A STUDY INTO THE AMOUNT OF RESIDUAL MICROPLASTICS PRODUCED FROM THE WEAR AND TEAR OF DIFFERENT TYPES OF COMMERCIAL PRODUCTS

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**i. Background Information**

Microplastics are largely defined as visible plastic pellets smaller than 5mm in size, but many of them tend to fragment or degrade under external forces, hence most of them are only visible under a microscope. A new study in the journal *Environmental Science and Technology* says it is possible that humans may be consuming anywhere from 39,000 to 52,000 microplastic particles a year. With added estimates of how much microplastic might be inhaled, that number is more than 74,000.

Total release of microplastic into oceans is estimated to be around 0.8 - 2.2 million tons per year. Once microplastics make it into rivers or oceans, they can have noticeable and chronic effects on marine life. John Weinstein (2017) exposed shrimp to tire particles in lab settings and found that the animals ate the particles, which also got stuck in their gills. Once ingested, particles balled up in the shrimp’s guts, choking them internally.

However, there are even more severe implications on the entire ecosystem. For example, microplastics can absorb a wide range of pollutants (Besseling et al. 2012) and are able to leach out plasticizers which can enter the tissues of aquatic species and pose a threat to humans or organisms on higher trophic levels. This is because microplastics are hydrophobic particles that act as chemical inhibitors within living organisms and bioaccumulate within the food web (Stevens 2015), greatly reducing the feeding activity and energy reserves of consumers.

**Impact of car tyres**

A 2017 study by Pieter Jan Kole at The Open University of The Netherlands, published in the *International Journal of Environmental Research and Public Health*, estimated that tires account for as much as 10 percent of overall microplastic waste in the world’s oceans. A 2017 report by the International Union for Conservation of Nature even put that number at 28 percent. This is because car tyres are actually made of 24% plastic (specifically SBRs and BRs). When car tyres rub off (abrade) asphalt surfaces after a period of time (due to their design to grip and manoeuvre), small cigar-shaped plastics break off from the surface of the synthetic rubber lining, which not many people know is a type of plastic polymer (derived from the copolymerization of several plastic compounds). The rain then washes these pieces of microplastics into drains and sewers along the road, which then collects all these pollutants and flows out as wastewater to the ocean.

A 2013 report by Tire Steward Manitoba, in Canada, found that passenger light truck tires lost nearly 2.5 pounds of rubber during their service life (average of 6.33 years). The Kohl study found that Americans produce the most tire wear per capita and estimates that, overall, tires in the U.S. alone produce about 1.8 million tons of microplastics each year.

**Impact of synthetic textiles (shoewear)**

Big companies like Adidas produce 600 million shoes a year with plastic soles. Like plastic clothing, shoe soles wear down and the micro shavings end up, from the street via the stormwater systems, in the ocean. In fact, shoes contribute to one of the largest proportions of microplastics pollution in our waters annually at a staggering average of around 200g per person each week.

**ii. Formulating the Research Question & Hypotheses**

Main Scientific Investigation:

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

**Which has a higher plastic content - car tyres or shoes?**

Car tyres are made of 43% plastic, 24% natural rubber, 19% synthetic rubber and the remaining 14% metal and other compounds. They also require around 7 gallons of oil to manufacture, while truck tyres take 22 gallons. On the other hand, textiles for shoes come in a huge variety of colors, weaves, knits, fibers, and denier. Denier is how thread weight is measured. 1 denier = 1 gram per 9000 meters of thread. Typical denier is 110D for very lightweight fabric, while 420D and 600D are common in shoe fabrics. Footwear textiles come in many fiber types including cotton, wool, nylon, polyester, polypropylene, rayon, lycra, and many others. Each has its own look and physical properties. For most shoes, they are made of around 40%-60% plastic, although currently, there are many companies seeking eco-friendly and zero-waste alternatives. Some conventional shoes can even be categorised into different types of leather, such as synthetic leather or PU leather.

**What factors determine the abrasion of microplastics from car tyres/shoes?**

The primary effect that is being examined in this study is wear and tear. This could be dependent on the type of surface. The rougher the surface of the ground is, the higher the tendency for tiny bits of these plastic polymers to break off from these materials. Moreover, in the case of car tyres, tyre tread patterns do help determine a vehicle's grip on the road, as well as handling, maneuvering, and breaking. However, having a better grip can also mean more friction, and as we drive, abrasion causes bits of our tyres to break off more easily. The same explanation applies to sole patterns to increase a person’s grip while running, climbing or simply walking.

Note that it is very difficult to quantify exactly how much microplastic waste ends up in waterways as it can depend on several variables, ranging from where the road is located to the weather; increased rainfall in a particular region, for example, can cause increased surface runoff, resulting in more particles flowing into the environment.

**Which product releases more microplastics through abrasion?**

Ultimately, activities and losses are computed in two ways.

The first approach combines the estimated driven distance covered by all vehicles in a region with reported particulate matter emissions from tyres per km per type of vehicle.

Study 1 (Krieder et al., 2010) was on the size of wear and tear of car tyres and the interaction with pavement in a road simulator using asphalt concrete pavement, i.e., a mixture of sand, gravel, crushed stone and recycled concrete bound together with asphalt. Their sampling device, consisting of a suction system located close to the tyre’s contact surface, only collected particles >0.3 μm; an upper size limit was not specified. They found particles sizes ranging from 4 to 350 μm with most particles having a size around 5 μm and 25 μm.

Study 2 (Aatmeeyata et al., 2017) was on wear and tear on a specially constructed road simulator using concrete pavement, i.e., a mixture of sand and granite stone bound together with cement. The air was withdrawn by suction and continuously analysed by a particle size analyser on particle number and size within a 0.3 to 20 μm range. Samples were also taken from the walls and the equipment afterwards, which were considered to represent run-off material. The emission of particulate matter with particles of 10 μm or less (PM10) to ambient air was compared to the total weight of the run-off of particles, and was found to be less than 0.1% by weight. Almost 50% of the PM10 mass had a size between 0.3 and 1 μm. No size distribution was given on the coarse particles, i.e., particles >PM10.

The second approach combines data on yearly global and regional sales of synthetic rubber for tyres with the typical particulate matter emissions over the lifecycle of a tyre.

Global consumption of synthetic rubber for tyres in 2010 was measured (ETRma, 2011). Firstly the study allocate transportation to regions based on (a) the number of vehicles per type (motorcycles, cars and light commercial vehicles, medium and heavy commercial vehicles) per region in 2010, (b) the number of wheels per type of vehicle, respectively 2 in scooters, and mini-automobiles, 4 in automobiles and 6 in carriers and, (c) an average tyre weight per type, respectively 10, 16 and 50 kg (selected values based on literature), and (d) a 25% share of rubber (tread pattern only) per tyre. The proportion of synthetic rubber per tyre is assumed to be around 24%. The study showed that there was a 10-25% microplastics loss over the expected life cycle of the tyre, which is supported by similar studies done by (Belleghem et al., 2017). The central value is set to 20%, which is interestingly equivalent to the global apparent loss of rubber.

**iii. Experiment & Methods**

**Research Question**: To find out whether shoes or tyres produce more microplastics after wear and tear

**Hypothesis**: An equal mass of tyres will produce more microplastics than shoes after wear and tear of a week

**Apparatus:**

1 pair of Nike running shoes

1 pair of ASICS running shoes

1 1600 cc. car tyre

Electronic balance

Sandpaper (40 grit)

Waxing strips

Lamp

White tile

Graph paper



 40 grt.

**Method:**

1. Cut a piece of waxing strip length 10 cm.
2. Using a 40 grit sandpaper (very coarse), sandpaper an area of the car tyre for around 1 minute.
3. Stick the waxing strip onto the car tyre, pressing down firmly on the strip to ensure that it is able to collect the most amount of microplastics present.
4. Firmly, in one stroke, peel off the waxing strip sharply.
5. Place the waxing paper on a while tile under white light.
6. With the aid of graph paper, count the number of microplastics adhered to the waxing paper.
7. In the form of a table, record the sizes of the visible segments of microplastics into three categories (more than 5mm, 3mm to 5mm and less than 3mm) (1cm = 10mm)
8. Repeat Steps 1 to 7 on different parts of the tyre for two more times and calculate the average number of microplastics for each category of size present for that particular tyre. Further repeat the experiment after usage for 1 week, 2 weeks and 3 weeks.
9. Repeat the test on the soles of both running shoes.
10. Get 2 volunteers to wear both pairs of shoes for 3 weeks. Take samples over the course of the 3 weeks to observe changes in the amount of microplastics.

Surface area of waxing paper used = Surface area of sandpaper used = 10 cm by 5cm (50cm2 fixed)

Surface area of tyre in contact with the ground in one revolution = $πdl $(l is the width)

To find the **total number of microplastics on the tyre** use the following formula:

$\frac{Area of Tyre}{Area of Waxing paper}×Average number of microplastic on the scotch tape$

To find the **total number of microplastics on the shoe** use the following formula:

$\frac{Area of Shoe}{Area of Waxing paper}×Average number of microplastic on the scotch tape$

**iv. Results & Discussion**

**Week 0**

|  |
| --- |
| Tyre |
| Region | Surface area of tyre in contact with ground in 1 rev./ cm2 | Number of microplastics on waxing paper | Estimated total number of microplastics on the tyre |
| Size is small(< 3mm) | Size is medium(3 - 5 mm) | Size is large(> 5 mm) |
| 1 | 4300 | 4 | 0 | 0 | 344 |
| 2 | 4289 | 3 | 0 | 0 | 257 |
| 3 | 4316 | 5 | 1 | 0 | 518 |
| **Average** | **4302** | **4** | **0.3** | **0** | **370** |

|  |
| --- |
| Shoe |
| Brand | Surface area of shoe in contact with ground/ cm2 | Number of microplastics on waxing paper | Estimated total number of microplastics on the shoe |
| Size is small(< 3mm) | Size is medium(3 - 5 mm) | Size is large(> 5 mm) |
| Nike | 431.5 | 0 | 1 | 3 | 35 |
| Asics | 440.5 | 0 | 2 | 3 | 44 |
| **Average** | **436** | **0** | **1.5** | **3** | **39** |

**Week 1**

|  |
| --- |
| Tyre |
| Region | Surface area of tyre in contact with ground in 1 rev./ cm2 | Number of microplastics on waxing paper | Estimated total number of microplastics on the tyre |
| Size is small(< 3mm) | Size is medium(3 - 5 mm) | Size is large(> 5 mm) |
| 1 | 4300 | 2 | 3 | 3 | 688 |
| 2 | 4289 | 1 | 4 | 6 | 944 |
| 3 | 4316 | 3 | 4 | 2 | 777 |
| **Average** | **4302** | **2** | **3.7** | **3.7** | **809** |

|  |
| --- |
| Shoe |
| Brand | Surface area of shoe in contact with ground/ cm2 | Number of microplastics on waxing paper | Estimated total number of microplastics on the shoe |
| Size is small(< 3mm) | Size is medium(3 - 5 mm) | Size is large(> 5 mm) |
| Nike | 431.5 | 1 | 4 | 2 | 60 |
| Asics | 440.5 | 1 | 3 | 1 | 44 |
| **Average** | **436** | **1** | **3.5** | **1.5** | **52** |

**Week 2**

|  |
| --- |
| Tyre |
| Region | Surface area of tyre in contact with ground in 1 rev./ cm2 | Number of microplastics on waxing paper | Estimated total number of microplastics on the tyre |
| Size is small(< 3mm) | Size is medium(3 - 5 mm) | Size is large(> 5 mm) |
| 1 | 4300 | 4 | 6 | 9 | 1634 |
| 2 | 4289 | 3 | 5 | 6 | 1201 |
| 3 | 4316 | 2 | 11 | 4 | 1467 |
| **Average** | **4302** | **3** | **7** | **6.3** | **1402** |

|  |
| --- |
| Shoe |
| Brand | Surface area of shoe in contact with ground/ cm2 | Number of microplastics on waxing paper | Estimated total number of microplastics on the shoe |
| Size is small(< 3mm) | Size is medium(3 - 5 mm) | Size is large(> 5 mm) |
| Nike | 431.5 | 0 | 6 | 4 | 86 |
| Asics | 440.5 | 2 | 3 | 2 | 62 |
| **Average** | **436** | **1** | **4.5** | **3** | **74** |

**Week 3**

|  |
| --- |
| Tyre |
| Region | Surface area of tyre in contact with ground in 1 rev./ cm2 | Number of microplastics on waxing paper | Estimated total number of microplastics on the tyre |
| Size is small(< 3mm) | Size is medium(3 - 5 mm) | Size is large(> 5 mm) |
| 1 | 4300 | 7 | 12 | 5 | 2064 |
| 2 | 4289 | 8 | 14 | 3 | 2145 |
| 3 | 4316 | 4 | 16 | 5 | 2158 |
| **Average** | **4302** | **6.3** | **14** | **4.3** | **2117** |

|  |
| --- |
| Shoe |
| Brand | Surface area of shoe in contact with ground/ cm2 | Number of microplastics on waxing paper | Estimated total number of microplastics on the shoe |
| Size is small(< 3mm) | Size is medium(3 - 5 mm) | Size is large(> 5 mm) |
| Nike | 431.5 | 4 | 5 | 3 | 104 |
| Asics | 440.5 | 4 | 4 | 3 | 97 |
| **Average** | **436** | **4** | **4.5** | **3** | **100** |

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As can be seen from the data, after 3 weeks of usage the tyres release more micro plastics than a pair of shoes. Generally, the number of microplastics across all 3 sizes increased. However, a drop in the number of larger particles was seen in several weeks while there was a significant increase in the number of small and medium particles. This is probably due to the multiple abrasions on the surface that degraded these microplastics, breaking them up into finer, less visible particles.

From the graph, it also showed that tyres were more susceptible to microplastics breaking off from the main product after friction (wear and tear), with a 514% increase in the number of microplastics produced by tyres at the end of Week 3 compared to a 156% increase for shoes. Dividing the total number of microplastics produced by the surface area in contact with the ground, tyres also prove to release more microplastics with an average of 0.49 pieces of microplastic per cm2 compared to an average of 0.23 pieces for that of shoes. A possible explanation could be that the tyres are put through more abrasion against the coarse grainy road than shoes, with more pressure being on to it due to the weight of the vehicle. In contrast, shoes are only pressed down by humans which exert much less force and hence pressure, and this could have an impact on the release. Cars also travel at a much higher speed compared to the walking pace of humans, since F = ma, the heavier body of the car, coupled with the increased acceleration while driving to a maximum speed generated more force to shed off these microplastics (synthetic rubber) particles.

**v. Conclusion**

The main findings of this experiment show that the tyres shed more micro plastics as compared to shoes, making it more harmful for the environment.

Two solutions can possibly be implemented. Instead of synthesising isoprene (plastic compound in tyres), the same material can be made out of natural sources such as grass, trees and corn instead of fossil fuels, soaking up carbon dioxide as it travels. Moreover, road surfaces can be made less abrasive or more porous to either reduce or help collect tire wear particles. Technologies to better capture tire particle runoff from roads should also be developed.

**vi. Limitations**

Several limitations of this project include not controlling the type of surface the shoe and the tyre was subject to. Furthermore, the small segment of the waxing strip is not representative of the entire surface of the tyre and the shoe, as only an arbitrary grid (graphing paper) was used to measure and count the microparticle size in relation to the sole/tyre surface area. Moreover, it was also difficult to differentiate between microscopic microplastics and dust/dirt particles, leading to a number recorded which could be much greater than in reality.

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