MICROPLASTIC OCCURRENCE IN BED SEDIMENT AND AFRICAN CATFISH IN JOHOR URBAN RIVERS

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DEDICATION

This thesis is dedicated to my mother and mother-in-law, who taught me that even the largest task can be accomplished if it is done one step at a time.

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ABSTRACT

Microplastics (MP) are plastic particles with size less than 5 mm and have been widely investigated for their occurrence in marine environments. Contrariwise, data on the abundance, sources and impact of MP to aquatic biota in freshwater ecosystems are still scarce. Previous studies were usually focused on spatial analysis to compare the MP concentration between different sites. In this study, the abundance of MP in bed sediment and fish community in Skudai and Tebrau River was temporally investigated. Sediments were collected across a seven-month sampling period. Meanwhile, fish were caught all year round from September 2017 until August 2018. In-situ water quality parameters were also recorded throughout the sampling process. The inspection of MP particles was carried out under compound microscope with 40x magnification. The type of plastic polymer was analysed using attenuated total reflectance-fourier transform infrared (ATR-FTIR) spectroscopy. The abundance of MP in sediment was in the range of 206.6 ± 79.6 (mean ± SE) to 813.4 ± 13.0 particles per kg dry weight (d.w.) in Skudai River and 286.6 ± 102 to 1020 ± 81.6 particles per kg d.w. in Tebrau River. There was a significant difference at 95% confidence interval in the abundance of MP between both rivers. The significant difference in the abundance of MP was also observed during March 2018. Six edible fish species were identified in Skudai River such as African catfish, *Clarias gariepinus*, tilapia, *Oreochromis mossambicus*, climbing perch, *Anabas testudineus*, Pangasius catfish, *Pangasius hypophthalamus*, beardless barb, *Cyclocheilichthys apogon* and marble goby, *Oxyeleotris marmorata*. However, only African catfish was caught in Tebrau River. Overall, 326 individuals were obtained from both rivers. The study has shown that a significant difference in the ingested MP was found among three fish species namely African catfish, climbing perch, and Pangasius catfish. Since African catfish was the most abundant fish found in both rivers, thus further investigation on the ingestion of MP by 287 individuals of this species was carried out. The study found that there was a significant difference in the MP ingested by African catfish between monsoon and transitional period. The study also showed a moderate strong correlation between the ingested MP and Fulton's condition. Interestingly, polyethylene and polypropylene were the most dominant polymers found in both sediment and fish samples. The relationship between the abundance of MP and water quality parameter was analysed via generalised linear model with Poisson regression. Three statistical models were developed to determine the relationships of MP from sediment and water quality parameters. In general, only TDS showed the positive relationship. When water quality parameters were paired with monsoon seasons, only turbidity and TDS influenced the abundance of MP. Meanwhile, both studied rivers and TDS have affected the abundance of MP in sediment when the model combines water quality parameter and sampling sites. Conversely, a model for the MP ingested by African catfish that combines water quality parameter and monsoon showed that only TDS influenced the number of MP. Overall, MP were found persistence in both studied rivers. All studied species ingested MP and the temporal retention of MP ingestion by African catfish indicated that fish could be a suitable indicator of regional MP pollution. The study also successfully proposed Poisson regression model in generalised linear model (GLM) on the MP pollution data.

ABSTRAK

Mikroplastik (MP) adalah partikel plastik bersaiz kurang daripada 5 mm telah dikaji secara meluas mengenai kehadirannya di persekitaran marin. Sebaliknya, data kelimpahan, sumber, dan impak terhadap ekosistem air tawar masih lagi kurang di mana kajian baharu sahaja bermula. Kebanyakkan kajian terdahulu biasanya tertumpu kepada analisis ruang bagi membandingkan kepekatan MP antara tapak yang berbeza. Dalam kajian ini, kelimpahan MP pada sedimen dan komuniti ikan di Sungai Skudai dan Sungai Tebrau telah disiasat secara temporal. Sedimen dasar telah diambil selama 7 bulan. Manakala, ikan telah ditangkap bermula September 2017 sehingga Ogos 2018. Parameter kualiti air telah direkodkan insitu sepanjang proses persampelan. Pemeriksaan partikel MP telah dilakukan dengan mikroskop dengan 40x pembesaran. Jenis polimer MP telah dianalisis menggunakan jumlah terkecil pantulan spektroskopi inframerah transformasi fourier. Kelimpahan MP pada sedimen adalah dari 206.6 ± 79.6 (purata ± ralat piawai) hingga 813.4 ± 13.0 partikel per kg berat kering di Sungai Skudai dan 286.6 ± 102 hingga 1020 ± 81.6 partikel per kg berat kering di Sungai Tebrau. Terdapat perbezaan bererti pada 95% selang keyakinan dalam kelimpahan MP di antara sungai. Perbezaan bererti turut diperhatikan pada bulan Mac 2018. Enam spesies ikan telah dikenal pasti di Sungai Skudai seperti ikan keli Afrika, *Clarias gariepinus*, tilapia, *Oreochromis mossambicus*, puyu, *Anabas testudineus*, patin, *Pangasius hypophthalamus*, lampam, *Cyclocheilichthys apogon* and ketutu, *Oxyeleotris marmorata*. Hanya ikan keli Afrika ditangkap di Sungai Tebrau. Keseluruhannya, sebanyak 326 ekor ikan telah ditangkap dari kedua-dua sungai. Kajian awal menunjukkan terdapat perbezaan bererti dalam MP yang ditelan oleh tiga spesies ikan iaitu ikan keli Afrika, ikan puyu, dan ikan patin. Kajian juga mendapati bahawa ikan keli Afrika adalah ikan yang paling banyak ditangkap, maka, siasatan lanjut terhadap MP yang ditelan oleh 287 individu ikan ini dilaksanakan. Hasil kajian menunjukkan terdapat perbezaan bererti dalam MP yang ditelan oleh ikan keli Afrika diantara monsun dan jangka masa peralihan. Sebuah korelasi sederhana kuat diantara MP yang ditelan dan badan Fulton turut diperolehi. Polietilena dan polipropilena adalah polimer yang paling dominan pada sedimen dan ikan. Manakala, hubungan di antara kelimpahan MP dan parameter kualiti air telah dianalisis menggunakan model linear teritlak dengan regresi Poisson. Tiga model statistik dibangunkan untuk menentukan hubungan MP dari sedimen dan parameter kualiti air. Umumnya, hanya TDS menunjukkan hubungan yang positif. Apabila parameter kualiti air digandingkan bersama monsun, hanya kekeruhan dan TDS mempengaruhi kelimpahan MP. Manakala, kedua-dua sungai dan TDS mempengaruhi kelimpahan MP pada sedimen apabila model menggabungkan parameter kualiti air dan tapak persampelan. Sebaliknya, model MP yang teringesi oleh ikan keli Afrika yang menggabungkan parameter kualiti air dan monsun menunjukkan hanya TDS mempengaruhi bilangan MP. Keseluruhannya, MP telah dijumpai persisten di kedua-dua sungai kajian. Kesemua spesies ikan menelan MP dan rentetan MP yang ditelan oleh ikan keli Afrika secara temporal menunjukkan ikan boleh dijadikan penunjuk yang sesuai untuk pencemaran MP serantau. Kajian juga berjaya mengusulkan model regresi Poisson dalam GLM pada data pencemaran MP.

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LIST OF ABBREVIATIONS

FTIR	-	Fourier Transform Infrared
ATR	-	Attenuated Total Reflection
GLM	-	Generalised Linear Model
HCl	-	Hydrogen chloride
CIS	-	Commonwealth of Independent States
MPMA	-	Malaysian Plastics Manufacturers Association
PET	-	Polyethylene terephthalate
H_2O_2	-	Hydrogen peroxide
H_2SO_4	-	Sulfuric acid
Fe	-	Ferum
NaOH	-	Sodium hydroxide
NaCl	-	Sodium chloride
KF	-	Potassium formate
NaI	-	Sodium iodide
$ZnCl_2$	-	Zinc chloride
$ZnBr_2$	-	Zinc bromide
PVC	-	Polyvinyl chloride
KOH	-	Potassium hydroxide
GI	-	Gastrointestinal
Pyr-GCMS	-	Pyrolysis Gas Chromatography–Mass Spectrometry
WWTP	-	Wastewater Treatment Plant
BOD	-	Biochemical Oxygen Demand
PP	-	Polypropylene
Cu	-	Copper
Zn	-	Zinc
ANOVA	-	Analysis of Variance
RA	-	Relative abundance
LOI	-	Loss on ignition
PETE	-	Polyethylene terephthalate
HDPE	-	High-density polyethylene

LDPE	-	Low-density polyethylene
PS	-	Polystyrene
ABS	-	Acrylonitrile butadiene styrene
CA	-	Cellulose acetate
EVA	-	Ethylene vinyl acetate
PC	-	Polycarbonate
PMMA	-	Poly(methyl methacrylate)
PTFE	-	Polytetrafluoroethylene
PU	-	Polyurethane
CI	-	Confidence Interval
SE	-	Standard Error
U.S. EPA	-	United States Environmental Protection Agency
cc	-	correlation coefficient
DO	-	Dissolved oxygen
TDS	-	Total dissolved solid

LIST OF SYMBOLS

μm	-	Micrometre
n_i	-	Total number of individuals of a species
N	-	Total number of individuals of all species
H'	-	Shannon-Wiener index of diversity
$\sum$	-	Summation
Pi	-	Proportion of each species in a sample
ln	-	Natural logarithm
°C	-	Degree Celsius
km	-	kilometre
mg	-	Milligram
mL	-	Millilitre
L	-	Litre
mm	-	Millimetre
g/cm^3	-	Gram per cubic centimetre
W_r	-	Weight of soil retained
W_t	-	Total soil weight
DW_{105}	-	Weight of sediment after preliminary burning
DW_{550}	-	Weight for post-burning sediment
cm	-	Centimetre
g	-	Gram
kg	-	Kilogram
v/w	-	Volume per weight
H_0	-	Null hypothesis
$\bar{x}$	-	Sample mean
$Z_{(\alpha/2)}$	-	Z value for the confidence level α
$\sigma/\sqrt{n}$	-	Standard error of the mean
y	-	Response variable
$\propto$	-	Intercept
β	-	Estimation
x	-	Explanatory variable

Y	-	Response variable
r^2	-	Coefficient of determination
Y_i	-	Random variable for Poisson distribution
Var	-	Variance
μ_i	-	Mean
x_i	-	Vector of covariates
$\boldsymbol{\beta}$	-	Vector of regression parameters
$L(\boldsymbol{\beta})$	-	Maximum likelihood estimation

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Plastic debris floating on surface water has become one of the environmental issues concerning its abundance and fate. In general, the degradation of plastic debris into smaller particles with a size of less than 5 mm known as microplastics. The breakdown of larger plastics is commonly aided by several actions such as mechanical and biological ways (Erik van et al., 2015). Microplastics are classified into primary and secondary based on their sources. Primary microplastics mainly derived from products that contain microbeads in personal care products such as cosmetics and facial cleansers as well as plastic pellets that usually used to manufacture plastic products (Hernandez et al., 2017). Secondary microplastics are fragments of plastics defragmented from larger plastic products, for example, plastic packaging and clothing (Li et al., 2018). Noteworthy, the densities of this pollutant has been recorded up to 100,000 of items/m^3 on surface water (Eerkes-Medrano et al., 2015), and up to 100,000 pellets/m from the beach sediment in the late 1970s (Van Cauwenberghe et al., 2015).

To date, the discovery of the impacts of microplastics in marine environments has been reported by numerous studies (Ferreira et al., 2020; Ivar Do Sul and Costa, 2014; Silva-Cavalcanti et al., 2017; Wright et al., 2013). The study on the density of microplastics in the estuarine environment has also been reported worldwide (Lima et al., 2014; Peng et al., 2017a; Sadri and Thompson, 2014; Sruthy and Ramasamy, 2017). There are only a few studies were reported on the occurrence of microplastics in freshwater ecosystems as it is just recently studied, mostly since 2014 (Rodrigues et al., 2018; Slootmaekers et al., 2019; Yin et al., 2020). As well as, the comprehensive database on its occurrence (i.e. distributions, category, types of polymer) in rivers is still scarce (Mani et al., 2015; Wang et al., 2017a).

It was unanimously agreed that river acts as a major pathway to transport most of the plastic debris from land to marine environment. A previous report has estimated 1.15 to 2.41 million tonnes of plastic waste is released to the ocean annually (Lebreton et al., 2017). However, in certain regions, not all plastic debris will be transported into the sea as most of this polymer is captured by trash traps, beaching, and entrapped in the trees along the river (Kooi et al., 2018). Most of the trapped debris will remain in the river bank and submerged in the water and subsequently affect the ecosystem and environmental health (Luís Gabriel Antão Barboza et al., 2018). It is worthy of note that the knowledge on the occurrence of microplastics in the freshwater environment is crucial to understand its sources and transport into the ocean (Fahrenkamp-Uppenbrink, 2018). Several studies have reported that the occurrence of microplastics in the environment possibly originated from various terrestrial sources (Figure 1.1). Of these, the sewage treatment plant indicated as one of the main contributors (Li et al., 2018).

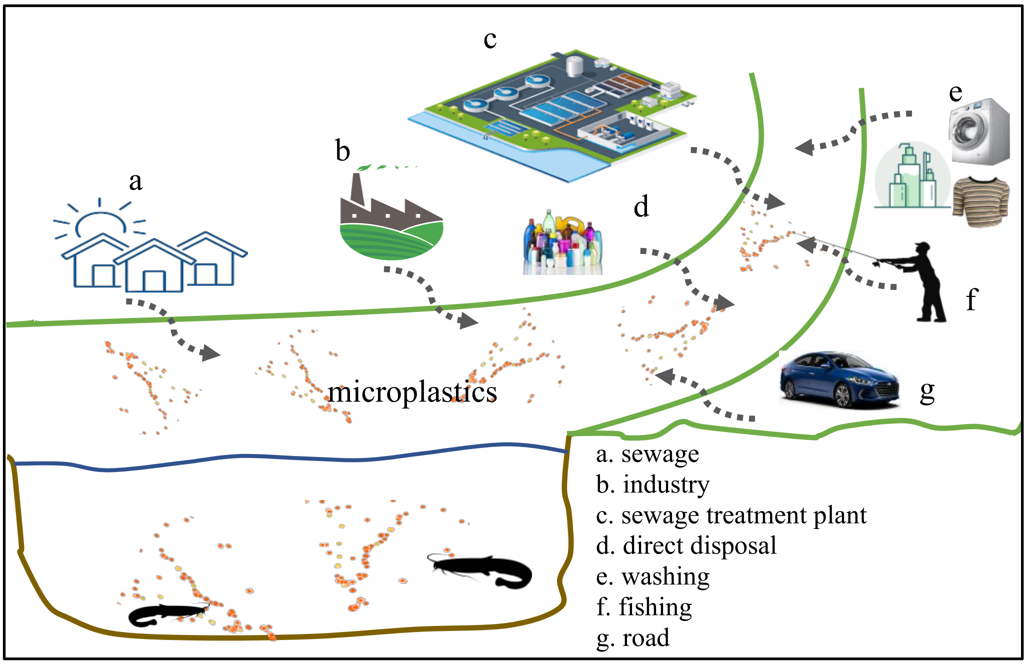

Figure 1.1 Microplastics pollution in aquatic environment from numerous ways. Microplastics can be settled down in sediments or ingested by aquatic organisms (adapted from Dris et al., 2018)

Rivers are one of the important sources of freshwater to provide pristine potable water for human consumptions. Regrettably, previous studies have found microplastic particles in potable water where this pollutant potentially influences human health (Pivokonsky et al., 2018). Besides, many edible aquatic organisms and commercially important fish species also occupy in river systems. Indeed, the inadvertent consumption of microplastics by living organisms is of great concern which occurs through the ingestion process. Many studies have reported the implication of the occurrence of microplastics in various marine animals than those in freshwater environments (Slootmaekers et al., 2019). For example, the ingestion of microplastics by numerous species of marine bivalve (Jiana Li et al., 2016; Van Cauwenberghe and Janssen, 2014), finfish (Lusher et al., 2013; Neves et al., 2015), sea turtles (Ostiategui-Francia et al., 2016) and also sea bird (Provencher et al., 2010).

In general, the sampling site in Skudai River is located near to sewage treatment plant (approximately 300 m) and residential areas (approximately 400 m). Sampling site in Tebrau River is within industrial areas. There are at least 1,166 industries operating along the Tebrau River (Bee-Kim, 2017). Based on the previous reports, most of the plastic wastes in both rivers were discarded by residents which led to the constant input of rubbish (Musa, 2017). Figure 1.2 shows that there are many plastic wastes observed to accumulate along the river bank during the sampling period. Some of the plastic waste also discarded from cars across the bridge as well as direct dumping by river-goers at sampling sites was observed although the awareness billboard on recycling campaign and river cleanliness built at the area. According to Peters and Bratton, (2016), roadway adjacent to the sampling site is considered as a non-point source of microplastic pollution through the direct disposal of trash illegally.

Both rivers are installed with trash traps. In Skudai River, about 15 tonnes of waste was collected per day using trash traps (Shah, 2012). The cost to remove bulk waste is much expensive and time-consuming (Ravindran, 2018). It has been reported that about RM 90,000 were spent for monthly maintenance in Tebrau River (Bee Kim, 2017). Thus, without proper management, it will only increase the accumulation of rubbish in the river bank. Indeed, the degradation of plastic debris will generate more microplastic particles and are ubiquitous in the environment.

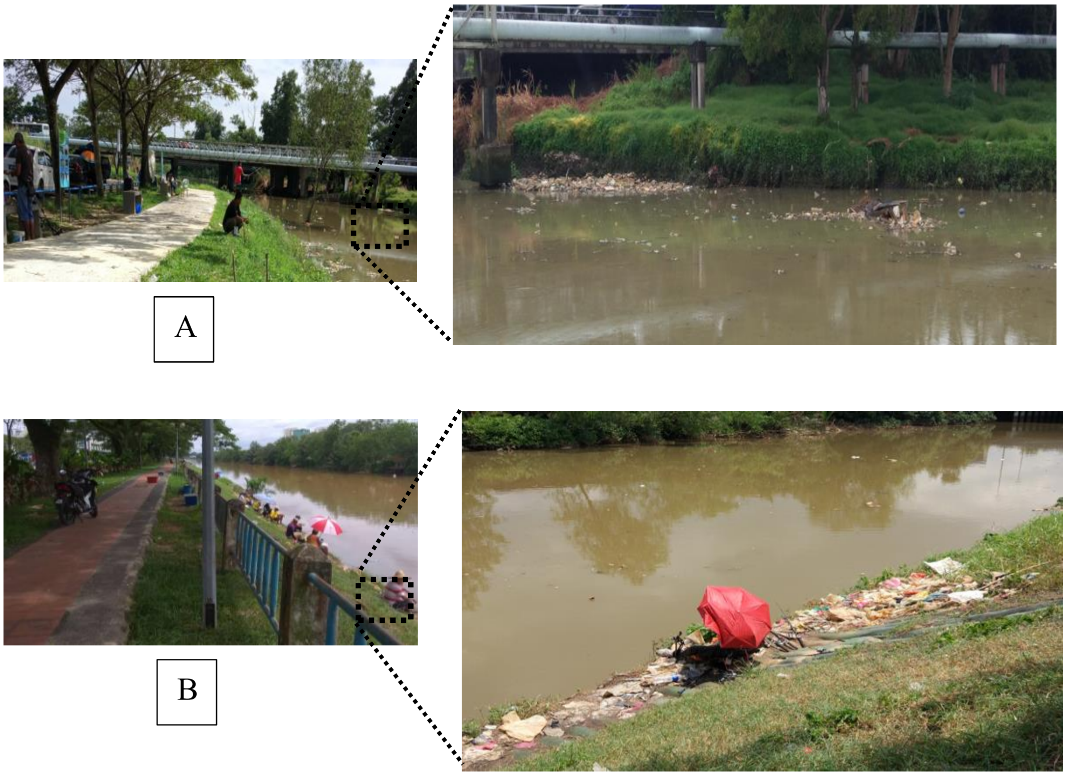

Figure 1.2 The presence of rubbish at sampling site in (A) Skudai and (B) Tebrau River.

Microplastics pollution have become a serious concern throughout the world due to its occurrence in living organisms and persistent in the aquatic ecosystems (Do-Sul and Costa, 2014). Li et al., (2018) has categorised the impact of microplastics in the environments into three categories, namely physical (entanglement and ingestion), chemical, and biological. Among these, chemical and biological represent the worst scenario which can cause toxicity effects to aquatic organisms and humans. Also, the ingestion of microplastics by several commercial fish species may potentially risk to human health. It is because these smaller particles in the gastrointestinal tract of the fish can translocate or transfer to its edible tissues (Fossi et al., 2018).

1.2 Problem Statement

Previous researches have been focusing greatly into the impacts of microplastics in the marine environment. The significant evidence on the potential effect of microplastics can be observed through its ingestion by various marine animals, from plankton up to the large mammals. The database on the occurrence of microplastics in freshwater environments is still scarce, resulting in the difficulty to understand its fates and sources (Peng et al., 2018; Schell et al., 2020). The study of microplastics associated with freshwater environments was only 3.7% (Lambert and Wagner, 2018). Interestingly, the information shows that the abundance of microplastics in freshwater is comparable to or more serious than those found in marine environments (Klein et al., 2018; Peng et al., 2017b; Yonkos et al., 2014).

The accumulation of plastic debris in river sediment was observed during low tide at both sampling sites in Skudai and Tebrau River. This occurrence will contribute to the high concentration of microplastics in sediments. Peng et al. (2018) have regarded the urban river sediment as a potential reservoir for the terrestrial source of microplastics and need further investigation. Sediment is also represented as the best environmental sample to investigate for long-term accumulation of microplastics compared with the water sample (Wang et al. 2017a). Besides, sediment samples from freshwater environments are seldomly investigated for the microplastic occurrence (Anderson et al., 2016). In this study, bed sediment was collected in Johor urban rivers to examine their abundance based on the temporal scale through different monsoon seasons in Malaysia.

Several efforts have been made to describe the impact of microplastics in the river. However, the study of microplastic ingestion by aquatic organisms in such area is less highlighted (Silva-Cavalcanti et al., 2017; Slootmaekers et al., 2019). Hitherto only a few organisms were reported to ingest microplastics intrinsically, such as deposit feeder, Chironomus spp. (Nel et al., 2018), sunfish, *Lepomis macrochirus* and *L. megalotis* (Peters and Bratton, 2016) and also the first report of microplastic ingestion by wild freshwater fish, gudgeon, *Gobio gobio* (Sanchez et al., 2014). The caught African catfish in Skudai River and Tebrau River are consumed by the local community. By nature, African catfish is known as a benthopelagic fish and living on the seafloor. In addition, this species is regarded as a very good scavenger and able to consume all types of feeds (Singh et al., 2014). Based on this feeding behaviour, hence, African catfish has a great potential to ingest microplastics during feeding time. On the other hand, the biomagnification of microplastics may also occur through the food web since African catfish is also recognized as among the final predator in river. The occurrence of microplastics can also affect other fish species occupy in these rivers which may lead to false satiation (Rummel et al., 2016), reduce predatory performance (de Sá et al., 2015) or translocate into internal tissue (Abbasi et al., 2018). Thus, the study of microplastic occurrence in the fish community is pertinent to examine the severity of these small plastic particles in freshwater environments, especially fish in the studied rivers.

The spatial variability of microplastics has been documented by numerous studies worldwide (Castañeda et al., 2014; Mani et al., 2015). In contrast, the spatiotemporal abundance of microplastics based on extreme events (e.g. floods, storms and seasons) has only received little attention (Han et al., 2020; Rodrigues et al., 2018; Yonkos et al., 2014; Zhao et al., 2015). Indeed, the study on the changes of microplastics pollution levels over time is vital to gain insight into the severity and persistence of this pollutant towards the environment (Fan et al., 2019; Shim et al., 2018). To date, only a few studies have reported on the relationships between microplastics abundance and other environmental factors such as water quality and seasonality. Kataoka et al. (2019) has recently investigated the significant between the number of microplastics and water quality parameters in Japan rivers. In their study, the annual mean of water quality data was used instead of regularly monitored during sampling work. By using a linear regression model, their study demonstrated that only biochemical oxygen demand has showed a positive relationship with the number of microplastics among the studied rivers. Meanwhile, Horton et al. (2018) suggested that both physiological traits of fish and environmental factors may be equally important in influencing ingestion of microplastics by fish. This indicated that the ingestion could be a result of a complex combination of different factors.

A better understanding of the relationships can be obtained through the statistical model by predicting the level of changes of microplastics based on multiple predictor variables. Modelling using a linear regression may not be suitable when it is a count data, highly skewed response variable distribution, and the mean is almost equal to the variance. Therefore, the selection of the appropriate statistical model is pertinent to represent the best description of results, able to yield an accurate analysis and fit the datasets. The Poisson model analysis using the generalized linear model function is commonly adopted to investigate the relationships among predictor variables and unknown parameters. This model is more appropriately applied to untransformed count data with the sample mean equal to the sample variance (Hutchinson and Holtman, 2005).

It is well known that the generalized linear model (GLM) with Poisson regression has widely applied in various fields of discipline, where most of the research context is in biomedical research. For example, the model is extensively used to investigate the occurrence of several diseases and the effects of clinical treatments (Parodi and Bottarelli, 2006). In the environmental study, most of the research scope has only focused on particulate air pollution (Zou, 2004). The application of this model in other pollution studies such as microplastics is still lacking, notably on their occurrence in the environment. In the present study, besides water quality parameter, further analysis on the relationship with other factors such as monsoon seasons and physiological traits of fish have been carried out. The relationships between the number of microplastics from sediments and those ingested by African catfish have also modelled been using the generalized linear model (GLM) with Poisson regression method.

1.3 Research Objectives

The objectives of this study are as follow:

(a) To determine the temporal abundance of microplastics in bed sediments from urban areas of Skudai River and Tebrau River.

(b) To examine the ingestion of microplastics by wild freshwater fish that inhabits Skudai River.

(c) To analyse the ingestion of microplastics by African catfish, *Clarias gariepinus* from Skudai and Tebrau River.

(d) To statistically model the occurrence of microplastics based on monsoon period, water quality and physiological traits of African catfish using generalized linear model (GLM) with Poisson regression.

1.4 Scope and Limitation of the Study

The study focuses on the occurrence of microplastics in Johor urban rivers, particularly in Skudai River and Tebrau River. Sediments were collected for seven months and catfish were collected for each month throughout a year-long study. Three replicates of sediments were collected using box corer (Wildco) and fish was caught using angling with hook and line technique. As a preliminary study, casting net was used to examine the occurrence of microplastics in the fish community in Skudai River. African catfish was chosen rather than other species due to its abundance and availability in the studied rivers where they possibly introduced by the human via releasing it to river systems. The collected samples were segregated based on different monsoon period in Malaysia, namely northeast (November to March), southwest (May to September) monsoons and transitional period (April and October). The *in-situ* measurements of pH, temperature, dissolved oxygen, total dissolved solid, salinity and turbidity were measured in both rivers. All samples were collected at the same sampling site in Skudai River and Tebrau River. Both sampling sites are located in the urban areas of Johor Bahru that close to residential areas and industrial regions. The standard unit for microplastics concentration from sediment is in dry weight per kilogram as has been reported by numerous study. Number of fish ingested microplastics per total number of dissected fish were analysed as to calculate the incidence of microplastics ingestion. Ten per cent of a subsample was selected for verification of polymer types based on the European Commission suggestion.

The statistical analysis was conducted based on the data normality by using Shapiro Wilk test. If the data is normally distributed, thus parametric tests are performed. Conversely, the non-parametric tests are used to analyse the significant difference of the predictor variables. Statistical analysis and model were performed by using R software (Version 3.3.3). The occurrence of microplastics in the environment was modelled using generalised linear model (GLM) with Poisson regression to investigate the relationship among studied variables.

There are also some constraints experienced while conducting the sampling work. The preliminary investigation of fish community in Tebrau River was carried out by using angling with hook and line technique instead of casting net. This is due to the presence of cement piling at the sampling location and the river bottom is mostly covered by mud patches. The collection of fish in Skudai River using casting net was initially approachable, however, sampling work using this technique have experienced difficulties due to slippery and steep slopes and vegetation along the river bank. Therefore, the angling with hook and line technique in both sampling sites was then standardised in the subsequent sampling period.

1.5 Significance of the Study

Based on recent information, only Amazon sailfin catfish, *Pterygoplichthys pardalis* and African catfish were reported in Skudai River and Tebrau River (Ann Kili, 2017; Landau, 2019). In 2018, the Johor Fisheries Department has recorded about 61% of *P. pardalis* occupied in Skudai River (Landau, 2019). It shows that the information on fish diversity in Skudai River and Tebrau River is still scarce. Hence, the present study provides new status on the fish community in both studied rivers, particularly at the fishing spots.

Skudai River and Tebrau River were reported as the most polluted rivers with a high amount of rubbish in Peninsular Malaysia (Aruna, 2014). Meanwhile sampling sites in this study are within a high population density and highly developed regions. Surrounded by urban area and mismanagement of landfill waste has caused garbage pollution in rivers. It will lead to the accumulation of plastic debris in the river bank and subsequently degrade to smaller pieces known microplastics. Microplastics also released into rivers from various sources. It demonstrates that the occurrence of microplastics in freshwater environments needs to investigate since most of the particles released to the ocean. The persistence of microplastics in the environment based on temporal trends also warrants further work where the study can reflect the overall health of the river.

Sediment is regarded as a pool of microplastics and this will affect the feeding behaviour of several fish species in the studied rivers. African catfish are the largest and abundant species in both studied rivers. This species is known as a good scavenger, able to consume all types of feeds. Thus African catfish has a great potential to ingest microplastics. African catfish is a commercial fish species, and like other commercial fish, microplastics in its tissue presents a potential risk to human health (Barboza et al., 2020). It is worthy of note that ingestion is considered the main pathway of human exposure to microplastic particles (Galloway, 2015; Prata et al., 2020). The ingestion is likely to occur and may reach the human gastrointestinal system by consuming contaminated food items such as seafood and commercial fish. The ingested microplastics could be adsorbed in the human intestine or translocate to the circulatory system and may induce inflammatory responses (Prata et al., 2020). The examination of microplastics in this species is pertinent to serve the public about the harmful of these particles.

The ingestion incidence of microplastics by African catfish against time shows the capability of this species as a bioindicator. As well as, the occurrence of microplastics in sediments and African catfish based on water quality parameter and monsoon seasons may also provide new insight into its abundance in the aquatic environments. Hence, the documentation of the occurrence of microplastics in freshwater sediments and commercial fish is significantly essential for the current issue of environmental pollution, potential impacts, and river rehabilitation planning.

REFERENCES

Abbasi, S., Soltani, N., Hassanaghaei, M., Keshavarzi, B., Moore, F., and Turner, A. (2018). Microplastics in different tissues of fish and prawn from the Musa Estuary, Persian Gulf. *Chemosphere*, *205*, 80–87.

Abdul-Malek, F. (2018). *Laporan Tahunan MBJB 2017*. Retrieved from file:///C:/Users/youhe/Downloads/kdoc_o_00042_01.pdf

Acosta-Coley, I., and Olivero-Verbel, J. (2015). Microplastic resin pellets on an urban tropical beach in Colombia. *Environmental Monitoring and Assessment*, *187*(7).

Alam, O., Billah, M., and Yajie, D. (2018). Characteristics of plastic bags and their potential environmental hazards. *Resources Conservation and Recycling*, *132*, 121-129.

Ali, A. B. (1990). Some ecological aspects of fish populations in tropical ricefields. *Hydrobiologia*, *190*(3), 215–222.

Ali, Z., Tan, L. W., Daud, I. M., and Ahmad, N. A. (2017). *Rainfall Characteristics of Johor Bahru and Kota Bharu , Malaysia*. *Journal of Science and Technology*, *9*(4), 77–83.

Alimi, O. S., Farner Budarz, J., Hernandez, L. M., and Tufenkji, N. (2018). Microplastics and nanoplastics in aquatic environments: aggregation, deposition, and enhanced contaminant transport. *Environmental Science & Technology*, *52*(4), 1704–1724.

Almazán-Rueda, P. (2004). Towards assessment of welfare in African catfish, Clarias gariepinus : the first step. PhD Thesis. Wageningen University.

Anderson, J. C., Park, B. J., and Palace, V. P. (2016). Microplastics in aquatic environments: Implications for Canadian ecosystems. *Environmental Pollution*, *218*, 269–280.

Andrady, A. L. (2011). Microplastics in the marine environment. *Marine Pollution Bulletin*, *62*(8), 1596–1605.

Andrady, A. L. (2017). The plastic in microplastics : A review. *Marine Pollution Bulletin*, *119*(1), 12–22.

Ann Kili, K. (2017, March 17). Stern warning to river polluters. *The Star*. Retrieved from http://weekly.cnbnews.com/news/article.html?no=124000.

Aruna, P. (2014, April 7). Rivers of filth and garbage. *The Star*. Retrieved from https://www.thestar.com.my/news/nation/2014/04/07/rivers-of-filth-and-garbage-pollution-a-contributing-factor-to-current-water-shortage/

Au, S. (2017). *Toxicity of Microplastics to Aquatic Organisms*. 1-226.

Avio, C. G., Gorbi, S., and Regoli, F. (2015). Experimental development of a new protocol for extraction and characterization of microplastics in fish tissues: First observations in commercial species from Adriatic Sea. *Marine Environmental Research*, *111*, 18–26.

Bakir, A., Rowland, S. J., and Thompson, R. C. (2014). Enhanced desorption of persistent organic pollutants from microplastics under simulated physiological conditions. *Environmental Pollution*, *185*, 16-23.

Ballent, A., Corcoran, P. L., Madden, O., Helm, P. A., and Longstaffe, F. J. (2016). Sources and sinks of microplastics in Canadian Lake Ontario shore, tributary and beach sediments. *Marine Pollution Bulletin*, *110*(1), 383–395.

Ballent, A. M. (2016). Anthropogenic particles in natural sediment sinks: Microplastics accumulation in tributary, beach and lake bottom sediments of Lake Ontario, North America. MSc Thesis, The University of Western Ontario..

Barboza, Luís Gabriel A., Lopes, C., Oliveira, P., Bessa, F., Otero, V., Henriques, B., Raimundo, J., Caetano, M., Vale, C., and Guilhermino, L. (2020). Microplastics in wild fish from North East Atlantic Ocean and its potential for causing neurotoxic effects, lipid oxidative damage, and human health risks associated with ingestion exposure. *Science of the Total Environment*, *717*, 134625.

Barboza, Luís Gabriel Antão, Dick Vethaak, A., Lavorante, B. R. B. O., Lundebye, A. K., and Guilhermino, L. (2018). Marine microplastic debris: An emerging issue for food security, food safety and human health. *Marine Pollution Bulletin*, *133*(June), 336–348.

Baresel, C., and Olshammar, M. (2019). On the Importance of Sanitary Sewer Overflow on the Total Discharge of Microplastics from Sewage Water. *Journal of Environmental Protection*, *10*(09), 1105–1118.

Barnes, D. K. A., Galgani, F., Thompson, R. C., and Barlaz, M. (2009). Accumulation and fragmentation of plastic debris in global environments. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *364*(1526), 1985–1998.

Baßmann, B., Brenner, M., and Palm, H. W. (2017). Stress and welfare of african catfish (Clarias gariepinus Burchell, 1822) in a coupled aquaponic system. *Water*

(Switzerland), Vol. 9.

Bee Kim, C. (2017, March 16). Gov't dept tasked to clean up Sungai Tebrau, run awareness campaigns. *New Straits Times*. Retrieved from https://www.nst.com.my/news/2017/03/221504/govt-dept-tasked-clean-sungai-tebrau-run-awareness-campaigns

Bellas, J., Martínez-Armental, J., Martínez-Cámara, A., Besada, V., and Martínez-Gómez, C. (2016). Ingestion of microplastics by demersal fish from the Spanish Atlantic and Mediterranean coasts. *Marine Pollution Bulletin*, *109*(1), 55–60.

Bergmann, R., Ludbrook, J., and Spooren, W. P. J. M. (2000). Different Outcomes of the Wilcoxon-Mann-Whitney Test from Different Statistics Packages. , 54(1), 72. doi:10.2307/2685616. *The American Statistician*, *54*(1), 72–77.

Bessa, F., Barría, P., Neto, J. M., Frias, J. P. G. L., Otero, V., Sobral, P., and Marques, J. C. (2018). Occurrence of microplastics in commercial fish from a natural estuarine environment. *Marine Pollution Bulletin*, *128*(October 2017), 575–584.

Boucher, C., Morin, M., and L.I., B. (2016). The influence of cosmetic microbeads on the sorptive behavior of cadmium and lead within intertidal sediments: A laboratory study. *Regional Studies in Marine Science*, *3*, 1–7.

Brand, T., and Choo, S. (2012). *"Market Watch 2012" The Malaysian Plastic Industry*.

Brennecke, D., Duarte, B., Paiva, F., Caçador, I., and Canning-Clode, J. (2016). Microplastics as vector for heavy metal contamination from the marine environment. *Estuarine, Coastal and Shelf Science*, *178*, 189–195.

Brooks, A. L., Wang, S., and Jambeck, J. R. (2018). Supplementary Materials for The Chinese import ban and its impact on global plastic waste trade. *Science Advances*, *0131*, 1–8.

Browne, M. A., Crump, P., Niven, S. J., Teuten, E., Tonkin, A., Galloway, T., and Thompson, R. (2011). Accumulation of microplastic on shorelines woldwide: sources and sinks. *Environmental Science & Technology, 45*(21), 9175-9179.

Bruton, M. (1979). The food and feeding behaviour of Clarias gariepinus (Pisces: Clariidae) in Lake Sibaya, South Africa, with emphasis on its role as a predator of cichlids. *The Transactions of the Zoological Society of London*, *35*(1), 47–114.

Budimir, S., Setälä, O., and Lehtiniemi, M. (2018). Effective and easy to use extraction method shows low numbers of microplastics in offshore planktivorous fish from the northern Baltic Sea. *Marine Pollution Bulletin*, *127*, 586–592.

Camacho, D. E. (2019). *Proximate and ultimate insights in the evolution of color vision in tropical freshwater fish*. University of Maryland.

Campbell, S. H., Williamson, P. R., and Hall, B. D. (2017). Microplastics in the gastrointestinal tracts of fish and the water from an urban prairie creek. *Facets*, *2*, 395–409.

Castañeda, R. A., Avlijas, S., Simard, M. A., Ricciardi, A., and Smith, R. (2014). Microplastic pollution in St. Lawrence River sediments. *Canadian Journal of Fisheries and Aquatic Sciences*, *71*(12), 1767–1771.

Cheng, X., Shi, H., Adams, C. D., and Ma, Y. (2010). Assessment of metal contaminations leaching out from recycling plastic bottles upon treatments. *Environmental Science and Pollution Research*, *17*(7), 1323-1330.

Cheung, P. K., Fok, L., Hung, P. L., and Cheung, L. T. O. (2018). Spatio-temporal comparison of neustonic microplastic density in Hong Kong waters under the influence of the Pearl River Estuary. *Science of the Total Environment*, *628–629*, 731–739.

Choi, J. S., Jung, Y. J., Hong, N. H., Hong, S. H., and Park, J. W. (2018). Toxicological effects of irregularly shaped and spherical microplastics in a marine teleost, the sheepshead minnow (Cyprinodon variegatus). *Marine Pollution Bulletin*, *129*(1), 231–240.

Claessens, M., Van Cauwenberghe, L., Vandegehuchte, M. B., and Janssen, C. R. (2013). New techniques for the detection of microplastics in sediments and field collected organisms. *Marine Pollution Bulletin*, *70*(1–2), 227–233.

Cole, M., Lindeque, P., Halsband, C., and Galloway, T. S. (2011). Microplastics as contaminants in the marine environment: A review. *Marine Pollution Bulletin*, *62*(12), 2588–2597.

Cole, M., Lindeque, P. K., Fileman, E. S., Galloway, T. S., Webb, H., and Halsband, C. (2014). Isolation of microplastics in biota-rich seawater samples and marine organisms. *Scientific Reports*, *4*(4528), 3–10.

Collard, F., Gasperi, J., Gilbert, B., Eppe, G., Azimi, S., Rocher, V., and Tassin, B. (2018). Anthropogenic particles in the stomach contents and liver of the freshwater fish Squalius cephalus. *Science of the Total Environment*, *643*, 1257–1264.

Collicutt, B., Juanes, F., and Dudas, S. E. (2019). Microplastics in juvenile Chinook salmon and their nearshore environments on the east coast of Vancouver Island.

Environmental Pollution, *244*, 135–142.

Compa, M., Ventero, A., Iglesias, M., and Deudero, S. (2018). Ingestion of microplastics and natural fibres in Sardina pilchardus (Walbaum, 1792) and Engraulis encrasicolus (Linnaeus, 1758) along the Spanish Mediterranean coast. *Marine Pollution Bulletin*, *128*(October 2017), 89–96.

Consoli, P., Andaloro, F., Altobelli, C., Battaglia, P., Campagnuolo, S., Canese, S., Castriota, L., Cillari, T., Falautano, M., Pedà, C., and Perzia, P. (2018). Marine litter in an EBSA (Ecologically or Biologically Significant Area) of the central Mediterranean Sea: Abundance, composition, impact on benthic species and basis for monitoring entanglement. *Environmental Pollution*, *236*, 405–415.

Coppock, R. L., Cole, M., Lindeque, P. K., Queirós, A. M., and Galloway, T. S. (2017). A small-scale, portable method for extracting microplastics from marine sediments. *Environmental Pollution*, *230*, 829–837.

Corcoran, P. L. (2015). Benthic plastic debris in marine and fresh water environments. *Environ. Sci. Process. Impacts*, *8*, 1363e1369.

Courtene-Jones, W., Quinn, B., Gary, S. F., Mogg, A. O. M., and Narayanaswamy, B. E. (2017). Microplastic pollution identified in deep-sea water and ingested by benthic invertebrates in the Rockall Trough, North Atlantic Ocean. *Environmental Pollution*, *231*, 271–280.

Cox, B. A. (2003). A review of dissolved oxygen modelling techniques for lowland rivers. *Science of the Total Environment, 314*, 303–334.

Dadebo, E., Aemro, D., and Tekle-Giorgis, Y. (2014). Dadebo, E., Aemro, D., & Tekle-Giorgis, Y. *Food and Feeding Habits of the A Frican Catfish C Larias Gariepinus (B Urchell, 1822)(P Isces: C Lariidae) in Lake Koka, Ethiopia.*, *52*(4), 471–478.

Dam, M., Auðunsson, G. A., Poulsen, H. H., Berg, I. A., Kristensen, L., Stenersen, J., Joensen, F.N., Davidsen, V.K. & Petersen, S. B. (2017). *Micropollutants in wastewater in four arctic cities:-is the treatment sufficient?* (Vol. 2017550). Nordic Council of Minister.

DanielaDe, C. (2019). Statistical Inference Techniques. *Encyclopedia of Bioinformatics and Computational Biology*, *1*, 698–705.

Davenport, J., and Matin, A. K. M. A. (1990). Terrestrial locomotion in the climbing perch, Anabas testudineus (Bloch) (Anabantidea, Pisces). *Journal of Fish Biology*, *37*(1), 175–184.

de Sá, L. C., Luís, L. G., and Guilhermino, L. (2015). Effects of microplastics on juveniles of the common goby (Pomatoschistus microps): Confusion with prey, reduction of the predatory performance and efficiency, and possible influence of developmental conditions. *Environmental Pollution*, *196*, 359–362.

de Sá, L. C., Oliveira, M., Ribeiro, F., Rocha, T. L., and Futter, M. N. (2018). Studies of the effects of microplastics on aquatic organisms: What do we know and where should we focus our efforts in the future? *Science of the Total Environment*, *645*, 1029–1039.

De Silva, S. S., Perera, M. K., and Maitipe, P. (1984). The composition, nutritional status and digestibility of the diets of Sarotherodon mossambicus from nine man-made lakes in Sri Lanka. *Environmental Biology of Fishes*, *11*(3), 205–219.

De Winter, J. C. (2013). Using the Student's t-test with extremely small sample sizes. *Practical Assessment, Research & Evaluation*, *18*(10).

Desforges, J. P. W., Galbraith, M., Dangerfield, N., and Ross, P. S. (2014). Widespread distribution of microplastics in subsurface seawater in the NE Pacific Ocean. *Marine Pollution Bulletin*, *79*(1–2), 94–99.

Devriese, L. I., De Witte, B., Vethaak, A. D., Hostens, K., and Leslie, H. A. (2017). Bioaccumulation of PCBs from microplastics in Norway lobster (Nephrops norvegicus): An experimental study. *Chemosphere*, *186*, 10–16.

Di, M., and Wang, J. (2018). Microplastics in surface waters and sediments of the Three Gorges Reservoir, China. *Science of the Total Environment*, *616*, 1620-1627.

Diallo, B., and Koch, W. (2018). Robots at Work. *Review of Economics and Statistics*, *100*(5), 753–768.

Digka, N., Tsangaris, C., Torre, M., Anastasopoulou, A., and Zeri, C. (2018). Microplastics in mussels and fish from the Northern Ionian Sea. *Marine Pollution Bulletin*, *135*, 30–40.

Dilkes-Hoffman, L. S., Pratt, S., Lant, P. A., and Laycock, B. (2019). *The Role of Biodegradable Plastic in Solving Plastic Solid Waste Accumulation. In Plastics to Energy*. William Andrew Publishing.

Ding, L., Mao, R. fan, Guo, X., Yang, X., Zhang, Q., and Yang, C. (2019). Microplastics in surface waters and sediments of the Wei River, in the northwest of China. *Science of the Total Environment*, *667*, 427–434.

Dris, R., Gasperi, J., Rocher, V., Saad, M., Tassin, B., and Renault, N. (2018).

Microplastic contamination in an urban area : a case study in Greater Paris. *Environmental Chemistry*, *12*(5), 592-599.

Dris, Rachid, Gasperi, J., Saad, M., Mirande, C., and Tassin, B. (2016). Synthetic fibers in atmospheric fallout: A source of microplastics in the environment? *Marine Pollution Bulletin*, 104, 290–293.

Dris, Rachid, Imhof, H. K., Löder, M. G. J., Gasperi, J., Laforsch, C., and Tassin, B. (2018). Microplastic Contamination in Freshwater Systems: Methodological Challenges, Occurrence and Sources. In *Microplastic Contamination in Aquatic Environments An Emerging Matter of Environmental Urgency* (pp. 51–93).

Duis, K., and Coors, A. (2016). Microplastics in the aquatic and terrestrial environment: sources (with a specific focus on personal care products), fate and effects. *Environmental Sciences Europe*, *28*(1), 1–25.

Dunn, O. J. (1964). Multiple comparisons using rank sums. *Technometrics*, *6*, 241–252.

Duwez, A. S., and Nysten, B. (2001). Mapping aging effects on polymer surfaces: specific detection of additives by chemical force microscopy. *Langmuir*, *17*(26), 8287–8292.

Eagan, J. M., Xu, J., Di Girolamo, R., Thurber, C. M., Macosko, C. W., La Pointe, A. M., Bates, F. S., and Coates, G. W. (2017). Combining polyethylene and polypropylene: Enhanced performance with PE/iPP multiblock polymers. *Science*, *355*(6327), 814–816.

Eerkes-Medrano, D., Thompson, R. C., and Aldridge, D. C. (2015). Microplastics in freshwater systems: A review of the emerging threats, identification of knowledge gaps and prioritisation of research needs. *Water Research*, *75*, 63–82.

Elert, A. M., Becker, R., Duemichen, E., Eisentraut, P., Falkenhagen, J., Sturm, H., and Braun, U. (2017). Comparison of different methods for MP detection: what can we learn from them, and why asking the right question before measurements matters? *Environmental Pollution*, *231*, 1256–1264.

Elliott, A. C., and Hynan, L. S. (2011). A SAS® macro implementation of a multiple comparison post hoc test for a Kruskal–Wallis analysis. *Computer Methods and Programs in Biomedicine*, *102*(1), 75–80.

Erik van, S., Chris, W., Laurent, L., Nikolai, M., Britta Denise, H., Jan, A. van F., Marcus, E., David, S., Francois, G., and Kara Lavender, L. (2015). A global inventory of small floating plastic debris. *Environmental Research Letters*, *10*(12), 124006.

Eriksen, M., Mason, S., Wilson, S., Box, C., Zellers, A., Edwards, W., Farley, H., and Amato, S. (2013). Microplastic pollution in the surface waters of the Laurentian Great Lakes. *Marine Pollution Bulletin*, *77*(1–2), 177–182.

Estahbanati, S., and Fahrenfeld, N. L. (2016). Influence of wastewater treatment plant discharges on microplastic concentrations in surface water. *Chemosphere*, *162*, 277–284.

Fahrenkamp-Uppenbrink, J. (2018). Microplastics everywhere. *Science*, *360*(6384), 44–46.

Fan, Y., Zheng, K., Zhu, Z., Guangshi, C., and Peng, X. (2019). Distribution, sedimentary record, and persistence of microplastics in the Pearl River catchment, China. *Environmental Pollution*, *251*, 862–870.

Fatollahi, M., and Kasumyan, A. O. (2006). The study of sensory bases of the feeding behavior of the African catfish Clarias gariepinus (Clariidae, Siluriformes). *Journal of Ichthyology*, *46*(2 SUPPL.).

Fazey, F. M. C., and Ryan, P. G. (2016). Biofouling on buoyant marine plastics: An experimental study into the effect of size on surface longevity. *Environmental Pollution*, *210*, 354–360.

Ferreira, M., Thompson, J., Paris, A., Rohindra, D., and Rico, C. (2020). Presence of microplastics in water, sediments and fishspecies in an urban coastal environment of Fiji, a Pacific small island and developing state. *Marine Pollution*, *153*(110991).

Ferreira, G. V., Barletta, M., Lima, A. R., Morley, S. A., Justino, A. K., and Costa, M. F. (2018). High intake rates of microplastics in a Western Atlantic predatory fish, and insights of a direct fishery effect. *Environmental Pollution*, *236*, 706=717.

Filella, M. (2015). Questions of size and numbers in environmental research on microplastics: methodological and conceptual aspects. *Environmental Chemistry*, *12*(5), 527–538.

Fischer, E. K., Paglialonga, L., Czech, E., and Tamminga, M. (2016). Microplastic pollution in lakes and lake shoreline sediments - A case study on Lake Bolsena and Lake Chiusi (central Italy). *Environmental Pollution*, *213*, 648–657.

Fischer, M., and Scholz-Böttcher, B. M. (2017). Simultaneous trace identification and quantification of common types of microplastics in environmental samples by pyrolysis-gas chromatography–mass spectrometry. *Environmental Science &*

Technology, *51*(9), 5052–5060.

Forte, M., Iachetta, G., Tussellino, M., Carotenuto, R., Prisco, M., De Falco, M., Laforgia, V., and Valiante, S. (2016). Polystyrene nanoparticles internalization in human gastric adenocarcinoma cells. *Toxicology in Vitro*, *31*, 126–136.

Fossi, M. C., Pedà, C., Compa, M., Tsangaris, C., Alomar, C., Claro, F., Ioakeimidis, C., Galgani, F., Hema, T., Deudero, S., Romeo, T., Battaglia, P., Andaloro, F., Caliani, I., Casini, S., Panti, C., and Baini, M. (2018). Bioindicators for monitoring marine litter ingestion and its impacts on Mediterranean biodiversity. *Environmental Pollution*, *237*, 1023–1040.

Free, C. M., Jensen, O. P., Mason, S. A., Eriksen, M., Williamson, N. J., and Boldgiv, B. (2014). High-levels of microplastic pollution in a large, remote, mountain lake. *Marine Pollution Bulletin*, *85*(1), 156-163.

Froese, R. (2006). Cube law, condition factor and weight-length relationships: History, meta-analysis and recommendations. *Journal of Applied Ichthyology*, *22*(4), 241–253.

Galloway, T. S. (2015). Micro- and nano-plastics and Human Health. In *Marine Anthropogenic Litter* (pp. 9–14).

Gatidou, G., Arvaniti, O. S., and Stasinakis, A. S. (2019). Review on the occurrence and fate of microplastics in Sewage Treatment Plants. *Journal of Hazardous Materials*, 504–512.

Geyer, R., Jambeck, J. R., and Law, K. L. (2017). Production, use, and fate of all plastics ever made. *Science Advances*, *3*(7), e1700782.

Ghosh, S. K. (2018). Anatomical and histological studies on the olfactory organ of riverine catfish, Eutropiichthys vacha (Hamilton, 1822). *Asian Journal of Animal and Veterinary Advances*, *13*, 245–252.

Gilbert, M. (2017). Plastics Materials: Introduction and Historical Development. In *Brydson's Plastics Materials (Eighth Edition)* (pp. 1–18).

Gourmelon, G. (2015). Global Plastic Production Rises, Recycling Lags | Worldwatch Institute. *WorldWatch Institute*, 1–7.

Gray, A. D., Wertz, H., Leads, R. R., and Weinstein, J. E. (2018). Microplastic in two South Carolina Estuaries: Occurrence, distribution, and composition. *Marine Pollution Bulletin*, *128*, 223–233.

Gregory, M. . (1999). Plastics and South Pacific Island shores: environmental implications. *Ocean Coastal Management*, *42*, 603–615.

Gregson, N., and Crang, M. (2018). Made in China and the new world of secondary resource recovery. *Environment and Planning A: Economy and Space*, 0308518X18791175.

Gusmao, F., Domenico, M. D., Amaral, A. C. Z., Martínez, A., Gonzalez, B. C., Worsaae, K., Ivar do Sul, J. A., and Cunha Lana, P. da. (2016). In situ ingestion of microfibres by meiofauna from sandy beaches. *Environ. Pollut.*, *216*, 584-590.

Hahladakis, J. N., Velis, C. A., Weber, R., Iacovidou, E., and Purnell, P. (2018). An overview of chemical additives present in plastics: migration, release, fate and environmental impact during their use, disposal and recycling. *Journal of Hazardous Materials*, *344*, 179–199.

Hamid, M. A., Bagheri, S., Sam, N., and Mansor, M. (2015). A comparative study of seasonal food and feeding habits of beardless barb, Cyclocheilichthys apogon (Valenciennes, 1842), in Temengor and Bersia Reservoirs, Malaysia. *Iranian Journal of Fisheries Sciences*, *14*(4), 1018–1028.

Hammer, J., Kraak, M. H., and Parsons, J. R. (2012). *Plastics in the marine environment: the dark side of a modern gift. In Reviews of environmental contamination and toxicology*.

Hammim, R. (2019). Dept to probe presence of alien species in Sg Skudai. *New Straits Time*. Retrieved from https://www.nst.com.my/news/nation/2019/02/457985/dept-probe-presence-alien-species-sg-skudai

Hammim, Z. (2017). *Garbage kills almost all life in Sungai Tebrau: MNS*. Retrieved from https://www.nst.com.my/news/nation/2017/04/229360/garbage-kills-almost-all-life-sungai-tebrau-mns

Han, M., Niu, X., Tang, M., Zhang, B. T., Wang, G., Yue, W., Kong, X., and Zhu, J. (2020). Distribution of microplastics in surface water of the lower Yellow River near estuary. *Science of the Total Environment*, *707*(135601).

Hangzo, P.K.K., Cook, A. D. (2014). *The rise of Iskandar Malaysia: Implications for Singapore's marine and coastal environment*.

Heiri, O., Lotter, A., and Lemcke, G. (2001). Loss on ignition as a method for estimating organic and carbonate content in sediments. *Journal of Paleolimnology*, *25*, 101–110.

Hernandez, L. M., Yousefi, N., and Tufenkji, N. (2017). Are there nanoplastics in your personal care products? *Environmental Science and Technology Letters*, *4*(7), 280–285.

Herrera, A., Ŝtindlová, A., Martínez, I., Rapp, J., Romero-Kutzner, V., Samper, M. D., Montoto, T., Aguiar-González, B., Packard, T., and Gómez, M. (2019). Microplastic ingestion by Atlantic chub mackerel (Scomber colias) in the Canary Islands coast. *Marine Pollution Bulletin*, *139*, 127–135.

Hidalgo-Ruz, V., and Thiel, M. (2012). Microplastics in the Marine Environment: A Review of the Methods Used for Identification and Quantification Cellular Effects of microplastics-uptake, fate and pathologies View project. *Environmental Science and Technology*, *46*, 3060–3075.

Hoeffding, W. (1948). A non-parametric test of independence. *The Annals of Mathematical Statistics*, 546–557.

Hoellein, T. J., McCormick, A. R., Hittie, J., London, M. G., Scott, J. W., & Kelly, J. J. (2017). Longitudinal patterns of microplastic concentration and bacterial assemblages in surface and benthic habitats of an urban river. *Freshwater Science*, *36*(3), 491–507.

Hopewell, J., Dvorak, R., and Kosior, E. (2009). Plastics recycling: challenges and opportunities. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *364*(1526), 2115–2126.

Horton, A. A., Jürgens, M. D., Lahive, E., van Bodegom, P. M., and Vijver, M. G. (2018). The influence of exposure and physiology on microplastic ingestion by the freshwater fish Rutilus rutilus (roach) in the River Thames, UK. *Environmental Pollution, 236*(188–194).

Horton, Alice A., Svendsen, C., Williams, R. J., Spurgeon, D. J., and Lahive, E. (2017). Large microplastic particles in sediments of tributaries of the River Thames, UK – Abundance, sources and methods for effective quantification. *Marine Pollution Bulletin*, *114*(1), 218–226.

Hotta, Y., Visvanathan, C., and Kojima, M. (2016). Recycling rate and target setting: challenges for standardized measurement. *Journal of Material Cycles and Waste Management*, *18*(1), 14–21.

Houlihan, D., Boujard, T., and Jobling, M. (2001). *Food Intake in Fish. Blackwell Science, London.* John Wiley & Sons.

Hua, A. K., and Kusin, F. M. (2015). Remote Sensing towards Water Quality Study in Malacca River. Case Study: A Review Perspective. *International Journal of Scientific Research in Science and Technology*, *1*(2), 9–15.

Hutchinson, M. K., and Holtman, M. C. (2005). Analysis of count data using poisson regression. *Research in Nursing & Health*, *28*(5), 408–418.

Imhof, H. K., Schmid, J., Niessner, R., Ivleva, N. P., and Laforsch, C. (2012). A novel, highly efficient method for the separation and quantification of plastic particles in sediments of aquatic environments. *Limnology and Oceanography: Methods*, *10*, 524–537.

Ivan, I. A., Stihi, V., Ivan, M., Stihi, C., Rakotondrabe, M., and Jelea, A. (2011). Battery powered cost effective TDS logger intended for water testing. *Romanian Reports of Physics*, *56*(3–4), 540–549.

Ivar Do Sul, J. A., and Costa, M. F. (2014). The present and future of microplastic pollution in the marine environment. *Environmental Pollution*, *185*, 352–364.

Ivleva, N. P., Wiesheu, A. C., and Niessner, R. (2017). Microplastic in aquatic ecosystems. Angew. Chem. Int. Ed. 56 (7),. *Angew. Chem. Int. Ed.*, *56*(7), 1720–1739.

Iwamoto, R., and Matsuda, T. (2005). Interaction of water in polymers: Poly(ethylene-co-vinyl acetate) and poly(vinyl acetate). *Journal of Polymer Science, Part B: Polymer Physics*, *43*(7), 777–785.

Jabeen, K., Su, L., Li, J., Yang, D., Tong, C., Mu, J., and Shi, H. (2017a). Microplastics and mesoplastics in fish from coastal and fresh waters of China. *Environmental Pollution*, *221*, 141–149.

Jabeen, K., Su, L., Li, J., Yang, D., Tong, C., Mu, J., and Shi, H. (2017b). Microplastics and mesoplastics in fish from coastal and fresh waters of China. *Environmental Pollution*, *221*, 141–149.

Jambeck, J. R., Geyer, R., Wilcox, C., Siegler, T. R., Perryman, M., Andrady, A., Narayan, R., and Law, K. L. (2015). Plastic waste inputs from land into the ocean. *Science*, *347*(6223), 768–771.

Jiang, C., Yin, L., Wen, X., Du, C., Wu, L., Long, Y., Liu, Y., Ma, Y., Yin, Q., Zhou, Z., and Pan, H. (2018). Microplastics in sediment and surface water of west dongting lake and south dongting lake: Abundance, source and composition. *International Journal of Environmental Research and Public Health*, *15*(10).

Jovanović, B., Gökdağ, K., Güven, O., Emre, Y., Whitley, E. M., and Kideys, A. E. (2018). Virgin microplastics are not causing imminent harm to fish after dietary exposure. *Marine Pollution Bulletin*, *130*, 123–131.

Jung, M. R., Horgen, F. D., Orski, S. V., Rodriguez C., V., Beers, K. L., Balazs, G. H., Jones, T. T., Work, T. M., Brignac, K. C., Royer, S. J., Hyrenbach, K. D., Jensen, B. A., and Lynch, J. M. (2018). Validation of ATR FT-IR to identify polymers of plastic marine debris, including those ingested by marine organisms. *Marine Pollution Bulletin*, *127*(November 2017), 704–716.

Kalčíková, G. (2020). Aquatic vascular plants – A forgotten piece of nature in microplastic research. *Environmental Pollution*, *262*.

Kang, H., Park, H., Kwon, O., Lee, W., Jeong, D., Ju, B., and Kwon, J. (2018). *Occurrence of microplastics in municipal sewage treatment plants : a review*. *33*(3), 43–48.

Karami, A., Golieskardi, A., Choo, C. K., Romano, N., Ho, Y. Bin, and Salamatinia, B. (2017). A high-performance protocol for extraction of microplastics in fish. *Science of the Total Environment*, *578*, 485–494.

Karlsson, T. M., Vethaak, A. D., Almroth, B. C., Ariese, F., van Velzen, M., Hassellöv, M., and Leslie, H. A. (2017). Screening for microplastics in sediment, water, marine invertebrates and fish: Method development and microplastic accumulation. *Marine Pollution Bulletin*, *122*(1–2), 403–408.

Karlsson, T. M., Vethaak, A. D., Carney, B., Ariese, F., Velzen, M. Van, Hassellöv, M., and Leslie, H. A. (2017). Screening for microplastics in sediment , water , marine invertebrates and fi sh : Method development and microplastic accumulation. *Marine Pollution Bulletin*, *122*(1–2), 403–408.

Kataoka, T., Nihei, Y., Kudou, K., and Hinata, H. (2019). Assessment of the sources and inflow processes of microplastics in the river environments of Japan. *Environmental Pollution*, *244*, 958–965.

Kawamura, G., Bagarinao, T. U., Asmad, M. F. Bin, and Lim, L. S. (2017). Food colour preference of hatchery-reared juveniles of African catfish Clarias gariepinus. *Applied Animal Behaviour Science*, *196*(March), 119–122.

Kay, P., Hiscoe, R., Moberley, I., Bajic, L., and McKenna, N. (2018). Wastewater treatment plants as a source of microplastics in river catchments. *Environmental Science and Pollution Research*, *25*(20), 20264–20267.

Kershaw, P., Katsuhiko, S., Lee, S., and Woodring, D. (2011). Plastic Debris in the Ocean. *United Nations Environment Programme.*, 21–33.

Kim, Y. K. (2017). *The use of polyolefins in industrial and medical applications*.

Klein, S., Dimzon, I. K., Eubeler, J., and Knepper, T. P. (2018). Analysis, occurrence, and degradation of microplastics in the aqueous environment. In *Freshwater*

Microplastics (pp. 51–67).

Klein, Sascha. (2015). *Microplastics in Freshwater Systems : Analysis , Occurrence , and Sorption of Organic Contaminants*. PhD Thesis. Technische Universität Dresden.

Klein, Sascha, Worch, E., and Knepper, T. P. (2015). Occurrence and spatial distribution of microplastics in river shore sediments of the rhine-main area in Germany. *Environmental Science and Technology*, *49*(10), 6070–6076.

Kleinteich, J., Seidensticker, S., Marggrander, N., and Zarf, C. (2018). Microplastics reduce short-term effects of environmental contaminants. part II: Polyethylene particles decrease the effect of polycyclic aromatic hydrocarbons on microorganisms. *International Journal of Environmental Research and Public Health*, *15*(2).

Knuuttila, H., Lehtinen, A., and Nummila-Pakarinen, A. (2004). *Advanced polyethylene technologies—controlled material properties. In Long Term Properties of Polyolefins*.

Koelmans, A.A., Bakir, A., Burton, G. A., and Janssen, C. R. (2016). Microplastic as a vector for chemicals in the aquatic environment: critical review and model-supported reinterpretation of empirical studies. *Environmental Science & Technology*, *50*(7), 3315–3326.

Koelmans, Albert A., Mohamed Nor, N. H., Hermsen, E., Kooi, M., Mintenig, S. M., and De France, J. (2019). Microplastics in freshwaters and drinking water: Critical review and assessment of data quality. *Water Research*, *155*, 410–422.

Kooi, M., Besseling, E., Carolien, K., van Wezel, P. A., and Koelmans, A. A. (2018). Modeling the Fate and Transport of Plastic Debris in Freshwaters: Review and Guidance. In *Freshwater Microplastics Emerging Environmental Contaminants?* (p. 125).

Kramer, D. L., and Bryant, M. J. (1995). Intestine length in the fishes of a tropical stream: 2. Relationships to diet - the long and short of a convoluted issue. *Environmental Biology of Fishes*, *42*(2), 129–141.

Kühn, S., van Werven, B., van Oyen, A., Meijboom, A., Bravo Rebolledo, E. L., and van Franeker, J. A. (2017). The use of potassium hydroxide (KOH) solution as a suitable approach to isolate plastics ingested by marine organisms. *Marine Pollution Bulletin*, *115*(1–2), 86–90.

Kuptsov, A. H., and Zhizhin, G. N. (1998). *Handbook of Fourier transform Raman* *and infrared spectra of polymers*. Elsevier.

Lai, A. (2017). More growth expected for Malaysian plastic industry. *The Star*.

Lambert, S., and Wagner, M. (2018). Microplastics Are Contaminants of Emerging Concern in Freshwater Environments: An Overview. In *Freshwater Microplastics* (pp. 1–23).

Landau, E. (2019). “Ikan bandaraya” “cleans out” local ecosystem. *New Straits Timesraits Times*. Retrieved from https://www.nst.com.my/news/nation/2019/02/457980/ikan-bandaraya-cleans-out-local-ecosystem

Law, K. . (2017). Plastics in the marine environment. *Annual Review of Marine Science*, *9*, 205–229.

Lebreton, L. C. M., Zwet, J. Van Der, Damsteeg, J., Slat, B., Andrady, A., and Reisser, J. (2017). River plastic emissions to the world ’ s oceans. *Nature Communications*, *8*, 1–10.

Lee, C. K., Kawamura, G., Senoo, S., Ching, F. F., and Luin, M. (2014). Colour vision in juvenile African catfish Clarias gariepinus. *International Research Journal of Biological Sciences*, *3*(1), 36–41.

Lee, H., Shim, W. J., and Kwon, J. H. (2014). Sorption capacity of plastic debris for hydrophobic organic chemicals. *Science of the Total Environment*, *470*, 1545-1552.

Lee, J., Hong, S., Song, Y. K., Hong, S. H., Jang, Y. C., Jang, M., Heo, N. W., Han, G. M., Lee, M. J., Kang, D., and Shim, W. J. (2013). Relationships among the abundances of plastic debris in different size classes on beaches in South Korea. *Marine Pollution Bulletin*, *77*(1–2), 349–354.

Lei, K., Qiao, F., Liu, Q., Wei, Z., Qi, H., Cui, S., Yue, X., Deng, Y., and An, L. (2017). Microplastics releasing from personal care and cosmetic products in China. *Marine Pollution Bulletin*, *123*(1–2), 122–126.

Leja, K., and Lewandowicz, G. (2010). Polymer Biodegradation and Biodegradable Polymers-a Review. *Polish Journal of Environmental Studies*, *19*(2), 255–266.

Leslie, H. A. (2014). *Review of microplastics in cosmetics. Institute for Environmental Studies, 4*.

Leslie, H. A., Brandsma, S. H., van Velzen, M. J. M., and Vethaak, A. D. (2017). Microplastics en route: Field measurements in the Dutch river delta and Amsterdam canals, wastewater treatment plants, North Sea sediments and biota.

Environment International, *101*, 133–142.

Li, Jiana, Qu, X., Su, L., Zhang, W., Yang, D., Kolandhasamy, P., Li, D., and Shi, H. (2016). Microplastics in mussels along the coastal waters of China. *Environmental Pollution*, *214*, 177–184.

Li, Jingyi, Liu, H., and Paul Chen, J. (2018). Microplastics in freshwater systems: A review on occurrence, environmental effects, and methods for microplastics detection. *Water Research*, *137*, 362–374.

Lima, A. R. A., Costa, M. F., and Barletta, M. (2014). Distribution patterns of microplastics within the plankton of a tropical estuary. *Environmental Research*, *132*, 146–155.

Lin, L., Zuo, L. Z., Peng, J. P., Cai, L. Q., Fok, L., Yan, Y., Li, H. X., and Xu, X. R. (2018). Occurrence and distribution of microplastics in an urban river: A case study in the Pearl River along Guangzhou City, China. *Science of the Total Environment*, *644*, 375–381.

Liu, S., Jian, M., Zhou, L., and Li, W. (2019). Distribution and characteristics of microplastics in the sediments of Poyang Lake, China. *Water Science and Technology*, *79*(10), 1868–1877.

Lorenz, C. (2014). *Detection of microplastics in marine sediments of the German Coast via FT-IR spectroscopy*. Doctoral dissertation, Universität Rostock.

Lu, Y., Zhang, Y., Deng, Y., Jiang, W., Zhao, Y., Geng, J., Ding, L., and Ren, H. (2016). Uptake and accumulation of polystyrene microplastics in zebrafish (Danio rerio) and toxic effects in liver. *Environmental Science & Technology*, *50*(7), 4054-4060.

Lucas, N., Bienaime, C., Belloy, C., Queneudec, M., Silvestre, F., and Nava-Saucedo, J. E. (2008). Polymer biodegradation: Mechanisms and estimation techniques–A review. *Chemosphere*, *73*(4), 429–442.

Lusher, A. L., McHugh, M., and Thompson, R. C. (2013). Occurrence of microplastics in the gastrointestinal tract of pelagic and demersal fish from the English Channel. *Marine Pollution Bulletin*, *67*(1–2), 94–99.

Mani, T., Hauk, A., Walter, U., and Burkhardt-Holm, P. (2015). Microplastics profile along the Rhine River. *Scientific Reports*, *5*, 1–7.

Marimuthu, K. (2019). A short review on induced spawning and seed production of African Catfish Clarias gariepinus in Malaysia. *IOP Conference Series: Earth and Environmental Science*, *348*(1).

Marui, T., and Caprio, J. (1992). Teleost gustation. In: Hara T.J. (eds). In *Fish Chemoreception.* (pp. 171–198).

Mason, S. A., Garneau, D., Sutton, R., Chu, Y., Ehmann, K., Barnes, J., Fink, P., Papazissimos, D., and Rogers, D. L. (2016). Microplastic pollution is widely detected in US municipal wastewater treatment plant effluent. *Environmental Pollution*, *218*, 1045–1054.

Mateos-Cárdenas, A., Scott, D. T., Seitmaganbetova, G., van, van P., John, O. H., and Marcel A.K., J. (2019). Polyethylene microplastics adhere to Lemna minor (L.), yet have no effects on plant growth or feeding by Gammarus duebeni (Lillj.). *Science of the Total Environment*, *689*, 413–421.

McCormick, A., Hoellein, T. J., Mason, S. A., Schluep, J., and Kelly, J. J. (2014). Microplastic is an abundant and distinct microbial habitat in an urban river. *Environmental Science and Technology*, *48*(20), 11863–11871.

McGoran, A. R., Clark, P. F., and Morritt, D. (2017). Presence of microplastic in the digestive tracts of European flounder, Platichthys flesus, and European smelt, Osmerus eperlanus, from the River Thames. *Environmental Pollution*, *220*, 744–751.

McGoran, A. R., Cowie, P. R., Clark, P. F., McEvoy, J. P., and Morritt, D. (2018). Ingestion of plastic by fish: A comparison of Thames Estuary and Firth of Clyde populations. *Marine Pollution Bulletin, 137*, 12–23.

McNeish, R. E., Kim, L. H., Barrett, H. A., Mason, S. A., Kelly, J. J., and Hoellein, T. J. (2018). Microplastic in riverine fish is connected to species traits. *Scientific Reports*, *8*(1), 1–12.

Mikulasch, F. (2016). *Country cluster: Plastics resin production and consumption in 63 countries worldwide 2009 – 2020. European Plastics and Rubber Machinery.*

Millet, H., Vangheluwe, P., Block, C., Sevenster, A., Garcia, L., & Antonopoulos, R. (2018). *The Nature of Plastics and Their Societal Usage. Plastics and the Environment, 47, 1.*

Miranda, D. de A., and de Carvalho-Souza, G. F. (2016). Are we eating plastic-ingesting fish? *Marine Pollution Bulletin*, *103*(1–2), 109–114. Retrieved from http://dx.doi.org/10.1016/j.marpolbul.2015.12.035

Mizraji, R., Ahrendt, C., Perez-Venegas, D., Vargas, J., Pulgar, J., Aldana, M., Patricio Ojeda, F., Duarte, C., and Galbán-Malagón, C. (2017). Is the feeding type related with the content of microplastics in intertidal fish gut? *Marine Pollution Bulletin*, *116*(1–2), 498–500.

Moh, Y. C., and Manaf, L. A. (2014). Overview of household solid waste recycling policy status and challenges in Malaysia. *Resources, Conservation and Recycling*, *82*, 50-61.

Mohamed Nor, N. H., and Obbard, J. P. (2014). Microplastics in Singapore's coastal mangrove ecosystems. *Marine Pollution Bulletin*, *79*(1–2), 278–283.

Mohtar, Z. A., Yahaya, A. S., Ahmad, F., Suri, S., and Halim, H. (2014). Trends for Daily Rainfall in Northern and Southern Region of Peninsular Malaysia. *Journal of Civil Engineering Research*, *4*(3A), 222–227.

Montagna, P., Palmer, T. A., and Pollack, J. B. (2012). *Hydrological changes and estuarine dynamics*. Springerbriefs in Environmental Science.

Moore, C. J. (2008). Synthetic polymers in the marine environment: A rapidly increasing, long-term threat. *Environmental Research*, *108*(2), 131–139.

Morais, S. (2017). The Physiology of Taste in Fish: Potential Implications for Feeding Stimulation and Gut Chemical Sensing. *Reviews in Fisheries Science and Aquaculture*, *25*(2), 133–149.

Morita, Y., and Hayashi, S. (2018). Proposals to Strengthen Japan's Domestic Measures and Regional Cooperation on Stable and Environmentally Sound Plastic Scrap Recycling: Response to China's Ban on Imports of Plastic Scrap. *IGES Policy Brief*, (41).

Munier, B., and Bendell, L. I. (2018). Macro and micro plastics sorb and desorb metals and act as a point source of trace metals to coastal ecosystems. *PloS One*, *13*(2), e0191759.

Murata, K., Sato, K., and Sakata, Y. (2004). Effect of pressure on thermal degradation of polyethylene. *Journal of Analytical and Applied Pyrolysis*, *71*(2), 569–589.

Murphy, F., Ewins, C., Carbonnier, F., and Quinn, B. (2016). Wastewater Treatment Works (WwTW) as a Source of Microplastics in the Aquatic Environment. *Environmental Science and Technology*, *50*(11), 5800–5808.

Musa, Z. (2017, September 28). Rivers become a dumping site. *The Star*. Retrieved from https://www.thestar.com.my/metro/metro-news/2017/09/28/rivers-become-a-dumping-site-irresponsible-folk-throw-rubbish-into-waterways/

Nakashima, E., Isobe, A., Kako, S. I., Itai, T., and Takahashi, S. (2012). Quantification of toxic metals derived from macroplastic litter on Ookushi Beach, Japan. *Environmental Science & Technology, 46*(18), 10099-10105.

Nall, D. H., and Sedlak, R. (2013). Total dissolved solids in reclaimed water. *ASHRAE Journal*, *55*(10), 28–38.

Napper, I. E., and Thompson, R. C. (2016). Release of synthetic microplastic plastic fibres from domestic washing machines: Effects of fabric type and washing conditions. *Marine Pollution Bulletin*, *112*(1–2), 39–45.

Nauendorf, A., Krause, S., Bigalke, N. K., Gorb, E. V., Gorb, S. N., Haeckel, M., Wahl, M., and Treude, T. (2016). Microbial colonization and degradation of polyethylene and biodegradable plastic bags in temperate fine-grained organic-rich marine sediments. *Marine Pollution Bulletin*, *103*(1–2), 168–178.

Negi, R. K., and Mamgain, S. (2013). Species diversity, abundance and distribution of fish community and conservation status of Tons river of Uttarakhand State, India. *Journal of Fisheries and Aquatic Science*, *8*(5), 617–629.

Nel, H. A., Dalu, T., and Wasserman, R. J. (2018). Sinks and sources: Assessing microplastic abundance in river sediment and deposit feeders in an Austral temperate urban river system. *Science of the Total Environment*, *612*, 950–956.

Neves, D., Sobral, P., Ferreira, J. L., and Pereira, T. (2015). Ingestion of microplastics by commercial fish off the Portuguese coast. *Marine Pollution Bulletin*, Vol. 101, pp. 119–126.

Nhi, N. H. Y., Preston, T. R., Ogle, B., and Lundh, T. (2010). Effect of earthworms as replacement for trash fish and rice field prawns on growth and survival rate of marble goby (Oxyeleotris marmoratus) and Tra catfish (Pangasius hypophthalmus). *Livestock Research for Rural Development*, *22*, 204.

Nuelle, M. T., Dekiff, J. H., Remy, D., and Fries, E. (2014). A new analytical approach for monitoring microplastics in marine sediments. *Environmental Pollution*, *184*, 161–169.

Olshanskiy, V. M., and Kasumyan, A. O. (2018). Electrical Activity and Predation in the Clariid Catfish Clarias macrocephalus (Clariidae) Exposed to Varying Illumination. *Journal of Ichthyology*, *58*(6), 902–915.

Ory, N. C., Sobral, P., Ferreira, J. L., and Thiel, M. (2017). Amberstripe scad Decapterus muroadsi (Carangidae) fish ingest blue microplastics resembling their copepod prey along the coast of Rapa Nui (Easter Island) in the South Pacific subtropical gyre. *Science of the Total Environment*, *586*, 430–437.

Ory, Nicolas Christian, Gallardo, C., Lenz, M., and Thiel, M. (2018). Capture, swallowing, and egestion of microplastics by a planktivorous juvenile fish.

Environmental Pollution, *240*, 566–573.

Ostiategui-Francia, P., Usategui-Martín, A., and Liria-Loza, A. (2016). Microplastics Presence in Sea Turtles. In *MICRO 2016: Fate and Impact of Microplastics in Marine Ecosystems: From the Coastline to the Open Sea* (p. 34).

Ozório, R. O. A., Van Eekeren, T. H. B., Huisman, E. A., and Verreth, J. A. J. (2001). Effects of dietary carnitine and protein energy: nonprotein energy ratios on growth, ammonia excretion and respiratory quotient in African catfish, Clarias gariepinus (Burchell) juveniles. *Aquaculture Research*, *32*, 406–414.

Paaijmans, K. P., Takken, W., K., G. A., and Jacobs, A. F. G. (2008). The effect of water turbidity on the near-surface water temperature of larval habitats of the malaria mosquito Anopheles gambiae. *International Journal of Biometeorology*, *52*(8), 747–753.

Paripatananont, T. (2002). Snakehead and Pangasius catfish. In *Nutrient requirements and feeding of finfish for aquaculture* (pp. 396–401).

Parodi, S., and Bottarelli, E. (2006). Poisson regression model in Epidemiology - An introduction. *Annali Della Facoltà Di Medicina Veterinaria Di Parma*, *XXVI*, 25–44.

Pazos, R. S., Maiztegui, T., Colautti, D. C., Paracampo, A. H., and Gómez, N. (2017). Microplastics in gut contents of coastal freshwater fish from Río de la Plata estuary. *Marine Pollution Bulletin*, *122*(1–2), 85–90.

Peixoto, D., Pinheiro, C., Amorim, J., Oliva-Teles, L., Guilhermino, L., and Vieira, M. N. (2019). Microplastic pollution in commercial salt for human consumption: A review. *Estuarine, Coastal and Shelf Science.*, *219*, 161–168.

Peng, G., Xu, P., Zhu, B., Bai, M., and Li, D. (2018). Microplastics in freshwater river sediments in Shanghai, China: A case study of risk assessment in mega-cities. *Environmental Pollution*, *234*, 448–456.

Peng, G., Zhu, B., Yang, D., Su, L., Shi, H., and Li, D. (2017a). Microplastics in sediments of the Changjiang Estuary, China. *Environmental Pollution*, *225*, 283–290.

Peng, J., Wang, J., and Cai, L. (2017b). Current understanding of microplastics in the environment: Occurrence, fate, risks, and what we should do. *Integrated Environmental Assessment and Management*, *13*(3), 476–482.

Peters, C. A., Thomas, P. A., Rieper, K. B., and Bratton, S. P. (2017). Foraging preferences influence microplastic ingestion by six marine fish species from the

Texas Gulf Coast. *Marine Pollution Bulletin*, *124*(1), 82–88.

Peters, Colleen A., and Bratton, S. P. (2016). Urbanization is a major influence on microplastic ingestion by sunfish in the Brazos River Basin, Central Texas, USA. *Environmental Pollution*, *210*, 380–387.

Phillips, M. B., and Bonner, T. H. (2015). Occurrence and amount of microplastic ingested by fishes in watersheds of the Gulf of Mexico. *Marine Pollution Bulletin*, *100*(1), 264–269.

Piringer, O. G., & Baner, A. L. (2008). Plastic packaging materials for food: barrier function, mass transport, quality assurance, and legislation. *John Wiley & Sons.*

Pivokonsky, M., Cermakova, L., Novotna, K., Peer, P., Cajthaml, T., and Janda, V. (2018). Occurrence of microplastics in raw and treated drinking water. *Science of the Total Environment*, *643*, 1644–1651.

Plastics. (2016). *Worldwide plastics industry: ASEAN countries rediscover their strengths.* Retrieved from https://www.plastics.gl/exhibit/worldwide-plastics-industry-asean-countries-rediscover-their-strengths/

Prata, J. C. (2018). Airborne microplastics: Consequences to human health? *Environmental Pollution*, *234*, 115–126.

Prata, J. C., da Costa, J. P., Duarte, A. C., and Rocha-Santos, T. (2019). Methods for sampling and detection of microplastics in water and sediment: A critical review. *TrAC - Trends in Analytical Chemistry*, *110*, 150–159.

Prata, J. C., da Costa, J. P., Lopes, I., Duarte, A. C., and Rocha-Santos, T. (2020). Environmental exposure to microplastics: An overview on possible human health effects. *Science of the Total Environment*, *702*, 134455. R

Provencher, J. F., Gaston, A. J., Mallory, M. L., O'hara, P. D., and Gilchrist, H. G. (2010). Ingested plastic in a diving seabird, the thick-billed murre (Uria lomvia), in the eastern Canadian Arctic. *Marine Pollution Bulletin*, *60*(9), 1406–1411.

Puka, L. (2011). Kendall's Tau. In M. Lovric (Ed.), *International Encyclopedia of Statistical Science* (pp. 713–715).

Qin, Y., Wang, Z., Li, W., Chang, X., Yang, J., and Yang, F. (2019). Microplastics in the sediment of Lake Ulansuhai of Yellow River Basin, China. *Water Environment Research*.

Qu, S., Guo, Y., Ma, Z., Chen, W. Q., Liu, J., Liu, G., Wang, Y., and Xu, M. (2019). Implications of China's foreign waste ban on the global circular economy. *Resources, Conservation and Recycling*, *144*, 252–255.

Ravindran, S. (2018, September 25). Fishing out rubbish from city's rivers a costly task. *The Star*. Retrieved from https://www.thestar.com.my/metro/metro-news/2018/09/25/fishing-out-rubbish-from-citys-rivers-a-costly-task/#B2litrkZ76DuBCoC.99

Reddy, M. M., Deighton, M., Gupta, R. K., Bhattacharya, S. N., and Parthasarathy, R. (2009). Biodegradation of oxo-biodegradable polyethylene. *Journal of Applied Polymer Science*, *111*(3), 1426–1432.

Revel, M., Châtel, A., and Mouneyrac, C. (2018). Micro(nano)plastics: A threat to human health? *Current Opinion in Environmental Science and Health*, *1*, 17–23.

Rillig, M. C. (2012). Microplastic in terrestrial ecosystems and the soil? *Environmental Science and Technology*, *46*(12), 6453–6454.

Roch, S., and Brinker, A. (2017). Rapid and Efficient Method for the Detection of Microplastic in the Gastrointestinal Tract of Fishes. *Environmental Science and Technology*, *51*(8), 4522–4530.

Roch, S., Walter, T., Ittner, L. D., Friedrich, C., and Brinker, A. (2019). A systematic study of the microplastic burden in freshwater fishes of south-western Germany - Are we searching at the right scale? *Science of the Total Environment*, *689*, 1001–1011.

Rochman, C.M., Kross, S.M., Armstrong, J.B., Bogan, M.T., Darling, E. S., Green, S.J., Smyth, A.R. Veríssimo, D. (2015). Scientific Evidence Supports a Ban on Microbeads. *Environmental Science & Technology*, 10759–11076.

Rochman, C. M., Hoh, E., Hentschel, B. T., and Kaye, S. (2013). Long-term field measurement of sorption of organic contaminants to five types of plastic pellets: implications for plastic marine debris. *Environmental Science & Technology*, *47*(3), 1646-1654.

Rochman, C. M., Hoh, E., Kurobe, T., and Teh, S. J. (2013). Ingested plastic transfers hazardous chemicals to fish and induces hepatic stress. *Scientific Reports*, *3*, 3263.

Rodrigues, M. O., Abrantes, N., Gonçalves, F. J. M., Nogueira, H., Marques, J. C., and Gonçalves, A. M. M. (2018). Spatial and temporal distribution of microplastics in water and sediments of a freshwater system (Antuã River, Portugal). *Science of the Total Environment*, *633*, 1549–1559.

Ronca, S. (2017). *Polyethylene. In Brydson's Plastics Materials (Eighth Edition)*.

Rounds, S. A. (2002). Development of a neural network model for dissolved oxygen in the Tualatin River, Oregon. *In Proceedings of the Second Federal Interagency Hydrologic Modeling Conference, Las Vegas, Nevada.*

Rummel, C. D., Löder, M. G. J., Fricke, N. F., Lang, T., Griebeler, E. M., Janke, M., and Gerdts, G. (2016). Plastic ingestion by pelagic and demersal fish from the North Sea and Baltic Sea. *Marine Pollution Bulletin*, *102*(1), 134–141.

Sabeen, A. H., Ngadi, N., and Noor, Z. Z. (2016). Minimizing the cost of municipal solid waste management in Pasir Gudang Johor Malaysia. *Journal of Materials and Environmental Science*, *7*(5), 1819–1834.

Sadri, S. S., and Thompson, R. C. (2014). On the quantity and composition of floating plastic debris entering and leaving the Tamar Estuary, Southwest England. *Marine Pollution Bulletin*, *81*(1), 55–60.

Salkind, N. (2000). *Statistics for people who think they hate statistics.* Thousand Oaks, Calif: Sage Publications, Inc.

Sanchez, W., Bender, C., and Porcher, J. M. (2014). Wild gudgeons (Gobio gobio) from French rivers are contaminated by microplastics: Preliminary study and first evidence. *Environmental Research*, *128*, 98–100.

Savoca, M. S., Tyson, C. W., McGill, M., and Slager, C. J. (2017). Odours from marine plastic debris induce food search behaviours in a forage fish. *Proceedings of the Royal Society B: Biological Sciences*, *284*(1860), 1–2.

Schell, T., Rico, A., and Vighi, M. (2020). Occurrence, fate and fluxes of plastics and microplastics in terrestrial and freshwater ecosystems. In *Reviews of Environmental Contamination and Toxicology (Continuation of Residue Reviews)*. (pp. 1–43).

Scherer, C., Weber, A., Lambert, S., and Wagner, M. (2018). Interactions of microplastics with freshwater biota. In *In Freshwater Microplastics* (pp. 153–180). Springer, Cham.

Schirinzi, G. F., Pérez-Pomeda, I., Sanchís, J., Rossini, C., Farré, M., and Barceló, D. (2017). Cytotoxic effects of commonly used nanomaterials and microplastics on cerebral and epithelial human cells. *Environmental Research*, *159*(June), 579–587.

Shah, A. A., Hasan, F., Hameed, A., and Ahmed, S. (2008). Biological degradation of plastics: A comprehensive review. *Biotechnology Advances*, *26*(3), 246–265.

Shah, F. (2012, December 16). Major clean-up of rivers. *The Star*. Retrieved from https://www.pressreader.com/malaysia/the-star-malaysia/20121216/281908770463275

Shannon, C. E., and Weaver, W. (1949). *A Mathematical Model of Communication*.

Sharma, S., and Chatterjee, S. (2017). Microplastic pollution, a threat to marine ecosystem and human health: a short review. *Environmental Science and Pollution Research*, *24*(27), 21530-21547.

Sharma, V. P., Singh, R. L., and Singh, R. P. (2017). *Degradable Polymers and Plastics of the Future: Steps Toward Environmental Sustainability, Regulations, and Safety Aspects. In Principles and Applications of Environmental Biotechnology for a Sustainable Future*.

Shen, L., and Worrell, E. (2014). Plastic Recycling. In *Handbook of Recycling: State-of-the-art for Practitioners, Analysts, and Scientists*.

Shim, W. J., Sang, H. H., and Eo, S. (2018). Marine Microplastics: Abundance, Distribution, and Composition. In *Microplastic Contamination in Aquatic Environments An Emerging Matter of Environmental Urgency* (pp. 1–26).

Shruti, V. C., Jonathan, M. P., Rodriguez-Espinosa, P. F., and Rodríguez-González, F. (2019). Microplastics in freshwater sediments of Atoyac River basin, Puebla City, Mexico. *Science of the Total Environment*, *654*, 154–163.

Silva-Cavalcanti, J. S., Silva, J. D. B., França, E. J. de, Araújo, M. C. B. de, and Gusmão, F. (2017). Microplastics ingestion by a common tropical freshwater fishing resource. *Environmental Pollution*, *221*, 218–226.

Singh, A. K., Ansari, A., Srivastava, S. C., and Shrivastava, V. K. (2014). An Appraisal of Introduced African Catfish Clarias gariepinus (Burchell 1822) in India: Invasion and Risks. *Annual Research & Review in Biology*, *6*(1), 41–58.

Singh, N., Hui, D., Singh, R., Ahuja, I. P. S., Feo, L., and Fraternali, F. (2017). Recycling of plastic solid waste: A state of art review and future applications. *Composites Part B: Engineering*, *115*, 409–422.

Siracusa, V., Rocculi, P., Romani, S., and Rosa, M. D. (2008). Biodegradable polymers for food packaging: a review. *Trends in Food Science and Technology*, *19*(12), 634–643.

Slaughter, E., Gersberg, R. M., Watanabe, K., Rudolph, J., Stransky, C., and Novotny, T. E. (2011). Toxicity of cigarette butts, and their chemical components, to marine and freshwater fish. *Tobacco Control*, *20*(1 SUPPL), 25–29.

Slootmaekers, B., Catarci Carteny, C., Belpaire, C., Saverwyns, S., Fremout, W., Blust, R., and Bervoets, L. (2019). Microplastic contamination in gudgeons

(Gobio gobio) from Flemish rivers (Belgium). *Environmental Pollution*, *244*(2019), 675–684.

Spalding, M. A., and Chatterjee, A. (2017). *Handbook of Industrial Polyethylene and Technology: Definitive Guide to Manufacturing, Properties, Processing, Applications and Markets Set.*

Sruthy, S., and Ramasamy, E. V. (2017). Microplastic pollution in Vembanad Lake, Kerala, India: The first report of microplastics in lake and estuarine sediments in India. *Environmental Pollution*, *222*, 315–322.

Stihi, C., Popescu, I. V, Bancuta, A., Stihi, V., and VLAICU, G. (2005). Inductively coupled plasma (icp) and total dissolved solids (tds) measurements of surface waters from ialomiþa river. *Romanian Journal of Physics*, *50*(9–10), 977–981.

Strand, J., Lassen, P., Shashoua, Y., and Andersen, J. H. (2013). Microplastic particles in sediments from Danish waters. *In ICES Annual Science Conference (ASC).*

Su, L., Nan, B., Hassell, K. L., Craig, N. J., and Pettigrove, V. (2019). Microplastics biomonitoring in Australian urban wetlands using a common noxious fish (Gambusia holbrooki). *Chemosphere*, 65–74. R

Su, L., Xue, Y., Li, L., Yang, D., Kolandhasamy, P., Li, D., and Shi, H. (2016). Microplastics in Taihu Lake, China. *Environmental Pollution*, *216*(July 2016), 711–719.

Sudhan, C., and Moulitharan, N. (2017). Short Communication on Record of Clarias gariepinus (Burchell, 1822) and its Impact on Biodiversity of Seasonal Swamp at Thoothukudi, Tamil Nadu. *National Journal of Advanced Research*, *3*(1), 10–16.

Sullivan, L. M. (2008). Power and sample size determination. In *Essentials of Biostatistics Workbook: Statistical Computing Using Excel*. Jones & Bartlett Learning.

Sun, J., Dai, X., Wang, Q., van Loosdrecht, M. C. M., and Ni, B. J. (2019). Microplastics in wastewater treatment plants: Detection, occurrence and removal. *Water Research*, *152*, 21–37.

Tagg, A. S., Sapp, M., Harrison, J. P., and Ojeda, J. J. (2015). Identification and quantification of microplastics in wastewater using focal plane array-based reflectance micro-FT-IR imaging. *Analytical Chemistry*, *87*(12), 6032–6040.

Tan, C. K. (2017). Lotte to list Malaysian unit for expansion drive. *Nikkei Asian Review*. Retrieved from https://asia.nikkei.com/Economy/Lotte-to-list-Malaysian-unit-for-expansion-drive

Tanaka, K., and Takada, H. (2016). Microplastic fragments and microbeads in digestive tracts of planktivorous fish from urban coastal waters. *Scientific Reports*, *6*, 1–8.

Tangang, F. T., Juneng, L., Salimun, E., Sei, K. M., Le, L. J., and Muhamad, H. (2012). Climate change and variability over Malaysia: gaps in science and research information. *Sains Malaysiana*, *41*(11), 1355–1366.

Thiele, C. J., Hudson, M. D., and Russell, A. E. (2019). Evaluation of existing methods to extract microplastics from bivalve tissue: Adapted KOH digestion protocol improves filtration at single-digit pore size. *Marine Pollution Bulletin*, *142*, 384–393.

Thompson, R. C., Olsen, Y., Mitchell, R. P., Davis, A., Rowland, S. J., John, A. W., McGonigle, D., and Russell, A. E. (2004). Lost at sea: where is all the plastic? *Science*, *304*(5672), 838.

Tibbetts, J., Krause, S., Lynch, I., and Smith, G. H. S. (2018). Abundance, distribution, and drivers of microplastic contamination in urban river environments. *Water (Switzerland)*, *10*(11).

Toumi, H., Abidli, S., and Bejaoui, M. (2019). Microplastics in freshwater environment: the first evaluation in sediments from seven water streams surrounding the lagoon of Bizerte (Northern Tunisia). *Environmental Science and Pollution Research*, *26*(14), 14673–14682.

Tuttle, M. E. (2012). *Structural analysis of polymeric composite materials.* Crc Press.

Ul Hassan, H., M. Ali, Q., Rahman, M., Kamal, M., Tanjin, S., Farooq, U., Mawa, Z., Badshah, N., Mahmood, K., Hasan, M., Gabool, K., A. Rima, F., Islam, M., Rahman, O., and Hossain, M. (2020). Growth pattern, condition and prey-predator status of 9 fish species from the Arabian Sea (Baluchistan and Sindh), Pakistan. *Egyptian Journal of Aquatic Biology and Fisheries*, *24*(4), 281–292.

Van Cauwenberghe, L., Devriese, L., Galgani, F., Robbens, J., and Janssen, C. R. (2015). Microplastics in sediments: A review of techniques, occurrence and effects. *Marine Environmental Research*, *111*, 5–17.

Van Cauwenberghe, L., and Janssen, C. R. (2014). Microplastics in bivalves cultured for human consumption. *Environmental Pollution*, *193*, 65–70.

van Wezel, A., Caris, I., and Kools, S. A. E. (2016). Release of primary microplastics from consumer products to wastewater in the Netherlands. *Environmental Toxicology and Chemistry*, *35*(7), 1627–1631.

Vassilopoulou, V. (2006). Dietary habits of the deep-sea flatfish Lepidorhombus boscii in north-eastern Mediterranean waters. *Journal of Fish Biology*, *69*(4), 1202–1220.

Vaughan, R., Turner, S. D., and Rose, N. L. (2017). Microplastics in the sediments of a UK urban lake. *Environmental Pollution*, *229*, 10–18.

Velzeboer, I., Kwadijk, C. J. A. F., and Koelmans, A. A. (2014). Strong sorption of PCBs to nanoplastics, microplastics, carbon nanotubes, and fullerenes. *Environmental Science & Technology*, *48*(9), 4869-4876.

Vendel, A. L., Bessa, F., Alves, V. E., Amorim, A. L., Patrício, J., and Palma, A.R. (2017). Widespread microplastic ingestion by fish assemblages in tropical estuaries subjected to anthropogenic pressures. *Marine Pollution Bulletin*, *117*(1–2), 448–455.

Vermaire, J. C., Pomeroy, C., Herczegh, S. M., Haggart, O., and Murphy, M. (2017). Microplastic abundance and distribution in the open water and sediment of the Ottawa River, Canada, and its tributaries. *FACETS*, *2*(1), 301–314.

Wagner, M., Scherer, C., Alvarez-Muñoz, D., Brennholt, N., Bourrain, X., Buchinger, S., Fries, E., Grosbois, C., Klasmeier, J., Marti, T., and Rodriguez-Mozaz, S. (2014). Microplastics in freshwater ecosystems: what we know and what we need to know. *Environmental Sciences Europe*, *26*(1), 1–9.

Walker, T. R. (2018). China's ban could curb plastic waste. *Nature*, *553*(7689), 404-404.

Wang, J., Peng, J., Tan, Z., Gao, Y., Zhan, Z., Chen, Q., and Cai, L. (2017a). Microplastics in the surface sediments from the Beijiang River littoral zone: Composition, abundance, surface textures and interaction with heavy metals. *Chemosphere*, *171*, 248–258.

Wang, L., Zhang, J., Hou, S., and Sun, H. (2017b). A simple method for quantifying polycarbonate and polyethylene terephthalate microplastics in environmental samples by liquid chromatography–tandem mass spectrometry. *Environmental Science & Technology Letters*, *4*(12), 530–534.

Weber-Scannell, P. K., and Duffy, L. K. (2007). Effects of total dissolved solids on aquatic organism: a review of literature and recommendation for salmonid species. *American Journal of Environmental Sciences*, *3*(1), 1–6.

Wen, X., Du, C., Xu, P., Zeng, G., Huang, D., Yin, L., Yin, Q., Hu, L., Wan, J., Zhang, J., Tan, S., and Deng, R. (2018). Microplastic pollution in surface sediments of urban water areas in Changsha, China: Abundance, composition, surface textures. *Marine Pollution Bulletin*, *136*(September), 414–423.

Whitt, M., Brown, W., Danes, J. E., and Vorst, K. L. (2016). Migration of heavy metals from recycled polyethylene terephthalate during storage and microwave heating. *Journal of Plastic Film & Sheeting*, *32*(2), 189–207.

Wong, S. L., Ngadi, N., Abdullah, T. A. T., and Inuwa, I. M. (2015). Current state and future prospects of plastic waste as source of fuel: A review. *Renewable and Sustainable Energy Reviews*, *50*, 1167–1180.

Woodall, L. C., Sanchez-Vidal, A., Canals, M., Paterson, G. L., Coppock, R., Sleight, V., Calafat, A., Rogers, A. D., Narayanaswamy, B. E., and Thompson, R. C. (2014). The deep sea is a major sink for microplastic debris. *Royal Society Open Science*, *1*(4), 40317.

Wright, S. L., Thompson, R. C., and Galloway, T. S. (2013). The physical impacts of microplastics on marine organisms : A review. *Environmental Pollution*, *178*, 483–492.

Wu, C., Zhang, K., and Xiong, X. (2018). Microplastic pollution in inland waters focusing on Asia. In *Freshwater Microplastics Emerging Environmental Contaminants?*

Wu, P., Huang, J., Zheng, Y., Yang, Y., Zhang, Y., He, F., Chen, H., Quan, G., Yan, J., Li, T., and Gao, B. (2019). Environmental occurrences, fate, and impacts of microplastics. *Ecotoxicology and Environmental Safety*, *184*(April), 109612.

Xiong, X., Tu, Y., Chen, X., Jiang, X., Shi, H., Wu, C., and Elser, J. J. (2019). Ingestion and egestion of polyethylene microplastics by goldfish (Carassius auratus): influence of color and morphological features. *Heliyon*, *5*(12), e03063.

Xiong, X., Zhang, K., Chen, X., Shi, H., Luo, Z., and Wu, C. (2018). Sources and distribution of microplastics in China's largest inland lake – Qinghai Lake. *Environmental Pollution*, *235*, 899–906.

Xue, Y., Peijnenburg, W. J., Huang, J., Wang, D., and Jin, Y. (2018). Trophic transfer of Cd from duckweed (Lemna minor L.) to tilapia (Oreochromis mossambicus). *Environmental Toxicology and Chemistry*, *37*(5), 1367–1377.

Yalçin, Ş., Akyurt, I., and Solak, K. (2001). Stomach contents of the catfish (Clarias gariepinus Burchell, 1822) in the River Asi (Turkey). *Turkish Journal of Zoology*, *25*(4), 461–468.

Yan, M., Nie, H., Xu, K., He, Y., Hu, Y., Huang, Y., and Wang, J. (2019). Microplastic abundance, distribution and composition in the Pearl River along Guangzhou city and Pearl River estuary, China. *Chemosphere*, *217*, 879–886.

Yang, Y., Rodriguez-jorquera, I. A., Mcguire, M., and Toor, G. S. (2015). *Contaminants in the Urban Environment: Microplastics. UF/IFAS Extension.*

Yin, L., Wen, X., Du, C., Jiang, J., Wu, L., Zhang, Y., Hu, Z., Hu, S., Feng, Z., Zhou, Z., Long, Y., and Gu, Q. (2020). Comparison of the abundance of microplastics between rural and urban areas: A case study from East Dongting Lake. *Chemosphere*, *244*.

Yonkos, L. T., Friedel, E., Perez-Reyes, A. C., Ghosal, S., and Arthur, C. D. (2014). Microplastics in Four Estuarine Rivers in the Chesapeake Bay, USA. *Environ. Sci. Technol.*, *48*(July), 14195–14202.

Yuan, W., Liu, X., Wang, W., Di, M., and Wang, J. (2019). Microplastic abundance, distribution and composition in water, sediments, and wild fish from Poyang Lake, China. *Ecotoxicology and Environmental Safety*, *170*, 180–187.

Zainudin, Z., Abd Rahman, N., Abdullah, N., and Mazlan, N. F. (2010). Development of water quality model for Sg. Tebrau using QUAL2K. *Journal of Applied Sciences*, *10*(21), 2748–2750.

Zakariah, M., Yahaya, A., Sonfada, M. L., and I., W. (2016). Male organs of African catfish (Clarias gariepinus) in spawning and non-spawning periods in Maiduguri, Borno State, Nigeria. *Sokoto Journal of Veterinary Sciences*, *14*(1), 34–38.

Zeileis, A., Kleiber, C., and Jackman, S. (2008). Regression models for count data in R. *Journal of Statistical Software*, *27*(8), 1–25.

Zhang, F., Wang, X., Xu, J., Zhu, L., Peng, G., Xu, P., and Li, D. (2019). Food-web transfer of microplastics between wild caught fish and crustaceans in East China Sea. *Marine Pollution Bulletin*, *146*, 173–182.

Zhao, S., Zhu, L., and Li, D. (2015). Microplastic in three urban estuaries, China. *Environmental Pollution*, *206*, 597–604.

Zheng, Y., Yanful, E. K., and Bassi, A. S. (2005). A review of plastic waste biodegradation. *Critical Reviews in Biotechnology*, *25*(4), 243–250.

Zimmerman, D. W., and Zumbo, B. D. (1993). Relative power of the Wilcoxon test, the Friedman test, and repeated-measures ANOVA on ranks. *The Journal of Experimental Education*, *62*(1), 75–86.

Zou, G. (2004). A modified Poisson regression approach to prospective studies with binary data. *Journal of Epidemiology*, *159*(7), 702–706.

LIST OF PUBLICATIONS

Indexed Journal

1. **Sarijan, S**., Azman, S., Said, M. I. M., and Jamal, M. H. (2020). Microplastics in Freshwater Ecosystems: A recent review of occurrence, analysis, potential impacts, and research needs. Environmental Science and Pollution Research DOI: 10.1007/s11356-020-11171-7.

2. **Sarijan, S**., Azman, S., Said, M. I. M., and Lee, M. H. (2019). Ingestion of Microplastics by Commercial Fish in Skudai River, Malaysia. EnvironmentAsia, 12(3), 75-84.

3. **Sarijan, S**., Azman, S., Lee, M.H. and Said, M. I. M. (2020). Poisson Regression Model to Determine Factors of Microplastic Ingestion by African catfish. Manuscript has been selected for publication in the Malaysian Journal of Mathematical Sciences (MJMS).

Indexed Conference Proceedings

1. **Sarijan, S**., Azman, S., Said, M. I. M., Andu, Y., and Zon, N. F. (2018). Microplastics in sediment from Skudai and Tebrau River, Malaysia: a preliminary study. In MATEC Web of Conferences (Vol. 250, p. 06012). EDP Sciences.

Non-Indexed Conference Proceedings

1. **Sarijan, S**., Azman, S., Said, M. I. M. and Lee, M.H. 2020. Occurrence of Microplastics in Freshwater Sediments. Manuscript will be submitted in the International Graduate Conference on Engineering, Science and Humanity 2020. Universiti Teknologi Malaysia on 17th – 19th August 2020.

2. **Sarijan, S**., Azman, S., Said, M. I. M. and Lee, M.H. 2019. Microplastics Ingestion by River Fish. Graduate Research Expo 2019. Universiti Teknologi Malaysia on 21st March 2019.

3. **Shazani,** S., Shamila, A., and Said, M. I. M. 2018. Microplastics Pollution in Skudai and Tebrau River, Malaysia. 2018. International Graduate Conference on Engineering, Science and Humanity 2018. Universiti Teknologi Malaysia on 13th – 15th August 2018.