2020 Y4 RA Biology

Organisms and Their Environment: An Inquiry into Microplastics From Tyres

Task 1:

Read the articles “Plastic From Tyres” and “Plastics In the Ocean”.

Make your own notes of the key points with the macroconcepts—Interactions and Systems, as a guide.

Plastic from tyres 'major source' of ocean pollution

Microplastics bigger source of marine pollution compared to larger plastics

↓

30% of plastic released is primary microplastics
(mainly from tyres and synthetic fabrics/textiles)

↓

use 60% synthetic rubber

2% from microplastic beads in personal care products

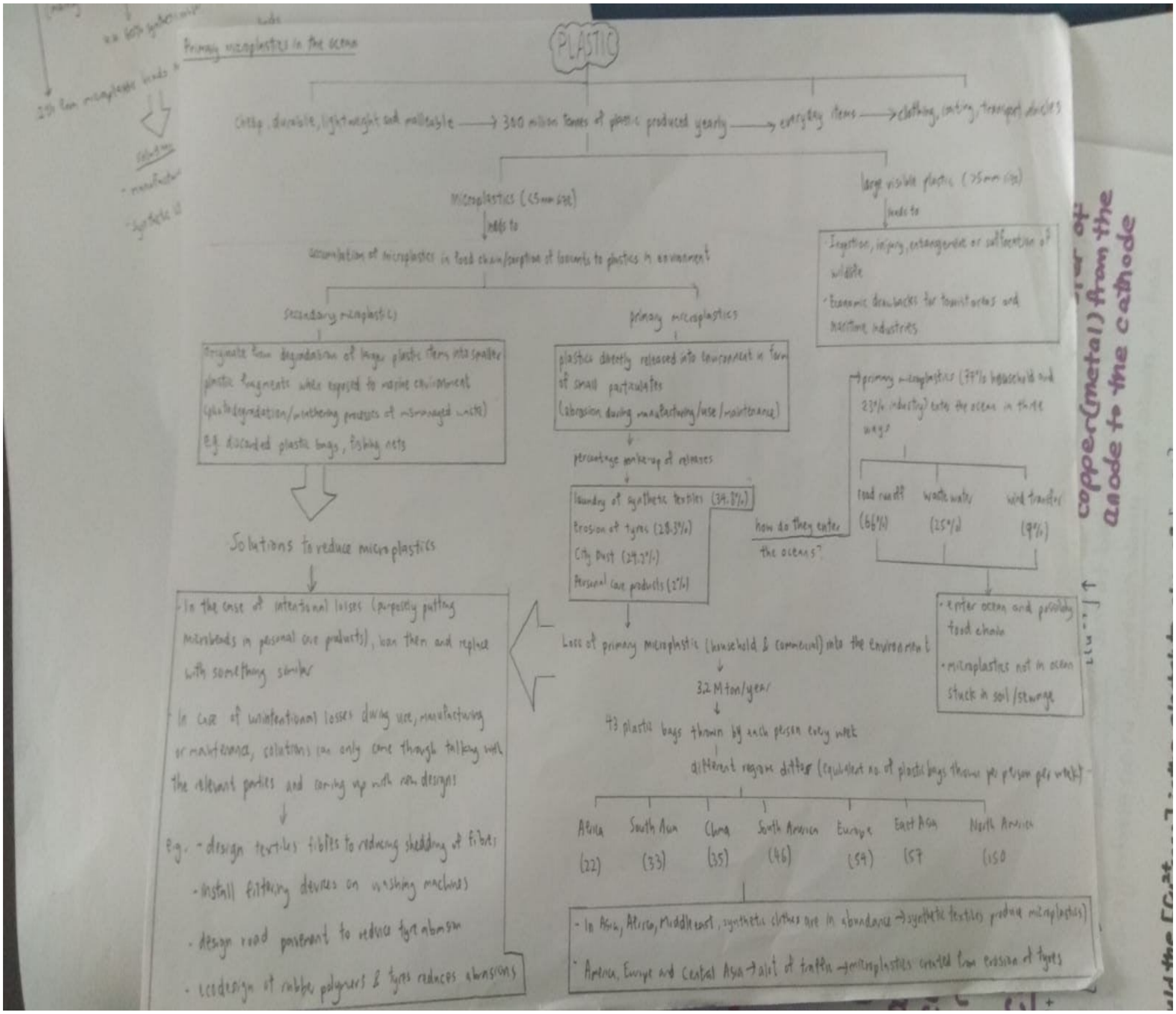
Impacts → leads to plastics in the food chain

↓

endangering human health

Solutions

- manufacturers removing microbeads in personal care products
- Synthetic clothes design to shed less fibres



Primary microplastics in the ocean
PLASTIC
Cheap, durable, lightweight and malleable → 300 million tonnes of plastic produced yearly → everyday items → clothing, coating, transport vehicles
microplastics (<5mm size)
leads to
accumulation of microplastics in food chain/sorption of toxicants to plastics in environment
large visible plastic (>5mm size)
leads to
· Ingestion, injury, entanglement or suffocation of wildlife
· Economic drawbacks for tourist areas and maritime industries
secondary microplastics
Originate from degradation of larger plastic items into smaller plastic fragments when exposed to marine environment (photodegradation/weathering process of mismanaged waste)
E.g. discarded plastic bags, fishing nets
primary microplastics
plastics directly released into environment in form of small particulates
(abrasion during manufacturing/use/maintenance)
percentage make-up of releases
laundry of synthetic textiles (34.8%)
Erosion of tyres (28.3%)
City Dust (24.2%)
Personal care products (2%)
how do they enter the oceans?
primary microplastics (77% household and 23% industry) enter the ocean in three ways
road runoff (66%)
waste water (25%)
wind transfer (9%)
· enter ocean and possibly food chain
· microplastics not in ocean stuck in soil/sewage
Solutions to reduce microplastics
- In the case of intentional losses (purposely putting microbeads in personal care products), ban them and replace with something similar
- In case of unintentional losses during use, manufacturing or maintenance, solutions can only come through talking with the relevant parties and coming up with new designs
E.g. - design textiles fibres to reducing shedding of fibres
- install filtering devices on washing machines
- design road pavement to reduce tyre abrasion
- ecodesign of rubber polymers & tyres reduces abrasions
Loss of primary microplastic (household & commercial) into the environment
3.2 M ton/year
43 plastic bags thrown by each person every week
different regions differ (equivalent no. of plastic bags thrown per person per week)
Africa (22)
South Asia (33)
China (35)
South America (46)
Europe (54)
East Asia (57
North America (150
- In Asia, Africa, Middle east, synthetic clothes are in abundance → synthetic textiles produce microplastics)
· America, Europe and Central Asia → a lot of traffic → microplastics created from erosion of tyres

Task 2

Scientific Investigation:

Compare the amount of microplastics from car tyres with the amount from shoe wear.

a) What are some questions you have about the inquiry question? What are your answers to those questions?

eesent 33% of all fibers in indoor environments.

Questions	Answers
What are microplastics?	Microplastics are very small pieces of plastic that pollute the environment. Microplastics are any type of plastic fragment that is less than 5 mm in length according to the U.S. National Oceanic and Atmospheric Administration (NOAA). They enter natural ecosystems from a variety of sources, including cosmetics, clothing, and industrial processes. Two classifications of microplastics currently exist. Primary microplastics are any plastic fragments or particles that are already 5.0 mm in size or less before entering the environment. These include microfibers from clothing, microbeads, and plastic pellets (also known as nurdles). Secondary microplastics are microplastics that are created from the degradation of larger plastic products once they enter the environment through natural weathering processes. Such sources of secondary microplastics include water and soda bottles, fishing nets, and plastic bags. Both types are recognized to persist in the environment at high levels,

	particularly in aquatic and marine ecosystems.
What are some sources of microplastics?	Sewage treatment plants Sewage treatment plants, also known as wastewater treatment plants (WWTPs), remove contaminants from wastewater, primarily from household sewage, using various physical, chemical, and biological processes. Most plants in developed countries have both primary and secondary treatment stages. In the primary stage of treatment, physical processes are employed to remove oils, sand, and other large solids using conventional filters, clarifiers, and settling tanks. Secondary treatment uses biological processes involving bacteria and protozoa to break down organic matter. Common secondary technologies are activated sludge systems, trickling filters, and constructed wetlands. The optional tertiary treatment stage may include processes for nutrient removal (nitrogen and phosphorus) and disinfection. Microplastics have been detected in both the primary and secondary treatment stages

	of the plants. A groundbreaking 1998 study suggested that microplastic fibers would be a persistent indicator of sewage sludges and wastewater treatment plant outfalls. A study estimated that about one particle per liter of microplastics are being released back into the environment, with a removal efficiency of about 99.9%. A 2016 study showed that most microplastics are actually removed during the primary treatment stage where solid skimming and sludge settling are used. When these treatment facilities are functioning properly, the contribution of microplastics into oceans and surface water environments from WWTPs is not disproportionately large. However, it is important to note that in certain countries sewage sludge is used for soil fertilizer, which exposes plastics in the sludge to the weather, sunlight, and other biological factors, causing fragmentation. As a result, microplastics from these biosolids often end up in storm drains and eventually into bodies of water. In addition, some studies show that microplastics do pass through filtration processes at some WWTPs (Microplastics as Contaminants,

	2011). According to a study from the UK, samples taken from sewage sludge disposal sites on the coasts of six continents contained an average one particle of microplastic per liter. A significant amount of these particles was of clothing fibers from washing machine effluent. Car and truck tires Wear and tear from tires significantly contributes to the flow of (micro-)plastics into the environment. Estimates of emissions of microplastics to the environment in Denmark are between 5,500 and 14,000 tonnes (6,100 and 15,400 tons) per year. Secondary microplastics (e.g. from car and truck tires or footwear) are more important than primary microplastics by two orders of magnitude. The formation of microplastics from the degradation of larger plastics in the environment is not accounted for in the study. The estimated per capita emission ranges from 0.23 to 4.7 kg/year, with a global

	average of 0.81 kg/year. The emissions from car tires (100%) are substantially higher than those of other sources of microplastics, e.g., airplane tires (2%), artificial turf (12–50%), brake wear (8%), and road markings (5%). Emissions and pathways depend on local factors like road type or sewage systems. The relative contribution of tire wear and tear to the total global amount of plastics ending up in our oceans is estimated to be 5–10%. In air, 3–7% of the particulate matter (PM2.5) is estimated to consist of tire wear and tear, indicating that it may contribute to the global health burden of air pollution which has been projected by the World Health Organization (WHO) at 3 million deaths in 2012. The wear and tear also enter our food chain, but further research is needed to assess human health risks. Cosmetics industry Some companies have replaced natural exfoliating ingredients with microplastics, usually in the form of "microbeads" or "micro-exfoliates". These products are typically composed of polyethylene, a

	common component of plastics, but they can also be manufactured from polypropylene, polyethylene terephthalate, and nylon. They are often found in face washes, hand soaps, and other personal care products; the beads are usually washed into the sewage system immediately after use. Their small size prevents them from fully being retained by preliminary treatment screens at wastewater plants, thereby allowing some to enter rivers and oceans. In fact, wastewater treatment plants only remove an average of 95–99.9% of microbeads because of their small design . This leaves an average of 0-7 microbeads per litre being discharged. Considering that one treatment plant discharges 160 trillion liters of water per day, around 8 trillion microbeads are released into waterways every day. This number doesn't account for the sewage sludge that is reused as fertilizer after the wastewater treatment that has been known to still contain these microbeads. This is an issue at the household level because it has been estimated that around 808 trillion beads per household are

	discharged in a single day whether due to cosmetic exfoliates, face wash, toothpaste, or other sources. Although many companies have committed to phasing out the use of microbeads in their products, according to research, there are at least 80 different facial scrub products that are still being sold with microbeads as a main component. This contributes to the 80 metric tons of microbead discharge per year by the United Kingdom alone, which not only has a negative impact upon the wildlife and food chain, but also upon levels of toxicity, as microbeads have been proven to absorb dangerous chemicals such as pesticides and polycyclic aromatic hydrocarbons. Clothing Studies have shown that many synthetic fibers, such as polyester, nylon, acrylics, and spandex, can be shed from clothing and persist in the environment. Each garment in a load of laundry can shed more than 1,900 fibers of microplastics, with fleeces releasing the highest percentage of fibers, over 170% more than other

	garments. For an average wash load of 6 kg, over 700,000 fibres could be released per wash. Washing machine manufacturers have also reviewed research into whether washing machine filters can reduce the amount of microfiber fibers that need to be treated by water treatment facilities. These microfibers have been found to persist throughout the food chain from zooplankton to larger animals such as whales. The primary fiber that persists throughout the textile industry is polyester which is a cheap cotton alternative that can be easily manufactured. However, these types of fibers contribute greatly to the persistence to microplastics in terrestrial, aerial, and marine ecosystems. The process of washing clothes causes garments to lose an average of over 100 fibers per liter of water. This has been linked with health effects possibly caused by the release of monomers, dispersive dyes, mordants, and plasticisers from manufacturing. The occurrence of these types of fibers in

	households has been shown to represent 33% of all fibers in indoor environments. Textile fibers have been studied in both indoor and outdoor environments to determine the average human exposure. The indoor concentration was found to be 1.0–60.0 fibers/m^3, whereas the outdoor concentration was much lower at 0.3-1.5 fibers/m^3. The deposition rate indoors was 1586–11,130 fibers per day/m^3 which accumulates to around 190-670 fibers/mg of dust. The largest concern with these concentrations is that it increases exposure to children and the elderly, which can cause adverse health effects. Manufacturing The manufacture of plastic products uses granules and small resin pellets as their raw material. In the United States, production increased from 2.9 million pellets in 1960 to 21.7 million pellets in 1987. Through accidental spillage during land or sea transport, inappropriate use as packing materials, and direct outflow from

	processing plants, these raw materials can enter aquatic ecosystems. In an assessment of Swedish waters using an 80 µm mesh, KIMO Sweden found typical microplastic concentrations of 150–2,400 microplastics per m3; in a harbor adjacent to a plastic production facility, the concentration was 102,000 per m3. Fishing industry Recreational and commercial fishing, marine vessels, and marine industries are all sources of plastic that can directly enter the marine environment, posing a risk to biota both as macroplastics, and as secondary microplastics following long-term degradation. Marine debris observed on beaches also arises from beaching of materials carried on inshore and ocean currents. Fishing gear is a form of plastic debris with a marine source. Discarded or lost fishing gear, including plastic monofilament line and nylon netting, is typically neutrally buoyant and can, therefore, drift at variable depths within the oceans. Various countries have

	reported that microplastics from the industry and other sources have been accumulating in different types of seafood. In Indonesia, 55% of all fish species had evidence of manufactured debris similar to America which reported 67%. However, the majority of debris in Indonesia was plastic, while in North America the majority was synthetic fibers found in clothing and some types of nets. The implication from the fact that fish are being contaminated with microplastic is that those plastics and their chemicals will bioaccumulate in the food chain. Packaging and shipping Shipping has significantly contributed to marine pollution. Some statistics indicate that in 1970, commercial shipping fleets around the world dumped over 23,000 tons of plastic waste into the marine environment. In 1988, an international agreement (MARPOL 73/78, Annex V) prohibited the dumping of waste from ships into the marine environment. In the United States, the Marine Plastic Pollution

	Research and Control Act of 1987 prohibits discharge of plastics in the sea, including from naval vessels. However, shipping remains a dominant source of plastic pollution, having contributed around 6.5 million tons of plastic in the early 1990s. Research has shown that approximately 10% of the plastic found on the beaches in Hawaii are nurdles. In one incident on July 24, 2012, 150 tonnes of nurdles and other raw plastic material spilled from a shipping vessel off the coast near Hong Kong after a major storm. This waste from the Chinese company Sinopec was reported to have piled up in large quantities on beaches. While this is a large incident of spillage, researchers speculate that smaller accidents also occur and further contribute to marine microplastic pollution. Plastic water bottles In one study, 93% of the bottled water from 11 different brands showed microplastic contamination. Per liter, researchers found an average of 325 microplastic particles. Of the tested brands, Nestlé Pure Life and Gerolsteiner bottles

	contained the most microplastic with 930 and 807 microplastic particles per liter (MPP/L), respectively. San Pellegrino products showed the least quantity of microplastic densities. Compared to water from taps, water from plastic bottles contained twice as much microplastic. Some of the contamination likely comes from the process of bottling and packaging the water.
How do we quantify the amount of microplastics if they are so small?	Due to a lack of professional equipment, for this experiment, transparency will be used to detect the amount of microplastics on the tape
Why do car tyres and shoewear release microplastics?	They release microplastics due to wear and tear. When these materials come into contact with surfaces, there will be friction produced, and the heat from friction cause microplastics to be weared off from the bottom of tyres or shoewear. Overtime, as the shoewear and tyre is subjected to more wear and tear, a lot of microplastics can be released into the atmosphere and washed into our sewage or the sea, damaging the environment.

Do different car tyres and shoe wear release different types/amounts of microplastics?	Different grades of tyre and shoewear release different amounts of microplastics into the atmosphere. For example, sports shoes are often made of ethyl vinyl acetate and polyurethane, and these materials tend to be softer, which results in higher amounts of microplastics being released into the atmosphere from shoes made of these materials due to them being eroded more easily. On the other hand, race car tyres have the highest contribution to microplastics pollution since their tyres are made of polybutadiene, which is, similar to polyurethane, a softer polymer more susceptible to wear and tear which contributes to microplastics pollution.
Do the different parts of shoe wear and tyre have an impact on the amount of microplastics collected?	Generally the parts more susceptible to wear and tear and which also come into contact with the ground more often for example the soles of the shoe, and the outer surface of the tyres (rubber ring) would see a higher percentage of microplastic density.

· How do we obtain microplastic samples from car tyres and shoe wear? · How do we quantify the amount of microplastics if they are so small?	· Use a piece of sticky tape and stick it onto the shoe wear and tyre then remove it to allow some of the microplastics from the tyre and shoewear to be stuck on to the sticky tape which simulates wear and tear of tyre and shoe on roads · Due to a lack of professional equipment, for this experiment, transparency will be used to detect the amount of microplastics on the tape · Generally the parts of the shoewear more susceptible to wear and tear would see a higher percentage of microplastic density

b) Plan the experiment and email it to Mrs Low (meichoo.low@ri.edu.sg) for approval before you begin the experiment. Your plan should have as much details as possible, such as what will you sample, where, when, etc. **(by 22 Nov 2019)**

Experimental Procedure

1. **Obtain a tyre and a piece of flip flop**
2. **Wash the tyre and flip flop with high pressure water jets to remove any dust or dirt which may interfere with the collection of microplastics**
3. **Air dry the 2 samples**
4. **Use a sandpaper to gently sand the sole of the flip flop and the outer layer of the tyre (3 rubs for each collection)**
5. **Cut out 2 sticky tapes of length 5cm by 5cm and stick them onto the base of the flip flop and the tyre**
6. **Wait for 10 seconds and remove the tape from both samples**
7. **In a dark room set-up a torch and light sensor to measure the amount of light passing through each tape**
8. **Record the results in a table**
9. **Repeat the experiment 3 times for more reliable results**

Safety Precautions: The experiment design should take safety into consideration. It should be conducted on stationary cars in the safety of a car park or home garage. Always keep an eye for traffic.

Raffles Institution

Research Education 2019

Final Report

Comparing the amount of microplastics in car tyres and shoe wear

Team Members: Chua Qi Long

Patrick Seow

Jin Xiang Jing

Teacher-Mentor: Mrs Low Mei Choo

Introduction

Problem

Plastic has penetrated almost every aspect of our daily lives, from the clothes we wear to the vehicles we drive, a large quantity of these everyday items contain some semblance of plastic. To meet this incredibly high demand, 300 million tonnes of plastic has to be produced yearly. However, this miracle material does not come without its cons. Plastic waste, being non biodegradable, builds up and collects in the oceans and marine environments all over the world are contaminated with plastics (GESAMP, 2015). These plastics can be categorised into large visible plastics and microplastics (less than 5mm in size). The large plastics can lead to ingestion, injury and entanglement or suffocation of our marine wildlife. Microplastics however pose a greater danger, especially to humans as they accumulate in the food chain and may eventually end up in our food.

Research Objective

Over 30% of plastic released into the oceans each year comes from primary microplastics (plastics directly released into the environment in the form of small particulates. They can be a voluntary addition to products such as scrubbing agents in toiletries and cosmetics (e.g. shower gels). They can also originate from the abrasion of large plastic objects during manufacturing, use or maintenance such as the erosion of tyres when driving or of the abrasion of synthetic textiles during washing). This study will focus on the primary microplastics from car tyres, as the erosion of tyres is a major source of primary microplastics (contributing to 28.3%). In addition, the research will compare the amount of microplastics from tyres with the amount of microplastics from shoewear, potentially determining how much more eco friendly walking is in relation to driving.

Literature Review

Microplastics are small plastic particles less than five millimetres in size consisting of synthetic organic compounds. The wide range of plastic products are made of just six major polymer types: polyethylene terephthalate (PET), polyethylene, polypropylene, polyvinyl chloride, polyamide (nylon), and polystyrene (GESAMP, 2015).

Tire treads consist of styrene butadiene rubber, which is based on styrene, a precursor of polystyrene, in a mix with natural rubber and many other additives (Sundt et al., 2014). The interaction between tire and road surface as well as brake pad and brake disk necessarily yields a frictional connection and thus, a reduction of this abrasion material is not to be expected in the near future (Amato et al., 2012; Grigoratos and Martini, 2015). Since several components of tires and brakes are proven toxic (Wik and Dave, 2006; Marwood et al., 2011; Bejgarn et al., 2015; Malachova et al., 2016), reducing the amounts of this material emitted into the environment is highly desirable.

Besides car tyres, shoewear is also another major source of microplastic pollutants, according to a study done by Denmark's EPA, as erosion of the shoe's soles, similar to the erosion of tyres, results in the production of these primary microplastics, including polyurethane, thermoplastic polyurethane, ethyl vinyl acetate and vinyl chloride.

However little research has gone so far as to compare the amount of microplastics from tyres and shoe wear, and no studies have been conducted in a tropical country such as Singapore, where the higher temperature might result in quicker erosion of tyres and shoewear and overall more microplastics. Hence, this research will strive to accomplish the above.

Methodology

Due to a lack of sophisticated technological equipment over the course of our study, we used sandpaper to mimic the abrasions on car tyres and shoewear. Then we used scotch tape in order to collect the microplastic samples which have been released from the tyres and shoewear. The microplastic samples collected were very small and cannot be counted particle for particle, we used light intensity to determine the amount of light blocked by the microplastic, which would in turn allow us to determine the amount of microplastics which have been released by the tyre and the shoe, eventually leading us to find out which item, shoe or tyre, is a bigger contributor to microplastic pollution. Below is the procedure for our experiment:

1. **Obtain a tyre and a piece of flip flop**
2. **Wash the tyre and flip flop with high pressure water jets to remove any dust or dirt which may interfere with the collection of microplastics**
3. **Air dry the 2 samples**
4. **Use a sandpaper to gently sand the sole of the flip flop and the outer layer of the tyre (3 rubs for each collection)**
5. **Cut out 2 sticky tapes of length 5cm by 5cm and stick them onto the base of the flip flop and the tyre**
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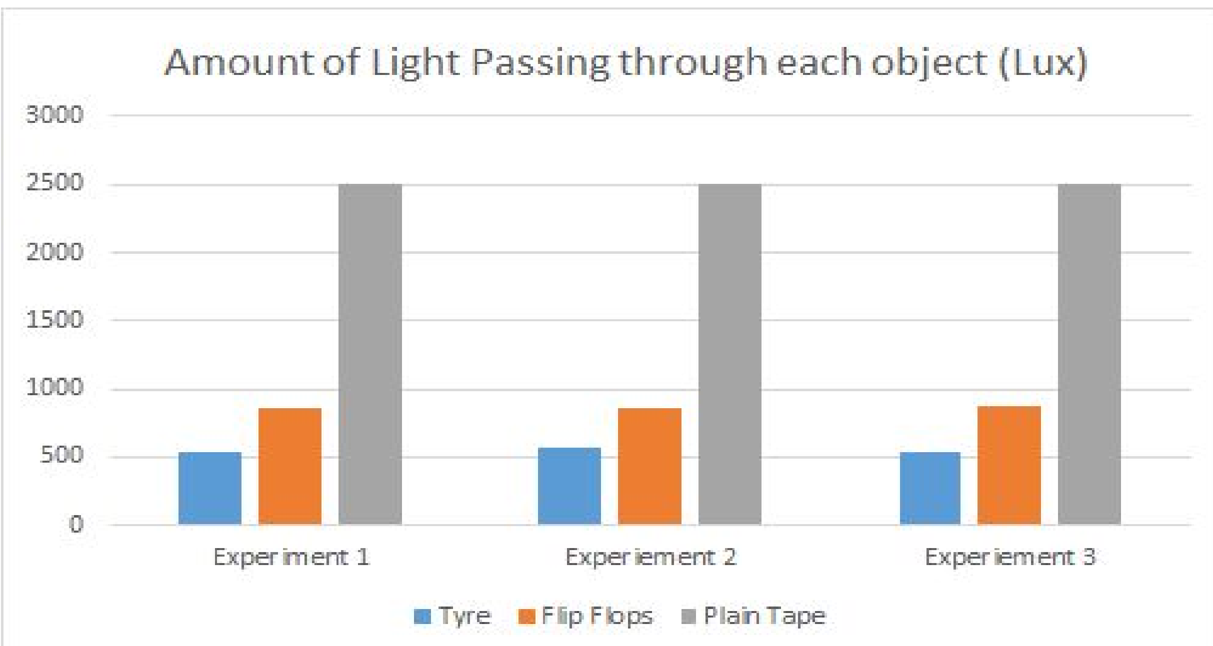
<u>Results</u>

Samples Tested	Amount Of Light Passing Through The Tape (Lux)		
	Experiment 1	Experiment 2	Experiment 3
Tyre	536	568	529
Flip Flops	852	859	873
Plain Tape	2500	2502	2506

Table 1



Graph 1

Analysis

As shown from Table 1, and illustrated in Graph 1, tyres and shoe wear (namely flip flops) both contain microplastics, as they both did not allow as much light to pass through as the control in all three experiments (average 2503 lux). This tallies with our literature review, confirming that the erosion of car tyres and shoe wear results in the production of microplastics.

In addition, the results reveal that car tyres have more microplastics than shoe wear, as the tape from the tyre only allowed 544 lux on average to pass through, while the tape from the flip flop allowed 861 lux on average to pass through. This implies that walking in general, creates less erosion than driving, and hence results in less microplastics.

Conclusion

Implications of findings

The presence of microplastics from both the tyres and shoe wear suggests that our daily activities (in this study transport) creates a lot of microplastics. This calls for concern, and emphasises the need to find methods to reduce the production of these harmful microplastics.

The research also indicates that walking could potentially aid in the fight against primary microplastic waste as the erosion shoe wear results in less microplastics than tyres.

Limitations

Due to the lack of funding, new tyres and shoes could not be obtained and hence the frequency of use of the tyres and shoewear could have been different, ultimately affecting the amount of microplastics on each item.

The lack of resources also limited this research's ability to accurately test for microplastics. The use of transparency as a measurement of microplastics may not be as accurate as alternative methods, as dust and other particles could have collected on the tape as well, affecting its transparency and the overall results.

Future research

Future research should try to explore how our other daily activities produce microplastics, and find the most eco friendly ways to carry out our lives. Studies can also be conducted to find ways to redesign common items so as to reduce the overall production of microplastics.

Impacts on organisms and the environment

The high amount of microplastics which we produce in our lives is a huge cause for concern for everyone. The impacts of microplastics stretch far beyond our imagination, affecting our plants, humans and animals in extremely harmful and prevalent ways. When these microplastics are washed into seas, rivers or any other water bodies, it can negatively affect the marine ecosystem, and this damage will ultimately and inevitably be felt by us. Fishes consume these microplastic which are washed into their environment. Since these plastics are not easily biodegradable, the concentration of microplastics in an organism increases overtime in the process of bioaccumulation. Eventually, when the organism is consumed by a predator, biomagnification occurs resulting in organisms residing in higher trophic levels of the food chain to end up with greater concentrations of microplastics in their bodies. As an apex predator (highest in terms of trophic level)), humans who consume seafood may have a high concentration of microplastics in their bodies due to these microplastics that were already present in the seafood they consumed. The eventual buildup of toxic microplastics in our body leads to a variety of diseases like cancer.

Apart from this, microplastics that enter sewage may end up in our drinking water. A case in point would be Singapore, where the consumption of Newater is very much integrated into our lives. Since microplastics are very small, some of them may bypass the filtration systems during the purification process, and end up in the water we drink. It is important to note that the concentration of microplastics in our water has a direct correlation to the amount of plastic we use. Ultimately, we, as humans, need to recognise that the detriments that microplastics bring about to the earth will be felt by us, hence we must do our best to reduce the use of microplastics in our lives.

Summary

Unfortunately, many of our daily activities produce harmful primary microplastics. However, there are ways we can reduce the amount of microplastics produced as in this research which has shown how walking results in less microplastic production then driving. Ultimately this research has come to the conclusion that since the fight against harmful microplastics will be long drawn out, finding alternatives that reduce the amount of microplastics we produce is the key to helping the situation.

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