Faculty of Resource Science and Technology

PRELIMINARY STUDY ON MICROPLASTICS IN SURFACE WATER OF SARAWAK RIVER

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PRELIMINARY STUDY ON MICROPLASTICS IN SURFACE WATER OF SARAWAK RIVER

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A thesis submitted in fulfillment of the

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Aquatic Science and Resource Management

Faculty of Resource Science and Technology

Universiti Malaysia Sarawak
2019

DECLARATION

I declare that the work in this project and the work presented in the report were carried out in accordance with the regulations of Universiti Malaysia Sarawak. The work presented on this report is the result of my work, unless otherwise indicated or acknowledged as referenced work. None of this work has been published before submission.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ABS	Acrylonitrile butadiene styrene
CA	Cellulose acetate
EVA Ethylene Vinyl Acetate	Ethylene Vinyl Acetate
HDPE	High density polyethylene
LDPE	Low density polyethylene
PVC	Polyvinyl chloride
PET	Polyethylene terephthalate
PE	Polyethylene
PP	Polypropylene
PS	Polystyrene
PA	Polyvinyl alcohol
POPs	Persistent organic pollutants
L	litre
µm	micrometre
°C	degree celcius
cm	centimetre
SEM	scanning electron microscopy
FTIR	fourier transformed infrared spectroscopy
ANOVA	analysis of variance

Preliminary Study on Microplastics in Surface Water of Sarawak River

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ABSTRACT

Degradation of plastics in the environment produce small fragments which the size is usually less than 5 mm, known as microplastics. This study was designed to investigate the abundance of the microplastics in Sarawak River including their morphological features, chemical characterisation and surface texture. Overall, there are 138 particles found. The identification of microplastics was conducted based on the physical characterisation (type, colour, size) and chemical characterisation (ATR FTIR analysis) for a functional group of polymers. Fragment type, white colour and size of 4 mm microplastics were most dominant in the area. Polypropylene was the most abundant chemical compound found. The result was analysed by One-way Analysis Variance (ANOVA), there was a significant difference of total microplastics between all the stations. It is recommended to conduct this research in future for baseline information on microplastic issue in Malaysia.

Keywords: Microplastics, Sarawak River, FTIR, Fragment, Polypropylene

ABSTRAK

Pemecahan plastik-plastik ke dalam sekitar menghasilkan serpihan kecil dimana saiznya adalah kurang daripada 5mm dan ia dikenali sebagai mikroplastik. Kajian ini bertujuan untuk mengetahui lambakkan mikroplastik dalam Sungai Sarawak termasuk ciri-ciri serpihan mikroplastik, pencirian kimia and tekstur permukaan. Keseluruhan, 138 partikel mikroplastik yang dijumpai. Kepastian mikroplastik dijalankan berdasarkan ciri fizikal (jenis, warna, saiz) dan pencirian kimia (ATR FTIR analisa) untuk jenis polimer. Jenis serpihan, warna putih, dan 4 mm saiz mikroplastik paling dominan dalam kawasan tersebut. Polypropylene paling banyak komponen kimia yang dijumpai. Keputusan dianalisa dengan One-way Analysis Variance (ANOVA), terdapat perbezaan yang signifikan pada keseluruhan jumlah mikroplastik di antara semua stesen. Adalah disyorkan untuk menjalankan kajian ini pada masa akan datang untuk maklumat asas tentang isu mikroplastik di Malaysia.

Kata kunci: Mikroplastik, Sungai Sarawak, FTIR, Serpihan, Polypropylene

1.0 Introduction

Microplastics has become the latest global environmental issue in the world. The concern about microplastic and its related environmental issues have arisen worldwide (Barboza and Gimenez, 2015). The plastics are very useful and bring advantages that led to a considerable increase in their production in the past 60 years which 1.7 million metric tonnes produced in 1950 compared with 335 million metric tons in 2017 worldwide (Plastic Europe, 2018). Plastics come various in size, origin, shape and composition. Generally, plastic will degrade into small particles and become abundance in the marine environment. Microplastics are spread throughout the world's ocean. They are often found in shorelines, beaches, seabed sediments, and wastewater effluents (Gallagher *et al.*, 2016). Approximately, 20% of the total debris found in the marine environment come from the activities of commercial fishing, vessels and other activities in marine environment (Andrady, 2011). Apart from that, larger plastic particles from waste dumps that have been degraded into smaller fragments can also be transported into seas which cause microplastic pollution (Alomar *et al.*, 2016). Some aquatic organisms such as bivalve can act as biomonitoring to detect the level of the microplastic pollution (Farrel and Nelson, 2013). Plastics are recorded about 50-80% of marine litter from the terrestrial sources. This could occur because plastic products are often mismanaged or abandoned in illegal dumping sites (Barnes *et al.*, 2009). All microplastics from the terrestrial will flow into the natural water systems and most of them will be transported to the ocean by the rivers. However, some of the microplastics could accumulate in freshwater environment (Browne *et al.*, 2010; Free *et al.*, 2014).

Water systems can be divided into two categories which is lotic water system and lentic water systems. Lotic water systems are those systems which contain flowing waters such as the river, spring, channel or stream while lentic water systems are those which contain stagnant waters for example lakes, seas and ponds. This study focus on the lotic water systems namely the river. All the microplastics from the terrestrial activities will usually end up in the river and this will affect on the abundance of the microplastic in the water system. Previous studies were mostly focused on the marine environment and only less than 4% of microplastic studies are related to freshwater system (Lambert and Wagner, 2018). However, more concern should also be given to microplastic studies in freshwater as the abundance of microplastic are relatively comparable to the marine environment (Peng *et al.*, 2017). Recently, Malaysian government have banned the usage of plastics and it applied to few states such as Melaka, Johor, Selangor and Kuala Lumpur. This is an initiative action made by the government to reduce the amount of plastics. However, level of plastics is still high, and this may also cause the amount of microplastics to become more abundance in the environment. Therefore, the objectives of this study were:

1. To investigate the abundance of the microplastics in the Sarawak River.
2. To determine the morphological features, chemical characterisation and surface texture of the collected microplastic fragments.

2.0 Literature review

2.1 Characteristics of microplastics

Microplastics are very resistant, durable and lightweight (Thompson *et al.*, 2009). During the production of the microplastics some additives such as alkylphenols, bisphenol and organophosphate are used to enhance the properties of the microplastics (Bakir *et al.*, 2014). Generally, in worldwide there is no internationally agreed upon the size of the microplastic classes (Arthur *et al.*, 2009). The term and size classes for the microplastics from selected literatures in Table 1 are relatively refers to plastic particles that are smaller than five millimetres (5 mm). Each microplastics has specific density. The density of the microplastics is invariably determines depending on the environment. Different types of microplastics have different densities and its affect the buoyancy. Microplastics are mainly composed of polyvinyl chloride (PVC), nylons and polyethylene terephthalate (PET), which are more likely to sink in the water because they are denser than water, while polyethylene (PE), polypropylene (PP) and polystyrene (PS), which are more likely to float in the water. Besides that, the other polymers include are polyvinyl alcohol (PA), and polyamide (PA) (Avio *et al.*, 2015; Carr *et al.*, 2016). Common types of microplastics can be in form of fragments, films, pellets, lines fibers, filaments, and granules (Driedger *et al.*, 2015).

Table 1: Definition of sizes for macroplastics, mesoplastics, and microplastics from selected literatures.

Study	Macroplastics	Mesoplastics	Microplastics
Lee *et al.*, (2013)	> 25 mm	5-25 mm	1-5 mm
Noik and Tuah, (2015)	> 20 mm	5-20 mm	1-5 mm
Blatter *et al.*, (2017)	> 25 mm	5-25 mm	<5 mm
Wahyuningsih *et al.*, (2018)	20-100 mm	5-20 mm	0.3-5 mm
This study	20-100 mm	5-20 mm	<5 mm

2.2 Microplastics in daily life

Microplastics basically are small and tiny ubiquitous plastic particles and originated from two sources. First, those that are manufactured purposely for particular industrial or domestic application such as exfoliating facial scrubs, toothpastes and resin pellets used in the plastic industry which is known as primary microplastics (Cole *et al.*, 2011). The other example of plastic particles that include in primary microplastics are cosmetics products, baby products, bubble bath lotions, hair coloring, nail polish, insect repellents and sunscreen. (Fendall and Sewell, 2009; Castaneda *et al.*, 2014; Costa *et al.*, 2014; Duis Coors, 2016). Gregory (1996) claimed that the microplastics in the cosmetic products are present of polyethylene and polypropylene granules (<5 mm) and polystyrene spheres (<2 mm) while study by Fendall and Sewell (2009) found that plenty of irregularly shape of microplastics, typically less than 0.5 mm in diameter with a mode size less than 0.1 mm in other cosmetic products. Microplastic beads that contain in the personal care products will wash out into the marine ecosystem through domestic and industrial drainage systems and wastewater treatment plants (Cole *et al.*, 2011; Murphy *et al.*, 2016). Furthermore, Wagner *et al.* (2014), stated that the first primary microplastics are usually in form of original when they had been collected such as the bottle caps, cigarettes butts, microbeads or resin pellets, synthetic clothing and air-blasting media (Gregory, 1996; Alomar *et al.*, 2016). The air- blasting technology process involves melamine, blasting acrylic and polyester microplastics scrubber at machinery, engines and boat hulls that is functioning to remove paint and rust. The scrubbers are repeatedly used until they become diminish in small cutting size and will be contaminated with heavy metals such as cadmium, chromium and lead (Cole *et al.*, 2011).

The second source of the microplastics are those formed from the breakdown of larger plastic items under ultraviolet radiation or mechanical abrasion known as secondary microplastics (International Maritime Organization, 2015). Disintegrated of the secondary microplastics affect by combination of some environmental factors and properties of the polymer such as the sunlight, temperature, size and density. Radiation of the ultraviolet (UV) from the sun and the exposure of the microplastics will resulting in photo-degradation of plastics. The ultra violet radiation in the sun causes oxidation of the polymer matrix which leads to the cleavage of bond (Mailhot *et al.*, 2000; Andrady, 2011; Cole *et al.*, 2011; Lucas *et al.*, 2008; Wagner *et al.*, 2014). From Cole *et al.* (2011) found that the most effective site that can change the microplastic production into a smaller size by fragmentation usually could occur on the beaches due to high UV, physical abrasion by waves and oxygen availability. Larger plastic will take longer time to degrade into small fragment of microplastics and soon their abundance in the marine environment also will increase. Hence, when the particle size decrease, the diversity of aquatic organisms that can ingest the debris will also increase. This will cause an increasing the susceptibility, enhanced leaching, desorption and adsorption potentials of the microplastics that can bring harmful impacts to the wildlife (Law and Thompson, 2014; Shim and Thompson, 2015). Morris and Chapman (2015) concluded that the combination of both primary and secondary microplastic exist in marine ecosystem at high concentration and reported that around 245 tonnes of the microplastics that produced each year contain in body and tissues of the marine organisms through the ingestion.

2.3 Way of microplastic spread into freshwater environment

The origin of the microplastics on freshwater environment is not well known and studied. Some of the microplastics present in products can enter the aquatic environment through industrial or domestic drainage systems from the primary and secondary sources (Murphy *et al.,* 2016). The microbeads present in the primary sources will be flushed down and shower drains in waste water collection systems. Some of the plastic fibres that come from the synthetic fabrics in washing machine can enter the water bodies from the effluents discharge of the waste water treatment plants (Eriksen *et al.*, 2013). However, the larger pellets may enter the river or stream via the spillage during manufacture or transport during the raw production process by the industrial.

In addition, microplastics from the river also can flow into the marine environment via storm sewers, wind, and currents (Zalasiewcz *et al.*, 2016). Previous studies by Collignon *et al.* (2012) reported that strong wind can increase the dissipation of floating microplastics. The distribution of the microplastics could also increase due to few factors such as large-scale forces as currents driven by wind and geostrophic circulation turbulence and oceanographic effects (Law *et al.*, 2010; Ballent *et al.,* 2012; Turra *et al.,* 2014).

Moreover, sewage sludge is one of the other possible route and source of microplastics pollution as it usually contains high amount of microplastics than effluent which are flow into the aquatic ecosystems (Auta *et al.,* 2017). The smaller size of the microplastics will easily spread and distribute. The abundance of the microplastics also cause by the anthropogenic activities by humans. Barnes *et al.* (2009) identified that improper human activities and unbridled waste management would cause the load of the microplastics in the environment.

Higher concentration of the microplastics are found in the tourism spot near the freshwater ecosystems. Some of the microplastics could flow to the freshwater environment from the poorly managed burial in landfills, storm discharge, windblown debris and riverine transport. Therefore, the accumulation of the plastics will easily flow into the ocean and riverine environment (Derraik, 2002). Studies by Fauziah *et al.* (2015) showed that quality microplastic debris in sand beaches in Peninsular Malaysia reached a total of 2542 pieces (265.30 gm^{-2}) where small microplastic debris were collected from six beaches while Isobe *et al.* (2015) investigated the concentrations of microplastics in the East Asian Seas around Japan and found a total particle count of 1.72 million pieces km^{-2} (10 times greater than in the North Pacific and 27 times greater than in the world oceans) were recorded. However, there is no statistics of microplastic in river recorded.

2.4 Effects of microplastics

There are many effects on the abundance of the microplastics to the marine ecosystem. Abundance of the microplastics also will cause bad effects to the aquatic ecosystem. For example, the small particles of the microplastic may accumulate in body tissues of some of the aquatic animals such as fish, shrimp, and bivalve. Microplastics give a health risk to some of the aquatic animals such as fish, turtles and bivalve. This could occur due to the possible ingestion of the microplastics by the organisms (Boerger *et al.*,2010). Sometime when the organisms ingest the microplastics, it will cause the internal bleeding, abrasion and ulcers, as well as blockage of the digestive tract (Wright *et al.*, 2013) However, Sutton *et al.* (2016) and Fossi *et al.* (2016), they reported that ingestion of the tiny particles may poses a great risk to the organisms and may cause pathological stress, false satiation, reproductive complications, blocked enzyme production, reduced growth rate, and oxidative stress. Some of the microplastics also may accumulate in the tissues of the organisms and stomach content. Several studies were conducted by Ferreira *et al.* (2016) in controlled laboratory experiments to detect the ingestion of the smaller size microplastics fragments by marine biota. Results showed that ingestion of marine biota has increased. Most of the marine organisms consume the microplastics unintentionally because they mistaken for food. This could give harmful effects to the physical organisms of the marine biota.

Besides, plastic debris may act as a vector for contaminants, including persistent organic pollutants (POPs) and heavy metals (Ashton *et al.*, 2010; Holmes *et al.*, 2012; Mato *et al.*, 2001; Rios *et al.*, 2010; Zarfl and Matthies, 2010). Microplastics that have been detected with POPs and heavy metals may be passed across the oceans and easily pollute other ecosystems (Zarfl and Matthies, 2010).

Microplastics can take toxic chemicals from nearest sea water which can be transferred into the food chain (Reisser *et al.*, 2014). Any organisms that have ingested microplastics and contained microplastics inside them may subsequently be fed upon by other higher animals in the food web thereby, transferring the microplastics to other animals in the trophic level (Farrel and Nelson, 2013). Microplastics can also give huge effects in animals and humans such as cancer, impaired of reproductive activity, decreased the immune response and malformation.

3.0 Materials and Method

3.1 Study area

The study method was proposed by Su *et al*. (2016) was used in this study. Sarawak River was chosen as the study area. Samples was collected on 6th November 2018. The site proposed sampling was marked using GPS (Garmin). Overall, there were 7 sampling stations with 3 replicates for each station.

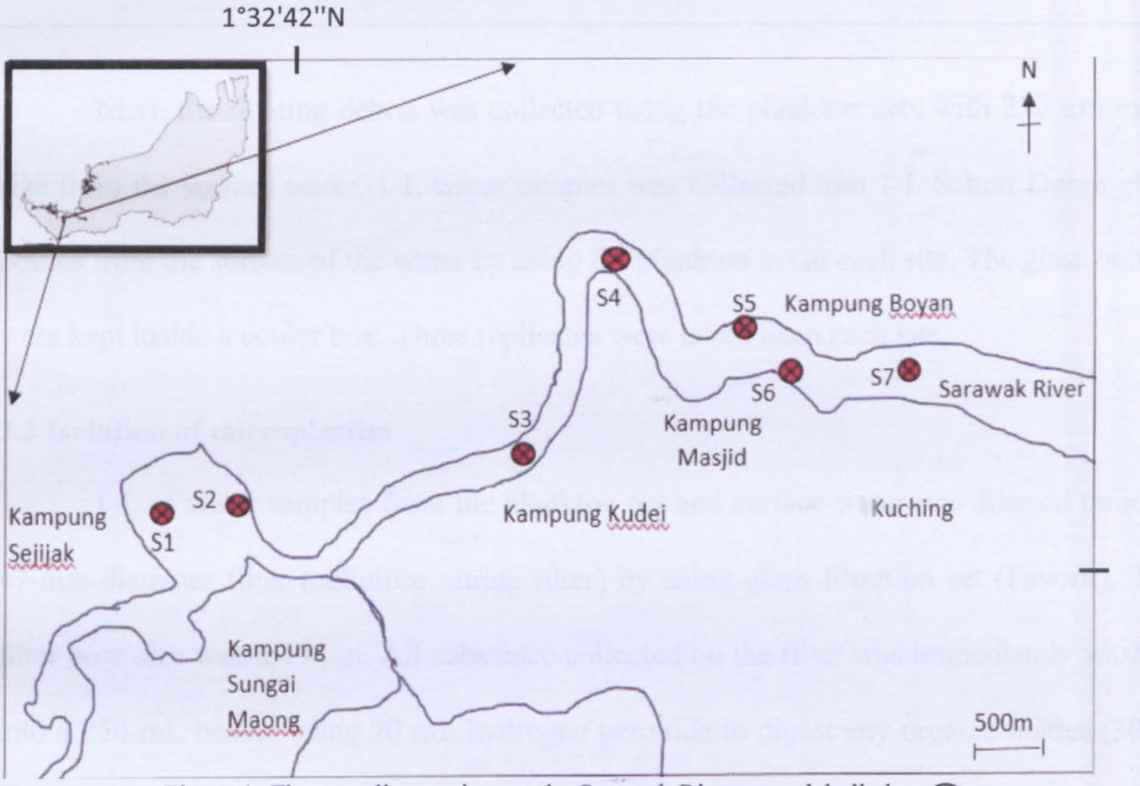

Figure 1: The sampling stations at the Sarawak River were labelled as ⊗ with S1 to S7

Table 2: Coordinates for each station.

Stations	Coordinate
Station 1	1.54859°N,110.29431°E
Station 2	1.54806°N,110.29854°E
Station 3	1.55471°N,110.32204°E
Station 4	1.56499°N,110.33292°E
Station 5	1.56283°N,110.34275°E
Station 6	1.55868°N,110.34548°E
Station 7	1.55934°N,110.35741°E

Next, the floating debris was collected using the plankton nets with 250 μm mesh size from the surface water. 1-L water samples was collected into 1-L Schott Duran glass bottles from the surface of the water by using the plankton net at each site. The glass bottles were kept inside a cooler box. Three replicates were taken from each site.

3.2 Isolation of microplastics

1-L of water samples from the plankton net and surface water was filtered through 47-mm-diameter filter (cellulose nitrate filter) by using glass filtration set (Favorit). The filter pore size was 0.45 μm. All substance collected on the filter was immediately washed into a 250 mL beaker using 20 mL hydrogen peroxide to digest any organic matter (30%, V/V). The beaker was placed in a hotplate with a 75 °C maintain temperature and gently stirred. At 30 min intervals, samples were re-examined, and additional hydrogen peroxide were added, and heating repeated, as necessary, until all organic material was digested (Yonkos et al.,2014). The liquid in the beaker was filtered again and these filters was stored dry in a petri dish for further investigations.

3.3 Observation of microplastics

The filter was observed using Motic SMZ-168 series stereo microscope to sort the plastics from other materials such as the scale fragments, shell and fish bones. Then, all the images were taken by using a digital camera. All the microscopic observation was repeated three times to ensure all plastics are precisely identified. Visual assessment was applied to quantify the suspected microplastics according to the physical characteristics of the particles. Next, the selected particles were verified using Scanning Electron Microscopy (SEM) by spreading the samples on double-sided adhesive tape and coated with a thin film of evaporated gold. Then, images were taken with an optimized accelation voltage of 3 kV and detector working distance of approximately 2 mm.

The sample was further identified by Fourier Transformed Infrared Spectroscopy (FTIR) as explained by Blettler *et al.* (2017). Microplastic particles were tested by ATR FTIR after cleaning the surface using sterile ethanol (96%). This method was conducted to analyse the origin particles confirmation from plastic composition that may be doubtful. Spectra ranges was set at 4000–400 cm^{-1}. The resulting spectra were directly compared with the available reference library databases and previous literature studies. Lastly, the microplastics were classified into their morphological types.

3.4 Statistical analysis

Comparison of the data between the stations by the differences of quantities microplastics then were determined by One-way ANOVA using statistical program Graphpad Prism 7 with confidence level 95% (significant difference, $p < 0.05$). Composition on the abundances of microplastics type as well the percentage abundances of polymer particles were calculated by the Microsoft Excel 2010.