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Accumulation of microplastic in road dust and in soil alongside roads – a case study from the Eastern Region, Abu Dhabi

HABIB R.Z.[1], AL KINDI R.[1], GHEBREMEDHIN, F.[2], ELKASHLAN, M.,[2] AJEJEVBE A.I.[2] and THIEMANN T.[2*]

[1]Department of Biology, College of Science, United Arab Emirates University, PO Box 15551, Al Ain, UAE
[2]Department of Chemistry, College of Science, United Arab Emirates University, PO Box 15551, Al Ain, UAE

*corresponding author:
e-mail: thies@uaeu.ac.ae

Abstract Roadsides and soil have been sampled for microplastic content in 7 locations in the Al Ain area, Eastern Region, Abu Dhabi, UAE. The collection sites constituted residential areas and fall-out roads, but also one Wadi and the shoreline of a man-make lake. The concentration of micro-tire particles was found to be high on the roadsides of the residential areas. While a significant amount of tire macroparticles could be found on the roadsides of fall-out roads, these exhibited less micro-tire particles. Here, significant amounts of micro-tires could be found off-road, along the fallout roads, indicating, in absence of run-off water, Aeolic transport of the particles. The Wadi and the lakeshore sites were essentially free of micro-tires, but in all sites, microfibers were found. Collection of run-off water from roads during a rare rainstorm event showed transport of plastic microparticles both into the storm drains as well as to the adjacent soil. High surface temperatures and extreme aridity in the summer leads to the evaporation of small organic additives from the plastic materials leaving them dry and brittle. This leads to easy further mechanical fragmentation of the particles.

Keywords: microplastic, micro-tires, microfibers, soil

1. Introduction

The global plastic production has increased from 1.5 million tons in 1950 to 335 million tons in 2016, with an average annual growth rate of 8.6% (PlasticsEurope, 2018). 79% of the global plastic waste is that are put in landfills (Geyer et al., 2017). Nevertheless, the current mass production of plastic, low rate of recycling, and use/disposal patterns contribute to the continuous accumulation of plastic waste in the environment (Kumar et al. 2020), where the soil can be considered as one of the final resting places. Plastic has an exceptionally slow rate of degradation (Zhang et al., 2019), with half-lives of some of the plastic types estimated at over one hundred years, where the degradation of the plastic involves weathering through ultraviolet irradiation, mechanical abrasion and oxidation and hydrolysis processes. Through these processes, larger plastic particles can fragment into smaller particles known as microplastic (MP), when less than 5 mm in size (Andrady, 2011). Fibers, and tire and road wear particles (TRWP) are released into the environment as MP, also (Kole et al., 2017).

MP transport from land to aquatic ecosystems, especially to the ocean, has been investigated, where in temperate zones microplastic is primarily transported through water. Run-offs can carry MP into riverine systems or into sewage systems to wastewater treatment plants, where MP is largely retained in the sludge. Air is another transport medium for MP. In arid regions, especially in areas where no riverine systems can carry MP to larger water bodies, such as on the Arabian Peninsula, the first method of transport fails, although there is still an appreciable input into the Arabian Gulf from the large metropolises on its shores. Rare rain falls can be intense, leading to run-offs in Wadis that often end in Sabkhas. Thus, the fate of the MP inland is largely unknown.

The current study, carried out in 2019 – 2021, is an attempt to quantify the MP content of soils along roadsides in different areas in the Eastern Region of Abu Dhabi, especially in Al Ain and to compare these with MP content at off-road locations. MP presence in roadside dust is an example of a diffuse MP source that contains a highly diverse mixture of MP, partially produced on-site such as TRWP and partially transported to the site, e.g., through areal deposition (Opher and Friedler 2010; Murakami et al., 2008). Soil samples were also collected along the shoreline of a man-made lake with no directly neighboring human built-up, and in Wadis. Collection of MP in the study focused on tire derived MP and fibers. MP in run-offs from the roadside to the adjacent areas and the sewerage system were also investigated during a rainfall event.

2. Methods

Road dust (here defined as any particles found on the road itself up to the curb) and soil samples (were collected **f**rom

7 different site location to analyze and characterize the rubber and microplastic contents (L1-L4 are residential areas with partially heavy but slow moving traffic, L5 and L6 is alongside an outfall route within the city confines with heavy traffic, L7 is an outfall route outside of the city confines. Roads L1-L6 have curbs, L7 does not). GPS device Garmin (Manotana 680) was used to record the coordinate points of these sites (Figure 1). Samples were carefully placed into sealed bags to avoid any further environmental contamination. Triplicate samples from each site (1g per photo) was photographed under the stereomicroscope (Model SZ2-ILST). The microphotos were used to identify the microplastic particles. The identified particles were processed through Fijji Image J for quantification and size distribution (Schindelin et al., 2012). The Feret's diameter was used to represent the size of microbeads. The Feret's diameter corresponds to the longest distance between any two points along the bead boundary (Santagapita et al., 2012). FT-IR spectroscopy of microtyre samples was carried out on KBr pellets of the samples with Perkin Elmer Spectrum Two and Thermo Nicolet Nexus 670 FT-IR spectrometers. Attenuated total reflection (ATR) of the tyre samples was performed with a Shimadzu IRPrestige-21 attached with Pike Miracle Single Reflection Horizontal ATR Accessory (Madison WI).

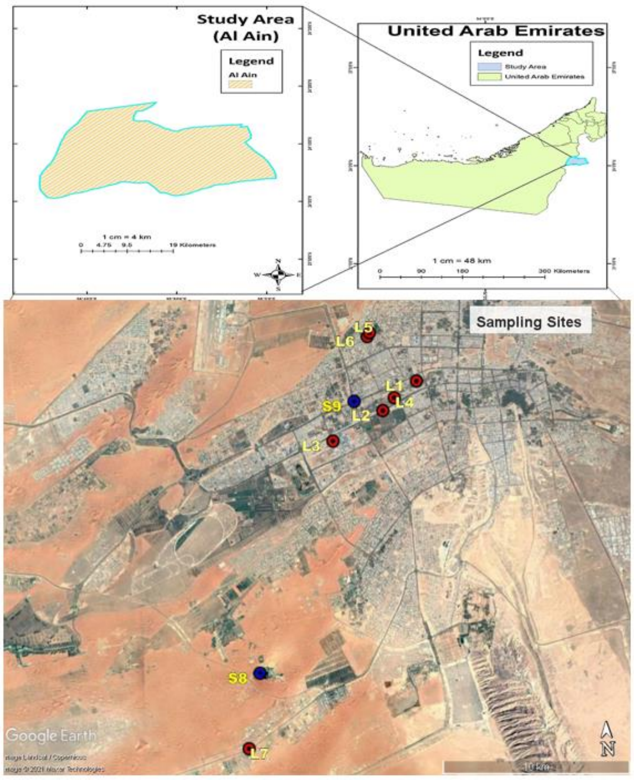

Figure 1. Location of the sampling sites L1-L7 (red) in Al Ain, Abu Dhabi and its vicinity. S8 (blue) is the sampling site at Zakher lake and S9 (blue) the sampling site at the Wadi.

Two run-off samples were taken in a rain event in the summer of 2020, within minutes of each other. One was a drain run-off, the other was a road run-off into the soil bordering the road. The water (16 L and 20L, repsectively) was collected in a bucket and brought to the laboratory, where it was vacuum filtered through a Whatman filter paper (ashless, grade 42, 2.5 μm pore size). The material collected in the filter was air-dried and subsequently examined with a stereomicro-scope (see above).

3. Results

Table 1 and Figure 2 show the abundance of microplastic particles as well as glass fragments and non-plastic beads at the 7 locations sampled. The greatest abundance of microtires was found in the residential areas and in the top-soil alongside the roads within the town confines. The latter may be due to the fact that some of the microtires may have been transferred to the roadside soil during regular road sweeping operations. The process of moving microplastics with road dust in sweeping operations has been reported from other cities, also (Polukarova et al., 2020). Other microplastic materials were also found, including plastic fragments, microplastic films, fragments from plastic bags and straws (Figure 2). The non-plastic beads found for the most part were reflective glass beads made for road and pavement markings (Figure 3). These beads loosen over time and can be found in road dust as well as in soil alongside roads, where they have been moved by sweeping operations and with the occasional water run-off. On the road, they migrate away from the original pavement marking sites with car movement. Microtire particles in road dust or alongside roads have been found to be hard and brittle.

Table 1A. MP particles found per gram of the road dust/soil samples (microtires, fibers, plastic bag debris, straw fragments)

Sample name	Microtires (per g)	Fibers (per g)	Plastic bag pieces (per g)	Straws (per g)
L1 (dust)	40	14.7	0.33	0.7
L2 (dust)	63.7	49.7	2.67	1
L3 (dust)	133.4	1.33	0	0
L4 (dust)	18.7	21	1	0
L5 (soil)	71.3	0	0	0
L6 (soil)	61.3	14.3	1	0
L7 (soil)	4	9	0	0

Table 1B. MP particles found per gram of the road dust/soil samples (Plastic films, plastic particles, glass pieces, non-plastic beads)

Sample name	Plastic films (per g)	Other plastic particles (per g)	Glass (per g)	Beads (per g)	Total MP (per g)
L1 (dust)	0.33	5	5	9.7	75.7
L2 (dust)	0.3	6.7	6.3	21.3	128.3
L3 (dust)	0	1.7	1.3	0.7	138.7
L4 (dust)	0	9	0	0	50.33
L5 (soil)	1	0	0	0	72.3
L6 (soil)	0	6.7	1.3	5	89.7
L7 (soil)	0	0	0	0	13

The reason for this is, as the authors could show with tests with cut pieces from tires and silicone rubber floor mats added to outdoor soil in the summer, that the materials can lose as much as 6.1% of their original mass by exuding small organic components such as oils and plasticizer. The brittleness leads to easy further fragmentation of the particles, when they are driven over by cars. A typical size distribution of the microtires for site L1 can be found in Figure 4. The abundance and distribution of microtires for the fallout road outside of the city confines (location L7) were different as both on the road and on the road shoulder few microtires could be found. The road does not have curbs and L7 is exposed to the wind, where the wind carries smaller particles as far as the first surface elevation, 50 m from the road, where again microtires can be found in abundancy.

Table 2. MP particles off-road (on the shore of Zakher lake and in one of Al Ain's Wadis) – the numbers are given per 3 g of soil.

Sample site	Micro-tires	Mixed MPs	Size range	Average size
Wadi	1	28 (all types of mixed MPs)	33.4 - 172.4 µm	87.5±39.62
Zakher lake	3	56 (mostly fibers)	38.4 – 468 µm	118.61±81.75

Samples were also collected from two locations that were at least 100 m from any road to see whether microtires and other microplastics had been transported to those locations. Very few microtires were found in both locations (Table 2). More pervasive are textile fibers which have been found in appreciable numbers in all locations sampled.

In regard to the run-off samples, 53 MP were found in 16L of water leading into a storm drain and 62 MP were found in 20L of water (28 microtires, 34 fibers), the second run off drained into the soil adjacent to the road.

4. Conclusions

The microtire load in soils in the residential areas in Al Ain and along its main outfall roads was found to be high. This is in agreement with the equally high load of macro-tire particles, derived from the significant tire road wear under the arid and hot conditions. All soil samples contained fibers. These included off-road samples, samples from Wadis and samples from the shoreline of a lake within the confines of Al Ain. Overall, it was found that aeolian transport plays a major role in the dispersal of MP in the Eastern Region, Abu Dhabi, similar to what has been reported recently from Fars Province in Iran, and from the Sonoran Desert, Arizona, USA (Zylstra, 2013). Oftentimes, MP were found to be deposited in sand dunes that presented the first surface elevation away from the road. High surface temperatures in the summer result in the dissipation of small organic molecules from MP material such as oils and plasticizers from microtires, making them brittle, leading to their facile mechanical fragmentation into even smaller particles. Run-offs created in rare rainfall events carry MP into the soil along the roadside, especially outside of the city confines.

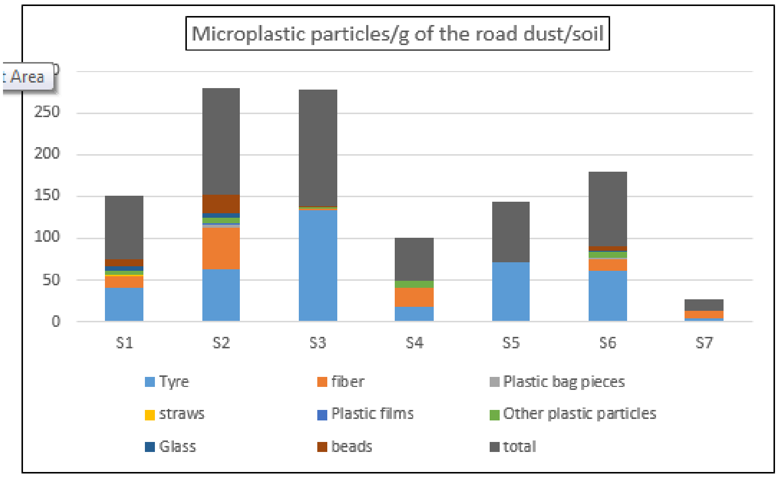

Figure 2. Distribution of micropartcles (plastic and non-plastic as to type) in the road dust/soil of sampling sites L1-L7.

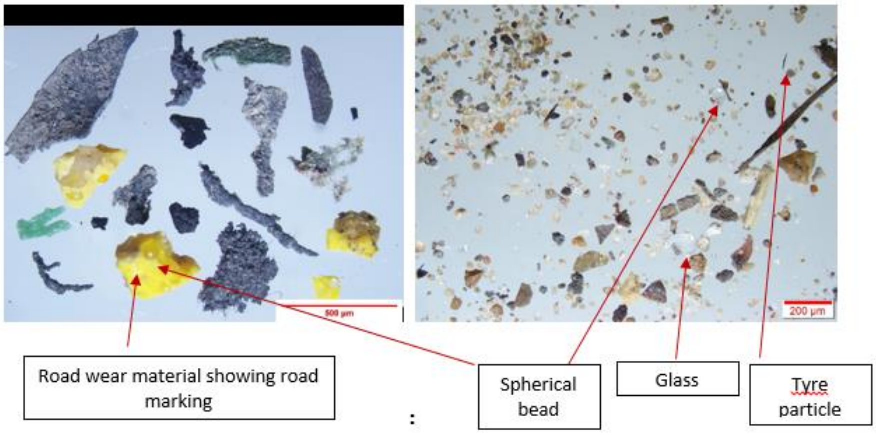

Figure 3. Typical road dust samples showing microtires, road wear material, and plastic fragments

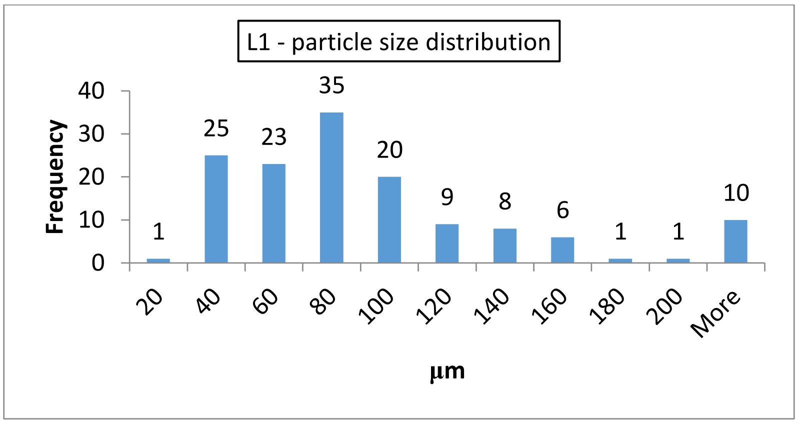

Figure 4. Particle size distribution over all MP for sampling site L1 (in 3g of road dust)

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