MICROPLASTICS IN EQUESTRIAN FIBRESAND SURFACES

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Project summary

Plastic waste pollution, including spread of microplastics, has become a major concern in environmental protection. The European Union has a strategy to reduce plastic pollution by 2030. The Swedish Environmental Protection Agency has carried out government assignments, including NV-08867-17, to identify and remedy important sources of dispersal of microplastics in water. Sport and recreational surfaces, including artificial turf football pitches and equestrian fibresand arena surfaces, were included. While the understanding of the presence and dispersal of microplastics in the environment have improved in recent years, there are still large voids in the knowledge. This has included microplastics in fibresand.

Equestrianism is one of Sweden's major sports. Riding arenas are a necessity for the practice of equestrian sport in a climate like the one in Sweden. As for participants in other sports, properties of arena surfaces are important both for the health and performance of the horse. Sand, woodchips/sawdust and grass are traditional choices. In recent decades synthetic polymers ("fibre") have been used as an additive to sand, with the aim of improving consistency of the surface. This mixture called "fibresand" is now the main choice for competition and training.

This project is a first pilot, or proof of principle, study. The aim of the project has been to improve the understanding of, and knowledge about, (micro)plastics in equestrian fibresand arenas; a) quantities in the raw material, b) its degradation or fragmentation into secondary microplastics, c) dispersal in the environment and d) possible impacts on respiratory health, through interdisciplinary scientific studies.

The background to this pilot study is the European Union's initiative to ban intentionally added microplastics in products including synthetic sports surfaces. In April 2023 REACH member countries voted in favour for a ban on sales, but not the use, of synthetic polymer microparticles in sport surfaces, expected to take effect in 2031; "*COMMISSION REGULATION (EU) …/… of XXX amending Annex XVII to Regulation (EC) No 1907/2006 of the European Parliament and of the Council concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) as regards synthetic polymer microparticles include granular infill for use on synthetic sports surfaces*. "

While contents and dispersal of microplastics (granular infill) in and from artificial turf has been widely studied, microplastics in equestrian surfaces, in effect fibresand, has been part of a knowledge gap. No laboratory data on microplastics in fibresand was available before this pilot study. Conclusions made previously have been based partly on extrapolation of data on artificial turf.

Our analysis consistently found very low concentrations of microplastics (< 5 mm) in fibresand material, drainage water and in the air of fibresand arenas. As a pilot study the sampling is at a spot check level, but the consistency of the low levels of microplastics (< 5) mm in fibresand throughout the study, was evident. The criteria in the REACH restrictions are broader than the 5 mm threshold, as it also includes the definition "the length of the particles is equal to or less than 15 mm and their length to diameter ratio is greater than 3" (that is threadlike, spheric particles up to 15 mm are not affected). These details are shown and discussed in the appendix and Discussion. The results demonstrate that fibresand have a much lower content of microplastics < 5 mm compared to for example artificial turf, and indicate that fibresand arenas installed by premium producers represent a minor source of microplastics dispersal in the environment.

However the wider scope of the REACH restrictions in short mean that equestrian fibresand arenas will be subject to the ban of sales from 2031.

Summary of results:

- Synthetic polymer raw materials: The amount of microplastics (< 5 mm) in producer samples of synthetic polymers used as additives in mixing of fibresand was between 0 and 9,38 %.
- Microplastics (< 5 mm) per ton fibresand: For 25 % (n 2) of the tested raw materials the presence of microplastics (< 5 mm) per ton fibresand mix, would be 0. For five products out of 8 the microplastic content would be between 0.04 % and 0.13 % per ton. The threshold in the new REACH restrictions taking effect in 2031 is 0.01 %.
- Microplastics per m^2: For a newly installed arena microplastics per m^2 fibresand equalled between 0 and 226 g per m^2. The corresponding figure for artificial turf is 11,1-14,8 kg of microplastics per m^2.
- Grams per kg in arenas > 2 years old: Four arenas from 2017-2020 contained a mean of 2,5 g of microplastics per kg fibresand.
- Fragmentation of synthetic polymer materials in fibresand: Microparticles (ca 1 mm) were analysed as an indirect measure of fragmentation/degradation. We found significant differences in the percentage of microparticles between two main locations in the arenas, reflecting respectively high and low levels of abrasion and UV exposure.
- Drainage water dispersal: In drainage water from outdoor arenas, a maximum of 304 particles (arena 1) were isolated by filters over a three-week period with 15 mm of precipitation (equilavent to 15 litres per m^2). Microplastic particles were found in all samples; in drainage filters from two fibresand arenas and a sand-only arena used as control, and blank controls at both. If the drainage water filter results were extrapolated to annual levels, -the dispersal from arena 1 would be 4,3 particles per m2. If results were extrapolated to national level (n 69 outdoor arenas), the water dispersal of microplastics would be 18-32 kg annually (see Future studies for caveats).
- Air concentrations: The concentrations of microplastic particles in the air in both indoor arenas tested were very low, below threshold levels for the outdoor arenas.

Our laboratory data thus indicate that equestrian fibresand is a minor source of microplastic dispersal. The Swedish Environmental Protection Agency government report no 6772 from 2017 lists roads and tyre wear as the largest source of microplastic dispersal in Sweden, with levels of 8 190 tons annually, and artificial turf as the second largest source of 1640-2460 tons (reduced to circa 500 ton in a 2019 report, followed by industrial production (310-530 ton), painting and surface treatments of buildings (130-250 ton) and plastic littering (no data

but estimated to be very large). Other microplastic sources reported are industrial production and handling of plastics, boat paint, household washing, and building waste.
In this pilot study laboratory analysis of raw material fibre, arena fibresand, drainage water from fibresand arenas and arena air consistently showed low amounts of microplastics. In addition the number of fibresand arenas in Sweden compared to artificial turf pitches is small. Swedish Equestrian Federation data up to 2022 indicate that there are 237 fibresand arenas in the country. One caveat is that not all private arenas are associated with the federation. A majority of registered arenas (n 169, or 72 % of the total) are indoors, where the potential for dispersal is limited. In September 2020 Sweden was estimated to have 1149 artificial turf pitches (Lozeno & Ferguson 2021).

Chemical analysis by Fourier-transform infrared spectroscopy (FTIR) analysis of the raw material samples indicated that polyester was the most common polymer.
The results in this pilot study demonstrate consistently low concentrations of microplastics and are primarily applicable to the premium producers represented in the study, and not necessarily the fibresand market as a whole, which is heterogenous in its nature. Wider conclusions would require future studies.
For example, EU (REACH) restrictions on synthetic polymers in sport surfaces approved in 2023, and wider efforts on sustainable plastic use, underline the importance of identifying alternative, non-synthetic materials for use in equestrian surfaces. As an example of changes in the industry The UK Environment Agency is banning the use of waste carpet in equestrian surfaces, likely as immediately as from January 1 2024 (Horse and Hound Oct 24).
This report uses the criteria of microplastics as synthetic particles < 5 mm. Further definitions based on the REACH sports surfaces initiative, in relation to the results of the present study, are listed in the Appendix and reviewed in the Discussion.

2 Equestrian arena materials in Sweden

Data from the Swedish Equestrian Federation show that traditional sand/gravel and sand/gravel/wood mixtures are the dominant materials used for equestrian surfaces.

Data up to year 2022, based on inspection visits of riding schools and equestrian centres, covered 680 outdoor and 597 indoor arenas, in total 1275. Of 680 outdoor arenas 10 % (n=68) were fibresand and 83 % (n=565) were sand/gravel/stone dust. In the 597 indoor arenas fibresand was the second most common at 28 % (n=169) and sand-wood at 51,5 % (n=304) of the arenas, respectively. The total number of fibresand arenas in this data was 237.
A separate 2014 survey – but with a part overlay with the 2022 data - by the Swedish Equestrian Federation and Swedish University of Agricultural Sciences included 373 outdoor arenas and 283 indoor arenas. 22 % of indoor arenas and 8 % of outdoor arenas had fibresand surfaces. Sand-mineral was the most common surface outdoors and sand-woodchip indoors. (Egenvall et al 2021).

3 Raw material synthetic polymer samples

3.1 Material and methods

In order to quantify the amount of microplastics in fibresand arenas, three premium companies within the EU were contacted and they supplied raw material (synthetic polymer fibre/geotextile-mixture) that they use as the additive in production of fibresand for equestrian arenas (n=8). One sample sent in by one producer was of a raw material they no longer use, but it was provided out of interest. Raw materials were selected in order to focus directly on the analysis of the synthetic fibres and calculating percentages of microplastics in fibresand. The samples were analysed at Chalmers University of Technology, Department of Chemistry**.**

3.1.2 FTIR

FTIR was used to distinguish what kind of material the fibres were made of. From each size category three pieces of fibre were analysed by using FTIR spectroscopy. Using Excel, the data was visualized in graphsin order to determine what possible substances the sample could contain.

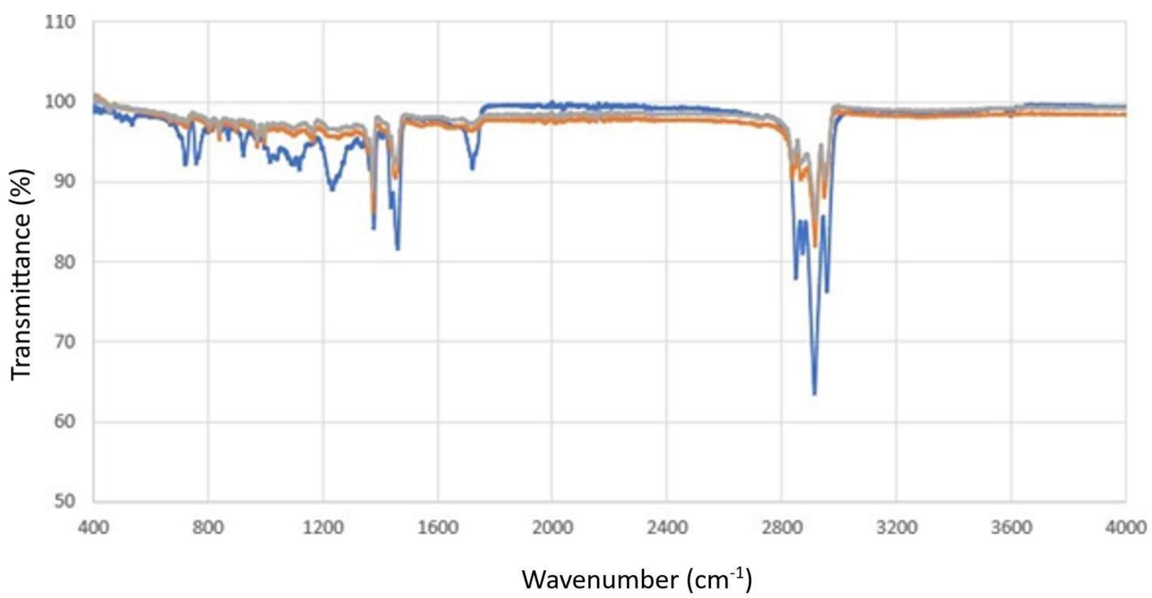

Figure 1 *Example of a FTIR analysis result of a sample of raw material fibre*

3.2 Results

FTIR analysis of the sample materials demonstrated that the most common material of the synthetic polymers was polyester. The samples were also divided into size fractions; < 5 mm, 5-15 mm and > 15 mm (see appendix and figure 2ab). The variation of percentage of the < 5 mm fraction was between 0 and 9,38 %. For one raw material sample the microplastics fraction (< 5 mm) was 0, and for another close to zero, or more precisely 0,24 %. For two samples the content of microplastics < 5 mm it was between 2,38 and 3,63 % and two between 6,35 and 9,38 %. Two samples were outside the standard fractions; one consisted of uniform filaments of approximately 4 cm in length and the other of finely divided material, that could plausibly be classified as 100% microplastics. The latter was the sample of a mixture that is no longer sold by that producer. The main part of the raw materials was > 15 mm, with a mean for all samples of 72,2 % (56,13-95,24 %).

Figure 2 a (above) and b (below) Example of fractioning of one of the raw material samples (photo Chalmers University of Technology)

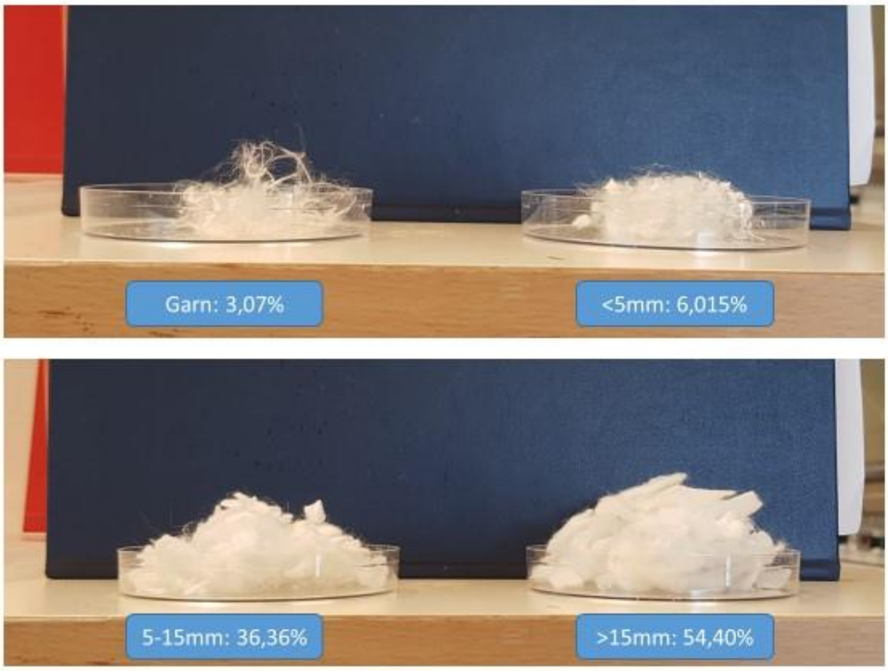

Figure 3 *For two raw material samples, of which one (top of the page) is no longer sold by the producer but was sent in as reference, the material was not possible to divide into fractions. These images meanwhile exemplify the heterogeneity of the fibresand raw material market. Compare also with Figure 2 ab*

Table 1 *Example of results of FTIR and fractioning for one raw material product, and observations of material properties*

Producer Xproduct b		
Molecular characterisation		
FT-IR		
polyester, polysiloxane		
Size of fiber		
Processed material	*Moisture content*	*Dry weight*
4.63 g	*2.02 percent*	*4.54 g*
Less than 5 mm´:	**5 mm - 15 mm:**	**More than 15 mm:**
2.38 percent (0.11 g)	**30.45 percent (1.41 g)**	**67.39 percent (3.12 g)**
5.09 g	2,02 percent	4.99 g
	Elastic	Stiff
Fragile	40.08 percent (2.04 g)	0.59 percent (0.03 g)
Robust	19.25 percent (0.98 g)	40.47 percent (20.06 g)

E-F	ElastieFragile	Can be stretched by hand but breaks easily
E-R	ElastieRobust	Can be stretched by hand without easily breaking
S-F	Stiff-Fragile	Stiff structure that breaks easily if pulled
S-R	Stiff-Rodust	Stiff structure that remains if pulled by hand

3.2.2 Quantification of microplastics in a newly installed arena

Producers also provided data on the quantity of fibre material used for mixing with the sand when a new surface is installed. One standard size for an equestrian arena is 20 m x 60 m, which equals the standard for higher level dressage competitions, and is a common size for indoor arenas. This equates to an area of 1200 m^2. The sand mixture with fibres is the surface layer, on top of the base (see Figure 4). One standard thickness for the sand fibre mixture at installation is 15 cm, which equates to 180 m^3 of surface material.

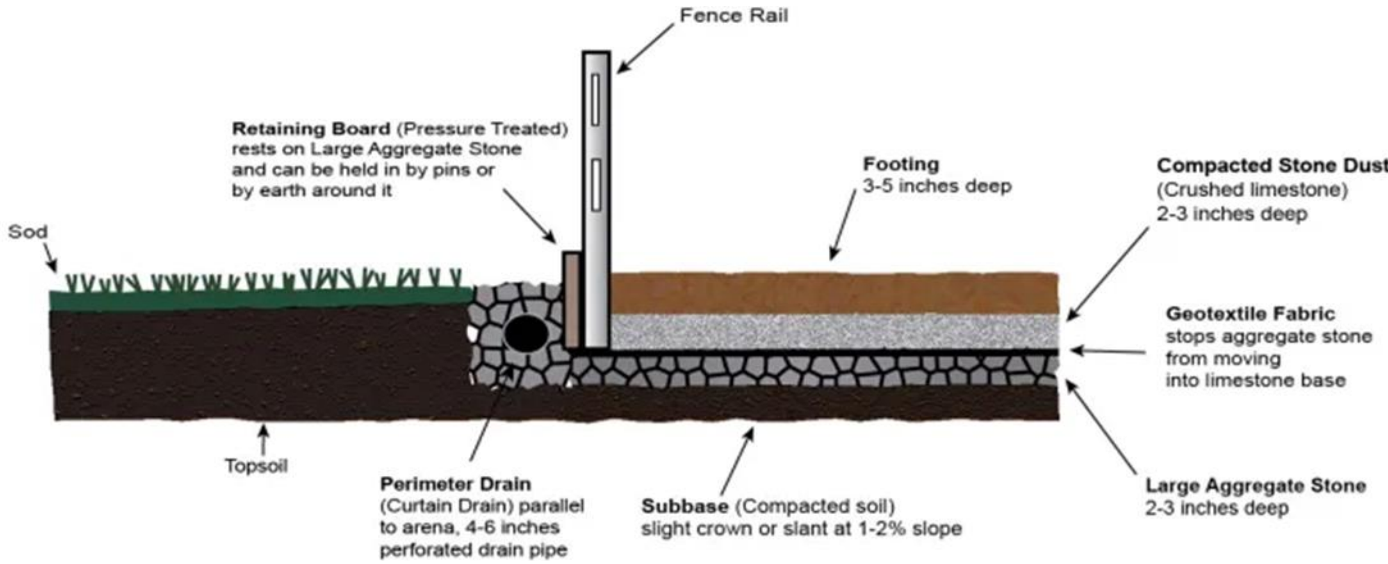

Figure 4 Example of the construction of an equestrian arena with fibresand footing

The amount of microplastics (as measured in the raw material samples) calculated per m2 of an equestrian arena will be a function of the percentage of microplastics in the raw material (see example Table 1) and the producer’s choice of ratio of fibre to sand in the finished product. As shown in Table 2 different producers use different concentrations of fibre material, depending on their own preference, the type of sand and the intended use of the arena. The unit m2 was chosen rather than m3, as different sands will have different weights and volumes.

In the examples provided by the producers in the study the amount of microplastics per m2 was between 0 and 226 g.

Table 2 *Microplastics per square meter in fibresand surfaces based on laboratory analysis of raw material samples and data on polymers vs sand content provided by producers.*

		Equestrian arena	
		20x60 m	
	Producer X	Producer Y	Producer Z
Kilo fibre per m3 sand	40*'/35**'/33***'		
Kilo fibre per m3 sand		20-25 (15*****)	18,5
Total synthetic polymers	5940	2400-3600	2900
Percentage mp < 5mm	0.24/na	2.38/3.63/6.35	0/9.38
Weight microplastics in arena	14 kilo	88-132 kilo*	0/272 kilo
Microplastics per m2 arena	11,6 grammes	73-110 grammes	0-226 grammes
		* based on mean 3000 kg	
-** higher ratio sand for professional use,		***** less fibre for optimal sand	
lower for semi-professional and riding school/leisure			

One important observation in the laboratory handling of the raw material samples were differences in properties on an axis of elastic-stiff and fragile-robust (see Table 1). This is likely to influence the material’s resistance to fragmentation and production of secondary microplastics, and also properties of the fibresand surface.

3.3 Artificial turf versus equestrian fibresand in numbers

Standard measures for artificial turf pitches are between 60 x 90 m, or 5 400 m2, and 110x68 meter (7 480 m2). An artificial turf pitch is estimated to contain between 60 and 200 tonnes of rubber granules (< 5 mm)**.** This corresponds to between 11,1 and 26 kg of microplastics per m2, versus 0-226 g per m2 in three examples of fibresand arenas (see Table 2). In September 2020 Sweden was estimated to have 1149 artificial turf soccer pitches, with a total area of 5 800 000 m2. This included 772 full size pitches, 289 smaller for 5-7-9 aside matches and 88 indoor arenas (Lozeno & Ferguson 2021). The number of equestrian fibresand arenas were 237, according to Swedish Equestrian Federation data. One standard size for riding arenas is 20x60 meters, or 1200 m2, but there are not the same detailed data available about sizes of all arenas as for artificial turf. The total number of fibresand arenas can be somewhat higher as there are private arenas not associated with the federation, but regardless a majority (n 169/72

% in federation data) are indoors, where irrigation water normally evaporate and do not pass out with drainage.

Data on arena sizes are again not as readily available for equestrian arenas as for artificial turf pitches, but if presumed to be 60x20 meters x 237 the total area of fibresand for Sweden would be 284 400 m2, versus 5 800 000 m2 for artificial turf.

4 Degradation and fragmentation

4.1 Background

Part 1 of the study quantified the amount of microplastics in raw material samples from premium producers of fibresand arenas. The second part of the study was to study degradation. Micro- and macroplastics in the environment degrade mechanically, chemically, and biologically. Degradation rates are associated with polymer characteristics, as well as environmental characteristics, including exposure to UV radiation from sunlight and mechanical abrasion. The latter could be expected to be especially relevant in an equestrian arena setting, due to the mechanical wear from hooves (which can produce a force of several tonnes in each step at higher speeds) and maintenance machinery, such as harrows.

One main factor prevented a study of fragmentation of the fibre material over time. This was the limited time frame of the field part of this pilot study, from May 2022 to late 2022. Instead we hypothesized that arenas could be their own controls. The top fibresand layer of an arena has a recommended thickness of about 15 cm. The immediate surface layer will be subject to constant abrasion from hooves and maintenance machinery such as harrows and tractor tyres, plus UV radiation. In contrast, unless the arena has been deep harrowed, the bottom layer should have remained undisturbed since it was installed, and of course not exposed to sunlight.

The difference in risk factors for fragmentation will not only be between the top and bottom layers, but also with different areas of the top layer. Riders use certain main routeswithin the arena, including the centre line and outer track, that can be expected to be subject to more wear and tear than zones with less “traffic”. Horses are too big to step into the corners, that will thus be subject to minimal wear.

We therefore hypothesized that comparing top and bottom layers and different locations in the same arena would reflect differences in degradation and fragmentation.

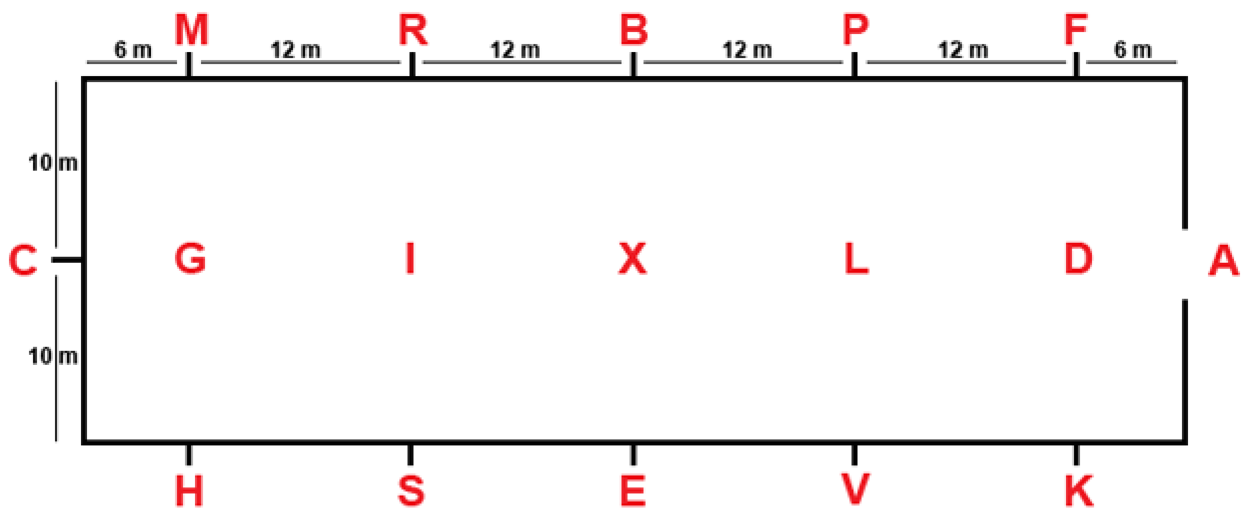

Figure 5 A dressage arena 20x60 m. The letters provide a "map" of the arena for different routes and exercises. The centre line route (see figure 6 and 7) runs from C to A (through G,I,X,L,D). The corners are left of M and H and right of F and K.

4.2 Material and methods

4.2.1 Location and exclusion criteria

We selected four arenas, two outdoor and two indoor. They were installed by two of the same producers that provided raw material samples. Selection criteria included that they had not had any topping up of materials since they were installed and had not been deep harrowed. For each arena four samples were taken; the top and bottom layer of one corner, and top and bottom layer from the centre line (which is one of the main "routes" in an arena, see Figure 5). We hypothesized that the quantity of microplastics would be higher in the immediate surface layer of the centre line, subject to both UV light and high levels of mechanical wear and tear, and lowest in the bottom layer, immediately over the base layer, that should have been untouched since being installed.

Each sample was of about 2 kgs of fibresand, taken from a square of about 20x20 cm and about 2 cm thickness. Due to the high degree of moisture plastic bags were the only possible storage.

The samples were analysed at the Department of Organic Chemistry at the Chalmers University of Technology in Göteborg, by FTIR and fractioning.

4.2.2 Preparation of the sample

100 gram of sample was weighed up and left in a plastic bucket at room temperature for three days to dry. This was done to get a qualitative value of the moist content of the fibresand.

4.2.3 Extraction of microparticles

The sample, 100 grams, was poured into a strainer and all sand was separated from the fibres into a plastic bucket. The fibres were placed in a container. 1 litre of water was poured over the sand, and it was left to settle for one minute. Eventual microparticles from the fibres were separated from the sand by pouring the water into a new container an leaving the sand in the bucket. The sand was thrown away.

It can be noted that the use of a plastic bucket was a potential source of contamination, but the same pieces of equipment were used throughout.

The water with the microparticles were left to settle for two minutes. The microparticles were separated by pouring the water between two buckets. Water without fibres was thrown away. When there was around 200 ml of water with particles left, the water was removed using membrame filtration. The microparticles were put in a container and placed to dry for 5 days. The dry microparticles were weighed.
‘

4.2.3 Sorting the fibres

The fibres were organized by size using a tweezers to sort the fibres into size intervals less than 5 mm, between 5 to 15 mm and bigger than 15 mm. The weight of each fraction was measured and the percentage of each size interval in the sample was determined in relation to the total weight of all fibres in the sample.

All data was recorded in a table (see example Table 1).

4.3 Results

4.3.1 Differences in presence of microparticles within an arena

Microparticles (ca 1 mm) were analysed as a measure of fragmentation. A paired t-test of the mean of all four arenas showed significant differences in the percentage of microparticles between the bottom (“deep”) layers, at corners versus centre lines (p=0,03), and a p-value of 0,08 for the difference between the surface layer of centre lines versus the bottom (“deep”) layer of corners. Due to the limited number of samples further comparisons between arenas and locations were inconclusive but however, the results indicated less differences in the two outdoor arenas than in the indoor arenas.

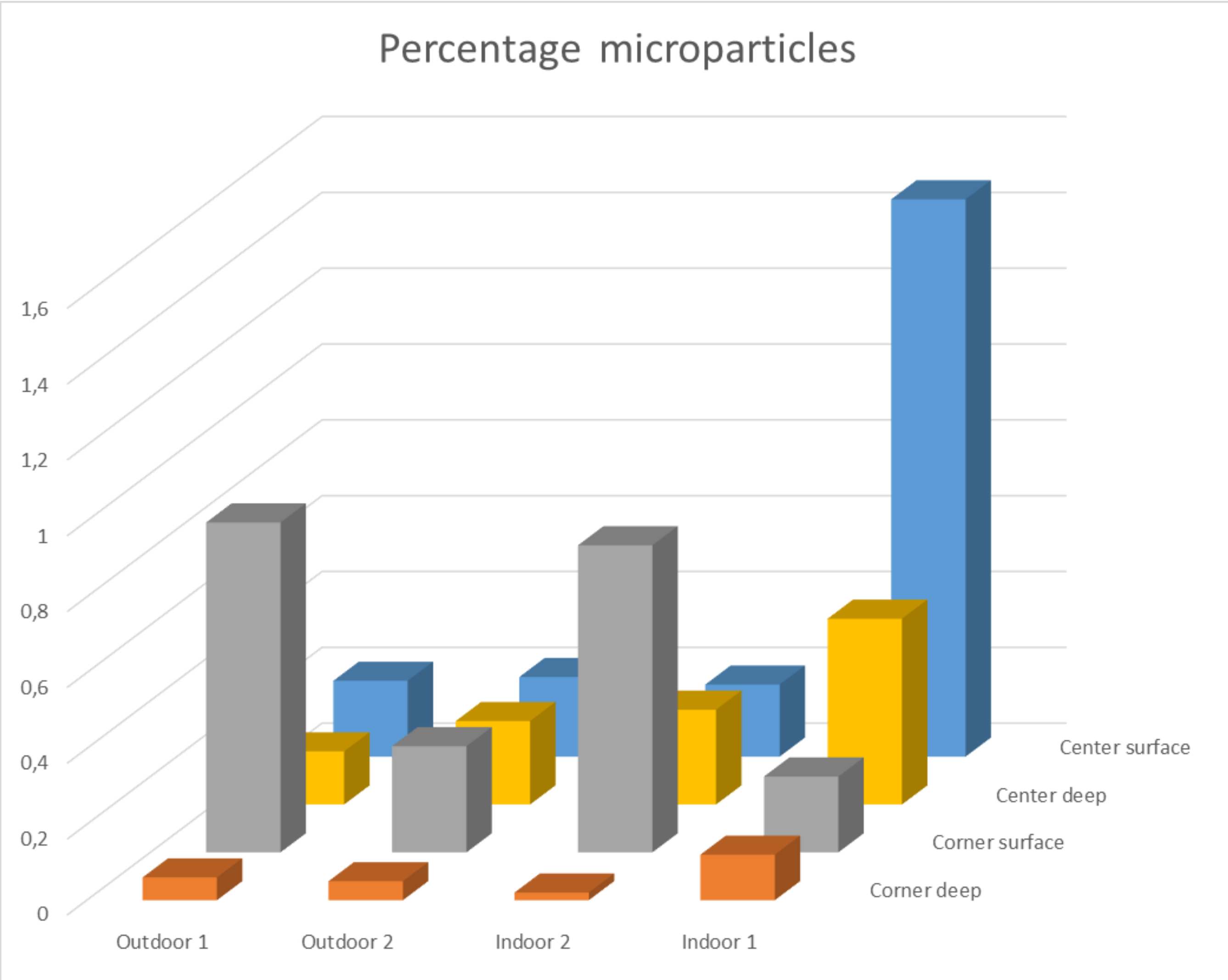

Figure 6 Differences in the presence of microparticles at different locations and depths in four arenas. A paired t-test of the mean of all four arenas showed significant differences between the bottom ("deep") layers, at corners versus centre lines (p=0,03) and a p-value of 0,08 for the difference between the surface layer of centre lines versus the bottom ("deep") layer of corners. The result supports the hypothesis that the wear and tear of the fibre material is high at the centre line and low at the bottom of the corners.

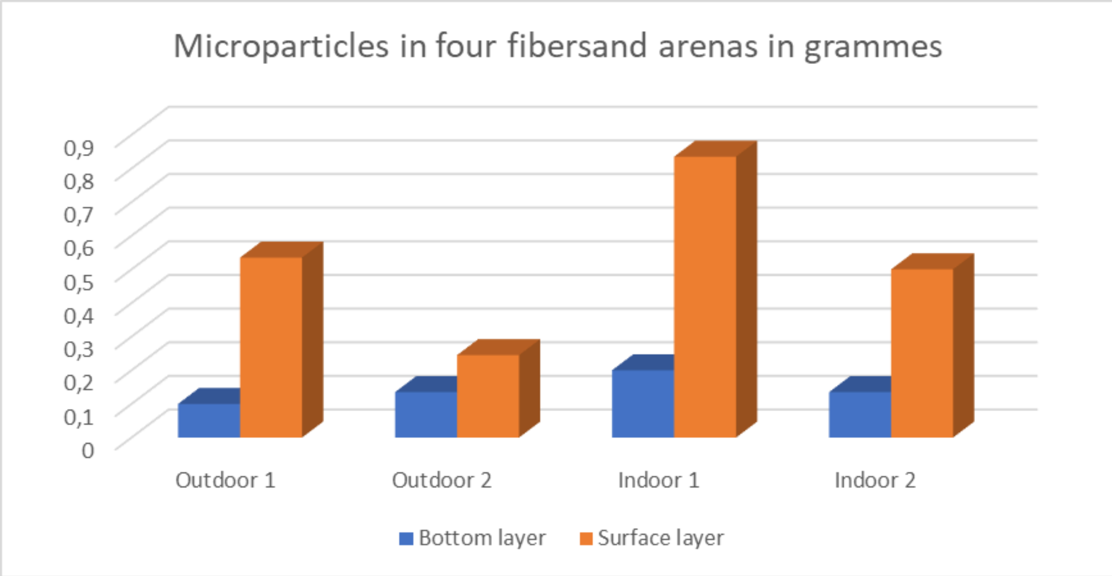

Figure 7 Mean differences in the presence of microparticles at different depths and locations in four arenas. "Bottom" is at a depth of 12-14 cm (in one sample 9 centimetres), immediately above the base layer. The surface layer is sampled from the immediate surface down 2-3 centimetres below.

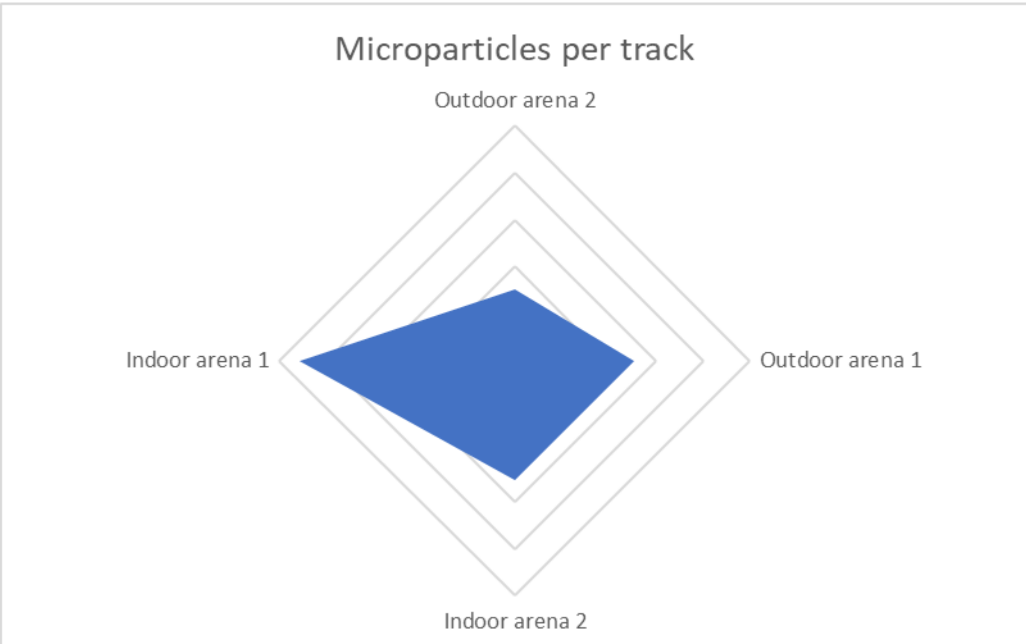

Figure 8 Differences in the mean presence of microparticles in four arenas. The Indoor no 1 has the highest year round intensity of use of all four, which entails the highest degree of wear and tear, both from the horses hooves and from maintenance machinery such as harrows and tractor tyres.

4.3.2 Microplastics in used fibresand

Samples taken for the degradation testing were also analysed for amount of microplastics per kg dry weight of sand. This showed a mean of 2,8 gram microplastics (< 5 mm) per kg sand (see Figure 9).

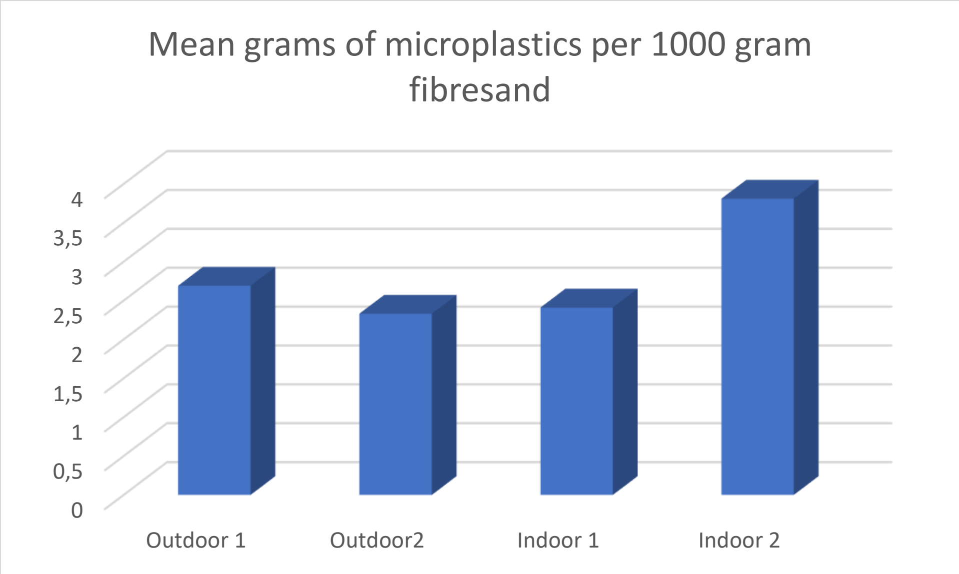

Figure 9 The mean amount of microplastics (<5 mm) in milligram per kg sand (dry weight) in four arenas installed between 2017 and 2020. The mean for all four arenas were 2,8 gram microplastics per kg.

5 Microplastic dispersal in water

The third part of the study was to study dispersal of microplastics from equestrian arenas. Dispersal of microplastics in the environment occur through contamination of both the air, water and soil. Detailed studies of dispersal from artificial turf have demonstrated granules dispersed by drainage and storm water, carried by clothing and shoes, and removed by snow plowing and other maintenance.

In this pilot study we focused on water dispersal, with a focus on a protocol avoiding environmental contamination from for example roads and housing. Concentrations of microplastic particles in air are analysed in part 4 of the study, see Chapter 6.

As drainage of water is mainly from outdoor arenas we concentrated on those. Indoor arenas seldom have separate drainage, with evaporation a prime loss of moisture.

5.1 Material and methods

For this pilot project we selected three outdoor arenas; two with fibresand and one with sand only as a control. They were selected to minimize risk of outside contamination, with a rural location. The nearest main road at distance of about 1 km and the nearest dwellings are a few hundred meter away. The arena with sand only was in a more built up area, within about 100 meters from dwellings and stables.

Samples were collected by placing filter holders at the opening of drainage pipes at the respective arenas. The holders were made from wood and wire netting (see Figure 10).

Figure 10 Water filter holders at two different outdoor arenas. The arena to the left is a sand only arena with no fibre added, used as a control. The filter at the bottom of the picture receives drainage water (pipe is shown). The filter above is an additional control, a "blank" receiving only rain water. The arena to the left had only one drainage pipe, the one to the right several, plus a "blank" (not shown). Both blanks collected microplastic particle, as did the sand-only arena drainage filter (see Table 3)

In two of the arenas, including the sand control, a second filter holder was placed alongside as a blank, receiving no drainage water but only rain water (see Figure 10). The filters were in place for three weeks in late autumn. A rain gauge was placed nearby. During this period 15 mm of rain (and some snow) fell. This equals 15 litres per m2.

The analysis was done by ALS Global in Stockholm, with FI-TR.

5.2 Results

The quantity of microplastic particles in the water filter samples were very low (Table 3). The total amount of particles collected in a period of three weeks and with 15 mm of rainfall, varied from 32 particles in the blank of a sand only arena to 304 particles collected from outdoor fibresand arena 1. The second highest amount collected was in the outdoor 2 arena blank. Some presence of polyester particles were found in all samples except from the sand only arena (number 3), where polyeten was the main material. This arena was used as a control, installed with sand only and no fibre, but none the less the filter, and adjoining blank (see Figure 10), had collected mainly and respectively polyester and polyeten particles.

Arena	Material	Polyeten	PET	Total <5mm
Outdoor 1	fibersand		272	304
Outdooor 2	fibersand		48	48
control filter			224	240
Outdoor 3	sand only	48		96
control filter			32	64

Table 3 Microplastic particles (< 5 mm) collected by filters in drainage water from three outdoor arenas during a three week period at end autumn and with 15 mm of rain. PET is polyester.

The highest number of particles (304) in the drainage water was isolated from outdoor arena 1. This equals 0.25 particles per m2 for the three week period.

The material FTIR profile of the Outdoor 1 and 2 water filters were compared with the FTIR material results of sand samples from the same arenas (see part 4 of the report). The aim was to try and determine if the polymers found in the filters corresponded to the material profile of the fibres in the arena, regarding possible sourcing of the contamination. However, the sand samples analysed was too small to represent the whole drainage area material wise and the comparison was inconclusive.

5.4 Comparative risk analysis

As data from the pilot study are limited, estimations of dispersal are uncertain. Data on fluctuations through the year would require further studies (see Chapter 9), and the fibresand arenas tested are from one single producer. Indoor arenas are excluded as they in general have no drainage, but instead moisture is released by evaporation. Data from the Swedish Equestrian Federation indicate that Sweden had 68 outdoor fibresand arenas. Meanwhile hypothetically, if the pilot data would be extrapolated as to being valid for all fibresand arenas in Sweden and annually instead of a 3 week period, and with the highest figure of 304 particles from arena 1 as a maximum, the annual drainage water release from outdoor fibesand arenas in Sweden would be 351 424 microplastic particles. If using the mean of fibresand arenas 1 and 2, and extrapolated to a total annually, the figure would instead be 203 456 particles. A possible recalculation would be 18-35 kg annually nationwide (Samiyappan M et al 2021; Leusch & Ziajchromi 2021).

One main source of microplastics release in the environment is household washing.

- One fleece garment could release approximately 110,000 fibres in one single wash (Carney-Almroth *et al* 2018
- Over 700,000 fibres could be released from an average 6 kg wash load of acrylic fabric (Napper et Thompson 2016).
- Release from a typical 5 kg wash load of polyester fabrics was estimated to be over 6,000,000, depending on the type of detergent used (de Falco et al 2018)

One example of airborne contamination of water is from Svalbard in the Arctic, where a study demonstrated > 10 000 microparticles per litre melted snow (Bergmann et al 2019). One draft of the REACH restrictions suggested a threshold of water dispersal at 7 gram per m2 arena and year. In our pilot results a maximum dispersal of 4,3 particles per m2 and year was indicated.

6 Airborne microplastics in fibresand riding arenas

The fourth part of the project was analysing possible effects of airborne microplastic particles on airways. There are occasional anecdotal reports on airways irritation from fibresand environments. This part of the pilot study had the aim to investigate how much microplastics may be present in dust from riding surfaces consisting of fibresand.

6.1 Material and methods

The study plan was to analyse possible effects on airways in horses and persons from microplastics in arena air, but this proved not possible in the limited timeframe of this pilot study. Instead, the concentration of microplastic particles in air was measured by air pumps. Air filter samples were taken during riding lessons at four different riding schools in the county of Västmanland, Sweden. Notes were made on the conditions during sampling. Each air filter was in use for three hours, during dressage lessons. Filters were divided into testing of two groups, outdoor versus indoor arenas with the same size. The filters were then analyzed by FTIR and Scanning electron microscopy (SEM) to evaluate their content.

Notes were taken regarding:

1. Activity, dressage or jumping lesson
2. Number of riders
3. Lesson time and date
4. Size of the riding arena
5. Age of the surface (when it was last replaced or refilled)
6. Subjective assessment of surface moisture (on a scale of 1-5 dry to wet)
7. Outdoor or indoor. In cases where the pumps were used indoors, it was also noted whether the riding halls were insulated or not.
8. All indoor and outdoor tracks were photographed.

Airpumps: Placement

Three SKC AirChek TOUCH Pump (SKC 2023) were used during all sampling sessions. These pumps were pre-calibrated to pump 2 L/m.

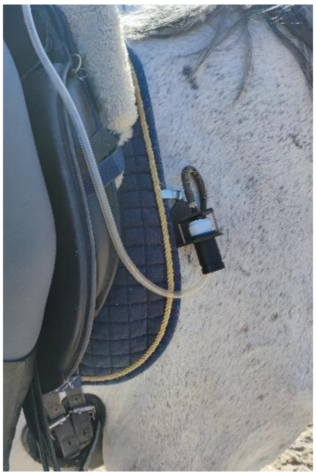

Figure 11 *Airpump placed by the rider's leg*

The riders each carried an air pump with a particle filter throughout the lesson. The pump was positioned at the rider's hip, with the filter attached to the horse's saddle pad. The filter and pump are connected by a hose.

In total there were 12 filters that were divided into four groups with three filters per group. Each filter was in use for a total of three hours, equaling an air volume of 25m3.

A random selection was made among less reactive horses (evaluated by experienced riding teacher) of who would carry the equipment. The choice of less sensitive horses was made based on a safety aspect as the pumps emit a weak sound which could be perceived as disturbing for some horses. At the end of the lesson, when the horses were lined up on the centre line, the pumps were turned off, the filters were plugged and then the equipment was removed. At any subsequent lesson, the same random selection was made.

The filters were kept closed until the beginning of the lesson and closed immediately at the end of the lesson. After the allotted time for sampling, three hours per filter group, the group of filters was placed in a labelled plastic bag and sealed.

6.2 Results

The analyses show that the air filters from both the indoor and outdoor arenas contain low amounts of microplastics, but with comparatively higher levels indoor.

In Group 4 (indoor arenas) the FTIR analysis found 12 microplastic particles per m3; 4 PET and 8 nylon. For group 2 (outdoor arenas), the amount of microplastics was below the measurable threshold value of 4 particles.

Filter Group	Date	Time	Facility	Arena size	Built/replaced	Arena	Moisture	Activity	Student count	Median Temperature
Group 1										
	2023-04-21	9:15-10:30	Facility 1	28x80	2019	Indoor*	5	Jumping	7	19,7°
	2023-04-21	10:30-11:45	Facility 1	28x80	2019	Indoor*	5	Jumping	8	19,7°
	2023-04-21	11:45-13:00	Facility 1	28x80	2019	Indoor*	5	Jumping	7	19,7°
Group 2										
	2023-04-17	9:30-10:15	Facility 1	24x60	2015	Outdoor	1	Dressage	7	14.3°
	2023-04-17	18:00-19:00	Facility 2	24x40	2017	Outdoor	2	Dressage	7	14.3°
	2023-04-17	19:00-20:00	Facility 2	24x40	2017	Outdoor	2	Dressage	4	14.3°
Group 3										
	2023-04-17	20:00-21:00	Facility 2	20x60	2021	Indoor*	2	Dressage	7	14.3°
	2023-04-17	21:00-22:00	Facility 2	20x60	2021	Indoor*	2	Dressage	9	14.3°
	2023-04-20	16:30-17:30	Facility 3	24x40	2017	Indoor	4	Dressage	8	16°
Group 4										
	2023-04-20	18:00-19:00	Facility 3	24x40	2017	Indoor	4	Dressage	8	16°
	2023-04-20	20:00-21:00	Facility 3	24x40	2017	Indoor	4	Dressage	7	16°
	2023-04-27	19:00-20:00	Facility 4	24x60	2019/2020	Indoor*	3	Dressage	6	17,1°

*Isolated indoor arena

**Moisture scale (1-5) 1: Very dry - 2:Dry - 3:Good balance between dry and wet - 4:Wet - 5:Very wet

Table 4 *Sampling sites and conditions for the air filter tests*

The FTIR analysis is confirmed by the SEM analysis. Conditions between the two groups are relatively similar in terms of weather conditions, size of the arenas, and age of the surfaces. The air filter samples from group 4 taken in indoor arenas contain more dust particles and microplastics, although the surfaces were more humid and the amount of dust in the air at the time of sampling should have been less. The reason that the outdoor arenas have the lowest air concentration of microplastic particles, below threshold levels, is believed to be the absence of containing walls.

6.3 Comparative risk analysis

In this pilot study concentrations of microplastics were low, also when compared to indoor air from residential environments. Testing indoor air in homes have found concentrations of microplastic particles from 9 ± 4 up to 1583 ± 1181 particles per m^3 (O´Brien et al. 2023), compared to 33 particles per m^3 for the group 4 indoor fibresand arenas (or values below the threshold levels for the other arenas). Group 4 results from indoor arenas can also be compared to the outdoor air in a large city with relatively low amounts of microplastic particles. Three studies have measured the concentration of microplastics in city air, in Paris, London and Hamburg. In Paris the 24-hour level per m2 was 110 (Dris et al. 2018). For the number 4 fibresand indoor arenas the equivalent number was 96. For London the figure was 771 ± 167 microplastic particles per m2/24 hours (Wright et al 2020) and for Hamburg 275 (Klein et al 2019).

A wider analysis of 124 peer-reviewed publications and industry reports of microplastics contamination of the air published in May 2023 (O'Brien et al 2023) found that the outdoor air concentration of microplastics varied between <1 and > 1000 microplastics/m3 air. Indoor concentrations varied between <1 microplastics/m3 and 1583 +-1181 (mean) microplastics/m3.

It is noted that city and home air constitutes a constant exposure, unlike that in a riding arena. The time spent in an arena will be high for a riding school teacher or coach or fulltime rider, and low for an amateur rider or riding school student.

Sports surface	Amount of granules/polymers (% < 5 mm	Annual filling up	Estimated dispersal(year)
Artificial turf	200-240 ton (100%)	6-10 ton	5,25-9.55 ton
70x105 meter			
Fibresand arena	2,4-5,9 ton(0-9.38%)	Usually 0	Negligeble *-***
20x60 meter			
*air concentration microplastic particles indoor riding arenas: 99/24 hours/ m3			
**Concentrations microplastic particles in drainage water from outdoor arena: equalling maximum 4.3 particles per m2 annually			
*** Concentration of synthetic particles < 5 mm in an arena: 0.2 %			

Table 6 *Comparison of contents of and dispersal of microplastics from artificial turf versus equestrian fibresand arenas*

7 Discussion

This pilot study is an initial attempt to quantify the presence and dispersal of microplastic particles in and from equestrian arena surfaces containing synthetic polymers. Unlike for artificial turf there are no previously published studies with laboratory data.

As a pilot and proof of principle study the data available is limited, and with that the scope for statistical testing. However, a main conclusion based on the consistent trend in all four parts of the study (raw material, fragmentation, dispersal in water and concentrations in arena air) is that the quantity of microplastics is very low in equestrian fibresand surfaces from the three producers participating in the study, and concentrations are also very low in the air of the indoor and outdoor arenas tested. Results indicate that levels of microplastics in fibresand surfaces is a fraction of that in for example artificial turf pitches, One prime example is the amount of microplastics per square meter in a fibresand equestrian arena versus an artificial turf pitch, at 0-226 g versus 11,1-26 kgs. The percentage of microplastics < 5 mm per ton fibresand varied from 0 to 0.13 %. Results also showed the content of microplastics to be in the order of a few milligrammes per kg dry weight of sand.

The same pattern of low concentrations of microplastics was seen for water dispersal from arenas, with small number of particles found both in drainage filters and microplastic and controls. Furthermore the concentration of microplastic particles in the air of riding arenas was also at a very low level. For the water dispersal testing the arenas were few but carefully selected to avoid outside contamination. In spite of this microplastic particles were found in both control filters receiving no drainage water, and a sand-only arena also used as control. The design of the filter holders was one possible source of error. It was an open shape, while a cylinder could have held collected material more safely in place and posted less risk of air contamination. One draft of the REACH restrictions suggested either a ban or a threshold of water dispersal at 7 g per m2 and year. Our pilot data results indicated a maximum dispersal of 4,3 particles per m2 and year. One example of recalculation of polyester particles into gram is 230 fibre particles/L equals 0.1 mg/L (Leusch & Ziajchromi 2021).

Although levels of microplastics were consistently low in this pilot study, one caveat is that the limited time frame meant that no longitudional work was possible. This would be needed in order to understand more of changes over time, both of fragmentation and drainage water dispersal. Further studies are needed (see Chapter 8 Future studies). One possible background of the low concentrations measured in drainage water is that the sand acts like a filter, holding the fibre material in place. Of course, a main objective of the fibre is to bind the sand.

One important observation in the laboratory handling of the raw material samples were differences in properties on an axis of elastic-stiff and fragile-robust. This merits further investigation as it is likely to influence the resistance of the material to fragmentation and possible production of secondary microplastics, and also properties of the fibresand surface.

Findings in this pilot study underline that the market for equestrian fibresand is heterogeneous, with variations in type of materials, their properties and percentage of microplastics, also within the 8 raw material samples provided for the study. This variation can be expected to be even greater in the fibresand market as a whole. Recycled materials have been one source of additives, including from the automotive industry and discarded carpet, but was not relevant here. The results described here only represent the three premium producers from the EU represented in the study, and not the fibresand market as a whole. Sampling of raw materials from additional producers would be valuable. This was part of the study design but had to be abandoned due to technicalities.

In part 2 of the study on fragmentation there were some differences between levels of microparticles, as a measure of fragmentation, between arenas and between spatial locations within each arena. Contrary to what was expected, the largest difference was between the bottom layer of corners versus bottom of centre lines. With the limited data available further testing is required, but it can be speculated that the repeated heavy loading from the horses' hooves on the centre line penetrate down to the bottom layer, unlike in the corners where horses do not move. However as expected the difference between the bottom of corners and surface layer of centre lines were close to significant. One option to improve the basis of conclusions and statistical analysis would be further sampling of the same and further arenas, plus longitudinal data.

One potential factor influencing the level of fragmentation was the age of the material, as the outdoor arenas were installed in 2017-2018 and the indoor arenas in 2020-2021. However, there was also a difference in intensity of use, with the indoors having a much higher year-round use.

One important caveat is that analysis of microplastics still lack a consensus on threshold value, analytic methods etc (Park&Park 2021).

REACH restrictions

The background of the study was the EU REACH initiative *"Annex XVII to Regulation (EC) No 1907/2006 of the European Parliament and the Council* "to reduce synthetic polymer microparticles include granular infill for use on synthetic sports surfaces". It was accepted by the REACH member countries in April 2023. The Commission adopted the restriction on September 25 2023:

"Shall not be placed on the market as substances on their own or, where the synthetic polymer microparticles are present to confer a sought-after characteristic, in mixtures in a concentration equal to or greater than 0.01 % by weight…

While the general definition of microplastics are synthetic polymer particles < 5 mm, the REACH restrictions include further definitions of what products come under the new restrictions. The criteria in the REACH restrictions are broader than the 5 mm threshold, as it also includes the definition “the length of the particles is equal to or less than 15 mm and their length to diameter ratio is greater than 3” (that is threadlike, spheric particles up to 15 mm are not affected).

Comment: This wording shows that also mixtures with very low concentrations of microplastics are subject to the REACH restrictions. In our study and one product 95,24 % of the material was above > 15 mm criteria (the dimensions length/width were not analysed). This equals 0.08 % of particles 0-15 mm by weight, so in spite the very low concentration still subject to the restrictions.

One reflection is that particles < 5 mm in a fibresand surface does not really confer a sought-after characteristic as described in the REACH document. In the samples analysed in this pilot study particles < 5 mm are rather the result of degradation of larger fragments through mechanical impact during production and handling. One exception was a product no longer used by one participating producer, that could not be fractioned but potentially consisted of 100 % of particles < 5mm. The purpose of the fibre material additive is to bind the sand and help support the horse’s hoof, and this is not achieved with the smallest particles. However it does apply to the fraction measuring 5-15 mm. Particles 5-15 mm do not fall under the restrictions if regular in shape, but if threadlike with a proportion of length vs width of at least 1/3. Such a subfractioning was not performed in our analysis.

The REACH restrictions on synthetic polymers in sport surfaces is thus very detailed, and the exact interpretations are yet to be clarified.

Theoretically a fibre raw material could be found that excludes the 0-15 mm and threadlike fraction, and if used in a fibresand mixture could then fall outside the REACH regulations. However, irrespective of definitions and threshold levels, it is important for equestrian sport to contribute to the reduction of plastics in the environment. The focus ahead needs to be researching alternative materials ahead of the 2021 ban on sales.

Microplastic pollution is an accumulation of microplastics from various sources, and therefore each one is important in its own right.

8 Future studies

While the results from this pilot study consistently found low levels of microplastics in, and dispersed in water and air from, fibresand from premium producers tested in the project, future studies would be necessary to broaden the scope of the studies and increase the amount of data. Previously there were no other laboratory data on microplastics in fibresand riding arenas available.

The REACH restrictions on synthetic polymers in sport surfaces expected to take effect in 2031 covers sales, not use. Further studies are necessary to identify and test non-synthetic alternative and more sustainable materials awaiting the 2031 restrictions on sales. (The length of the transition period was determined in order to facilitate for existing arenas to reach their end of use). Fibre is an additive that is used to improve surface function and properties, so properties of any new materials used in equestrian surfaces need to be carefully considered, prior to modification of the surface materials to reduce microplastics.

To further the knowledge of microplastics in fibresand we suggest:

- Longitudinal sampling of drainage water from a number of arenas from when they are newly installed (and investigate the optimum design of drainage filter holders/fibre traps)

Comment: Data from artificial turf studies indicate that the release of particles is greatest when the arena is new. There are some parallels in the findings of microplastic release from household washing of new synthetic clothes, which is highest when the garments are new, and the levels of microplastic release are lower after repeated washing.

- Drainage water sampling should also be repeated longitudinally, to include different levels of precipitation. This could alternatively be modelled by sampling in connection with planned irrigation, to mirror different amounts of rainfall. A period of drought and heavy use of the arena could potentially produce an aggregate of microparticles, followed by a washout with heavy precipitation. Conversely dispersal can be expected to be lower after a period of repeated rainfall and with low usage of the arena. This is relevant for the results in this pilot study, where sampling was done in late autumn and limited to a three-week period.

Indoor and outdoor arenas

- Testing microplastic content of fibre material from additional producers
- Testing longitudinal fragmentation of synthetic polymers in fibresand
- Development of alternative, non-synthetic materials that provide similar arena properties as synthetic polymers currently do
- Testing the presence of microplastics that adhere to manure from fibresand arenas and exploring optimum handling protocols

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Appendix

Definitions for REACH restrictions on sport surfaces *(Commission Regulation (EU) 2023/2055 of 25 September 2023 amending Annex XVII to Regulation (EC) No 1907/2006 of the European Parliament and of the Council concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) as regards synthetic polymer microparticles):*

Annex

"Shall not be placed on the market as substances on their own or, where the synthetic polymer microparticles are present to confer a sought-after characteristic, in mixtures in a concentration equal to or greater than 0,01 % by weight".

Synthetic polymer microparticles:

polymers that are solid and which fulfil both of the following conditions:

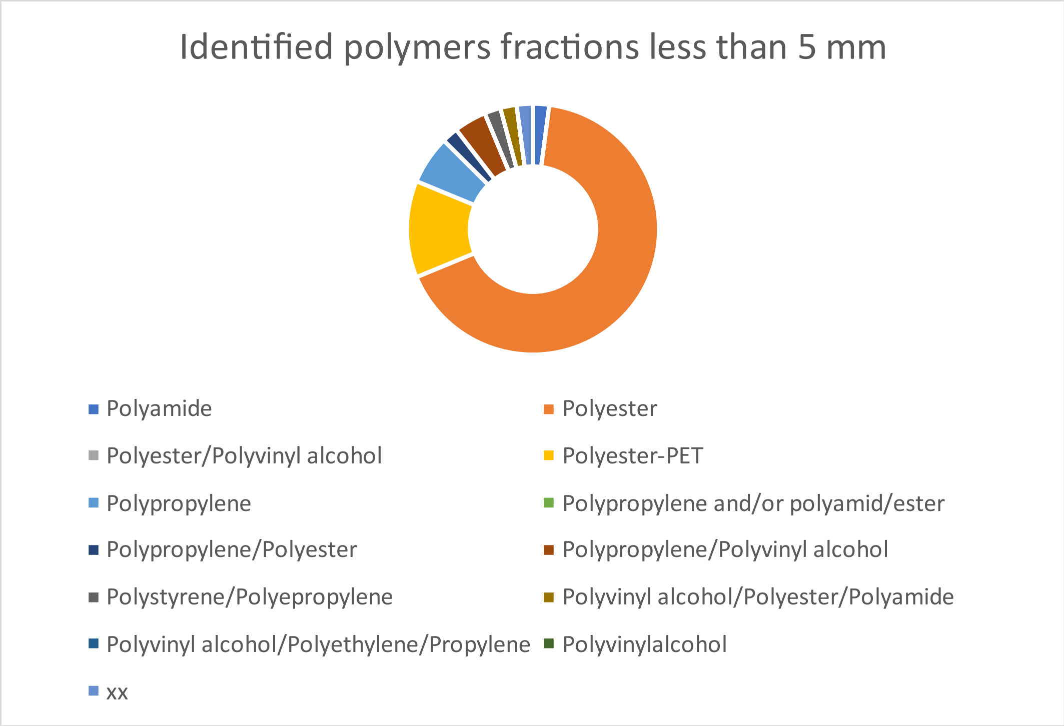
(a) are contained in particles and constitute at least 1 % by weight of those particles; or build a continuous surface coating on particles;
(b) at least 1 % by weight of the particles referred to in point (a) fulfil either of the following conditions:

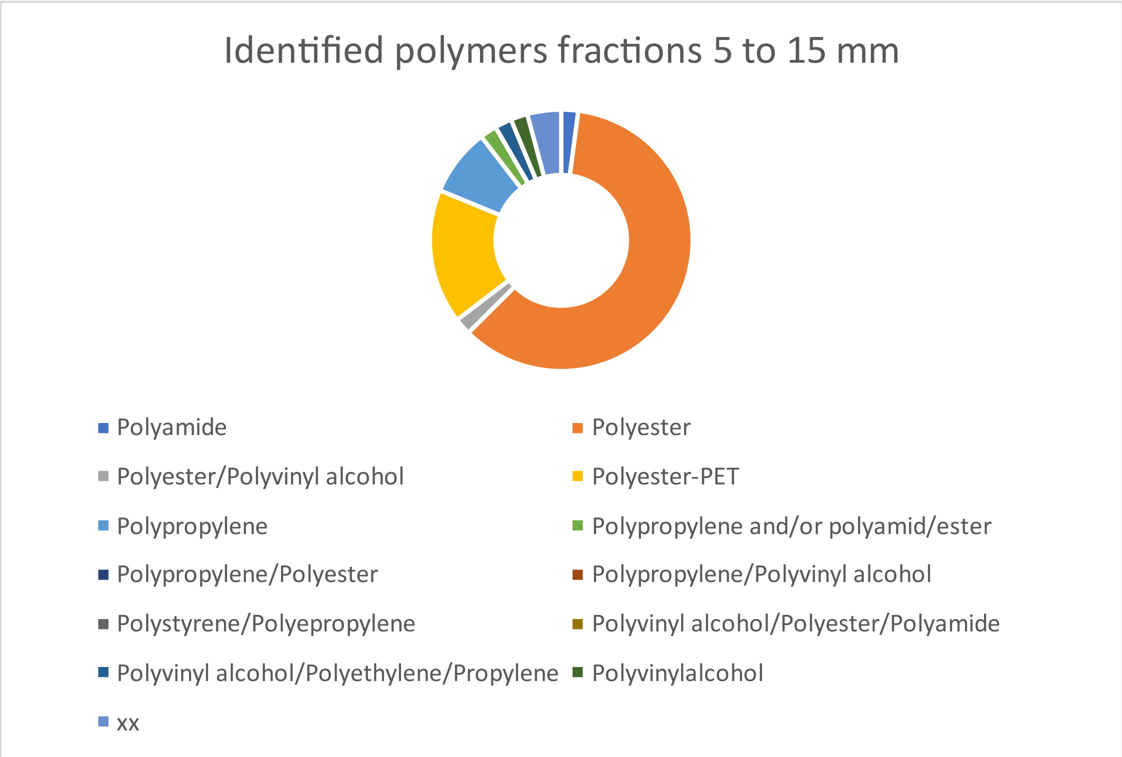
(i) all dimensions of the particles are equal to or less than 5 mm;
(ii) the length of the particles is equal to or less than 15 mm and their length to diameter ratio is greater than 3.

https://ec.europa.eu/transparency/comitology-register/screen/documents/083921/7/consult?lang=en

Example of raw material sample analysis

Material profiles for different size fractions (next page)


Identified polymers fractions less than 5 mm
Polyamide
Polyester
Polyester/Polyvinyl alcohol
Polyester-PET
Polypropylene
Polypropylene and/or polyamid/ester
Polypropylene/Polyester
Polypropylene/Polyvinyl alcohol
Polystyrene/Polyepropylene
Polyvinyl alcohol/Polyester/Polyamide
Polyvinyl alcohol/Polyethylene/Propylene
Polyvinylalcohol
xx


Identified polymers fractions 5 to 15 mm
Polyamide
Polyester
Polyester/Polyvinyl alcohol
Polyester-PET
Polypropylene
Polypropylene and/or polyamid/ester
Polypropylene/Polyester
Polypropylene/Polyvinyl alcohol
Polystyrene/Polyepropylene
Polyvinyl alcohol/Polyester/Polyamide
Polyvinyl alcohol/Polyethylene/Propylene
Polyvinylalcohol
xx