Publications/Files/WUP2018-Report.pdf>
- United Nations Environment Programme (UNEP). (2005). *Marine Litter: An analytical overview*. 1–58.
- United Nations Environment Programme, & Caribbean Environment Programme. (2015). *Plastics and Microplastics - Factsheet July 2015*. <https://doi.org/10.1016/j.marpolbul.2015.07.029>
- United States Environmental Protection Agency. (1996). *Soil Screening Guidance : User ' s Guide*. July.
- United States Environmental Protection Agency. (2021). *Land Use: What are the trends in land use and their effects on human health and the environment?* <https://www.epa.gov/report-environment/land-use>
- Wagner, M., & Lambert, S. (2018). *Freshwater Microplastics*. <https://doi.org/https://doi.org/10.1007/978-3-319-61615-5>
- Wang, W., Ge, J., Yu, X., & Li, H. (2020). Environmental fate and impacts of microplastics in soil ecosystems: Progress and perspective. *Science of the Total Environment*, 708, 134841. <https://doi.org/10.1016/j.scitotenv.2019.134841>
- Wong, N. H., Chai, C. S., Bamgbade, J. A., Ma, G. F., & Hii, G. W. (2021). Detection of Microplastics in Bottled Water. *Materials Science Forum*, 1030(June), 169–176. <https://doi.org/10.4028/www.scientific.net/msf.1030.169>
- Wu, Y., Zhang, X., & Shen, L. (2011). The impact of urbanization policy on land use change: A scenario analysis. *Cities*, 28(2), 147–159. <https://doi.org/10.1016/j.cities.2010.11.002>
- Xu, C., Zhang, B., Gu, C., Shen, C., Yin, S., Aamir, M., & Li, F. (2020). Are we underestimating the sources of microplastic pollution in terrestrial environment? *Journal of Hazardous Materials*, 400(June), 123228. <https://doi.org/10.1016/j.jhazmat.2020.123228>
- Yang, L., Zhang, Y., Kang, S., Wang, Z., & Wu, C. (2021). Microplastics in soil : A review on methods , occurrence , sources , and potential risk *Science of the Total Environment* Microplastics in soil : A review on methods , occurrence , sources , and potential risk. *Science of the Total Environment*, 780(March), 146546. <https://doi.org/10.1016/j.scitotenv.2021.146546>
- Zhang, K., Shi, H., Peng, J., Wang, Y., Xiong, X., Wu, C., & Lam, P. K. S. (2018). Microplastic pollution in China's inland water systems: A review of findings, methods, characteristics, effects, and management. *Science of the Total Environment*, 630, 1641–1653. <https://doi.org/10.1016/j.scitotenv.2018.02.300>
- Zhang, Y., Kang, S., Allen, S., Allen, D., Tanguang, G., & Mika, S. (2020). *Atmospheric microplastics_ A review on current status and perspectives / Elsevier Enhanced Reader*. <https://reader.elsevier.com/reader/sd/pii/S001282521930621X?token=A1760069B551BFC1B6789C76F783FD89A663C6C6387D3FD8C2FEAC99BC569D9F7A55D391DBD7213776618A0CC24DD976&originRegion=eu-west-1&originCreation=20220126215920>

APPENDICES

Location	Cyber	Land use description	Photos of the sampling sites	
S1	Cyber 1	Roadway: Roadside of a vacant land		
S2	Cyber 1	Commercial area: Electrical supply infrastructure building (TNB)		
S3	Cyber 1	Commercial area: Mosque and parking area		

S4 Cyber Construction
 2 area



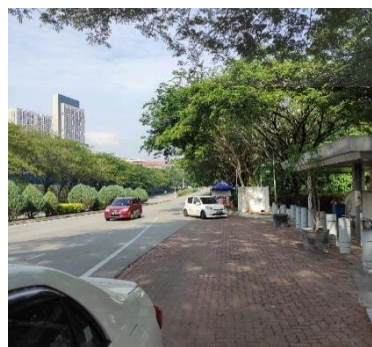
S5 Cyber Commercial
 10 area:
 Tamarind
 Square's area



S6 Cyber Residential
 9 area:
 KSG
 (residential
 compound)



S7 Cyber Roadway:
 11 Cyberia (food
 stall and bus-
 stop)



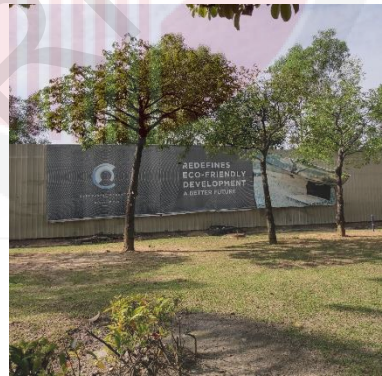
S8 Cyber 12 Residential area:
Block D of D-Melor



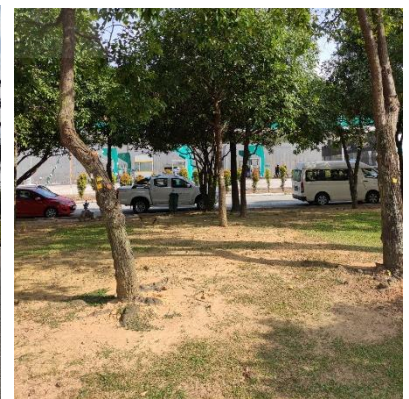
S9 Cyber 3 Construction area



S10 Cyber 3 Roadway:
The road across the gas station



S11 Cyber 3 Commercial area:
In front of gas station



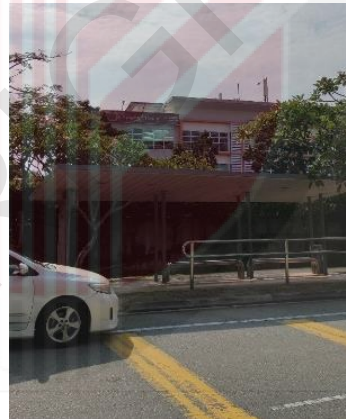
S12 Cyber
 4 Commercial
 area:
 Universiti
 Islam
 Malaysia &
 Radius
 Cyberjaya



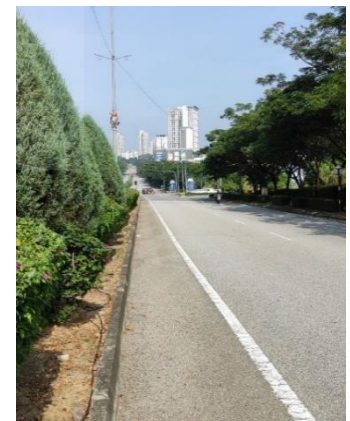
S13 Cyber
 4 Commercial
 area:
 MKN
 Embassy
 Techzone



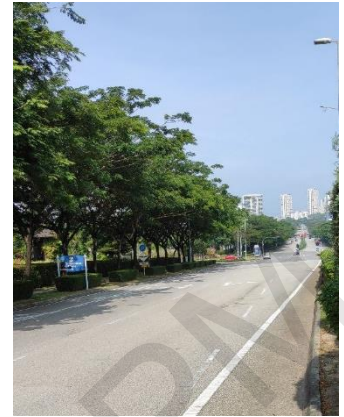
S14 Cyber
 6 Commercial
 area:
 Glomac
 Cyberjaya



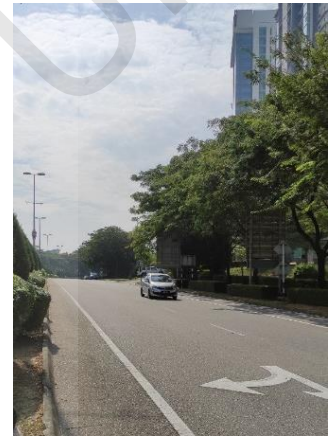
S15 Cyber
 6 Roadway:
 Quill 4
 Cyberjaya
 (bus-stop)



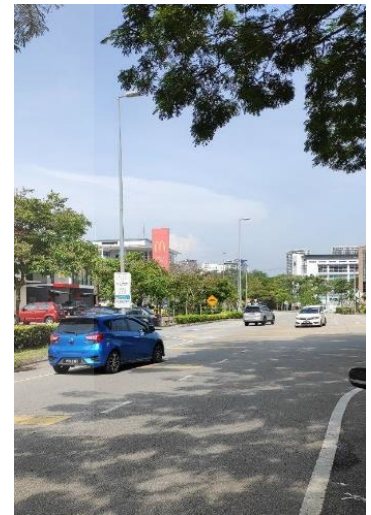
S16 Cyber Commercial
 6 area:
 MDEC
 (office
 building)



S17 Cyber Commercial
 6 area:
 Shaftsbury
 Square



S18 Cyber Commercial
 5 area:
 DHL(Quill 4)



S19 Cyber
 5 Residential
 area:
 Prima
 Avenue 2



S20 Cyber
 8 Commercial
 area:
 Prima 11



S21 Cyber
 7 Residential
 area:
 Cyberview
 Resort
 Garden Villas



S22 Cyber Roadway:
7 Between
 Perdana
 Lakeview
 East and
 Summer
 Glades



S23 Cyber Roadway:
7 Near Lim
 Kok Wing
 house.



S24 Cyber Vacant land:
7 Near
 abandoned
 playground



S25 Cyber Vacant land:
7 Same area as
 S24 but in the
 deeper area
 near the
 bushes



Appendix 1 Sampling site for each soil sample.

