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Dispersal of microplastic from a modern artificial turf pitch with preventive measures

- Case study Bergaviks IP, Kalmar

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SVENSK DÄCKÅTERVINNING

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SUMMARY

In September 2018, a new artificial turf pitch was installed at Bergavik IP in Kalmar Municipality, largely following the Swedish Football Association's recommendations for the construction of artificial turf pitches. Several dispersion prevention measures for microplastics were applied in addition to these recommendations. Sampling and measurement of the spread of microplastics has been carried out for surface and drainage water, players and maintenance vehicles in the vicinity of the artificial turf. The measurements were carried out during the period September 2018 - October 2019. The purpose was to assess and quantify the most important pathways for microplastics. The spread has been divided into the potential spread to water and the environment respectively.

The results indicate that the dispersal to water, with dispersal prevention measures installed, was about 0.1 kg per year, about 10% of which is estimated to be granules. Dispersal to the recipient takes place from the collection well, which receives water from the other wells. Stormwater drains constituted the largest potential source of dispersal, where it was possible to capture approximately 15.5 kg per year in the granular traps in the drains.

Table A. Microplastic dispersal routes and potential dispersal to recipient before and after installation of measures

Dispersal route	***Potential annual spread (kg)***	***Spread that can be prevented (%)***	***Spread to recipient***
A. *Stormwater drains (mp > 200 µm)*	~ 15.5 kg	~ 100 %	-
B. *Surface water from asphalt (10 µm < mp < 200 µm)*	~ 0.01 kg	~ 100 %	-
C. *Drainage water from the pitch (10 µm < mp)*	~ 0.07 kg	~ 100 %	-
D. *Collection well (10 µm < mp < 100 µm)*	~ 0.1 kg *(of which approx. 10 % granules)*	0 %	0.1 kg
TOTAL*		> 99 %	**0.1 kg**

** The detection limit for microplastics in water is 10 µm with the analytical methods used. Microplastics below this size are not quantified.*

The results indicate that the spread of microplastics to the environment can be prevented using the right measures. The spread via players is measured on multiple occasions, while the spread via maintenance vehicles is based on a small number of measurements.

Table B. Microplastic dispersal routes and potential dispersal to the environment before and after installation of measures.

Dispersal route	*Potential annual spread (kg)*	*Spread that can be prevented (%)*	*Spread to environment*
E. *Players (shoes & socks)*	~ 26.8 kg	~ 100 %	Ground, greywater
F. *Maintenance vehicles (excl. brush)*	-----	-----	----
The pitch is 100% brushed when 100% dry	~ 12.4 kg [a] ~ 0,1 kg [b]	~ 100 %	Ground, stormwater
The pitch is brushed 50/50 % dry/wet	~ 24.1 kg [c] ~ 6.2 kg [d]	~ 100 %	Ground, stormwater
TOTAL		~ 100 %	-----

a) The amount is from both brushing the vehicle and then blowing with compressed air. Based on 1 measurement under dry conditions.
b) The amount is from blowing off the vehicle with compressed air after routine brushing has taken place. Based on 3 measurements under dry conditions.
c) The amount is from both brushing the vehicle and then blowing it off with compressed air. Based on 2 measurements; 1 in dry conditions and 1 in wet.
d) The amount is from blowing off the vehicle with compressed air after routine brushing has taken place. Based on 5 measurements; 3 in dry conditions and 2 in wet

The study shows that at least 99% of the potential spread of microplastics can be prevented. The annual distribution to water that is not currently addressed amounts to about 0.1 kg of microplastics of various types, about 10% of which is considered to be rubber granules.

The spread to water that could not be prevented was greatest immediately after installation and decreased over time; About 96% of the spread occurred during the first half of the year after the installation of the artificial turf, and only 4% (which corresponds to about 4 grams) was spread during the second half of the year.

One conclusion from the study is that wet weather conditions contribute to greater potential microplastics spread via players and maintenance vehicles, but that the spread regardless of weather can be prevented, provided that both players and maintenance vehicles have all microplastics brush away before leaving the facility.

Recommendations for facility owners who are in a suitable position to build are to follow the Swedish Football Association's recommendations for construction. Dispersion

prevention measures that have been identified and which are important in minimising microplastics dispersal from artificial turf are;

1) Operatives brush/blow off vehicles and implements from granules and artificial grass after each operation, and that tools are left at the field.
    a. The Swedish Football Association's training programmes suggest that artificial turf should be brushed 1-2 times a week and in dry weather.
2) Install a fence around the pitch and brush station(-s) at entrances exits and supplemented with information signs
3) Insert and maintain granule traps and/or filters in stormwater drains
4) Open water drains should be minimised and, if possible, completely avoided
5) Strategically designated surface for snow - the snow should preferably not leave the field, but if so, it should be shielded and prevented from spreading outside the fence around the pitch

The dispersion prevention measures mentioned above can also be applied to existing facilities to the extent deemed necessary and feasible.

CONTENTS

1. PURPOSE AND OBJECTIVE

The project's overall purpose is to verify that all-weather and artificial turf pitches that are constructed and maintained according to Svff's recommendations (*The Swedish Football Association's recommendations for installation of artificial turf pitches & Svff's training courses)* facilitate the work of ensuring that the granulate stays on the artificial turf pitch.

The aim of the project is to assess the spread of microplastics and substances from a modern artificial turf pitch with preventive measures, and how it relates to other sources in the runoff area.

2. BACKGROUND

2.1. *What are microplastics & how are they spread from artificial turf pitches*

Microplastic is defined according to ECHA as very small plastic particles, usually less than five millimetres (ECHA, 2019). Examples of microplastics from artificial turf pitches are rubber granulate, which is used as filling material, and wear of the actual artificial turf. The rubber granulate that is used at Bergaviks IP is called SBR (Styrene-butadiene rubber), and consists of rubber from worn out tyres which has been granulated down to a size of 1.0-2.8 millimetres.

Previous studies (Regnell, 2017) of the material flow of microplastics shows possible causes of dispersal, dispersal routes and size of the spread. References are presented in the Appendix. Regnell (2017) has shown that dispersal can take place through

1) Players after activity on the pitch
2) Operation and Maintenance
    a. Primarily through snow clearing and brushing/grooming
3) Precipitation and runoff

The study developed a flow chart to illustrate that the dispersal can be classified as distribution to different system levels, see figure 1 below. The size of the arrows does not represent the size of the flow.

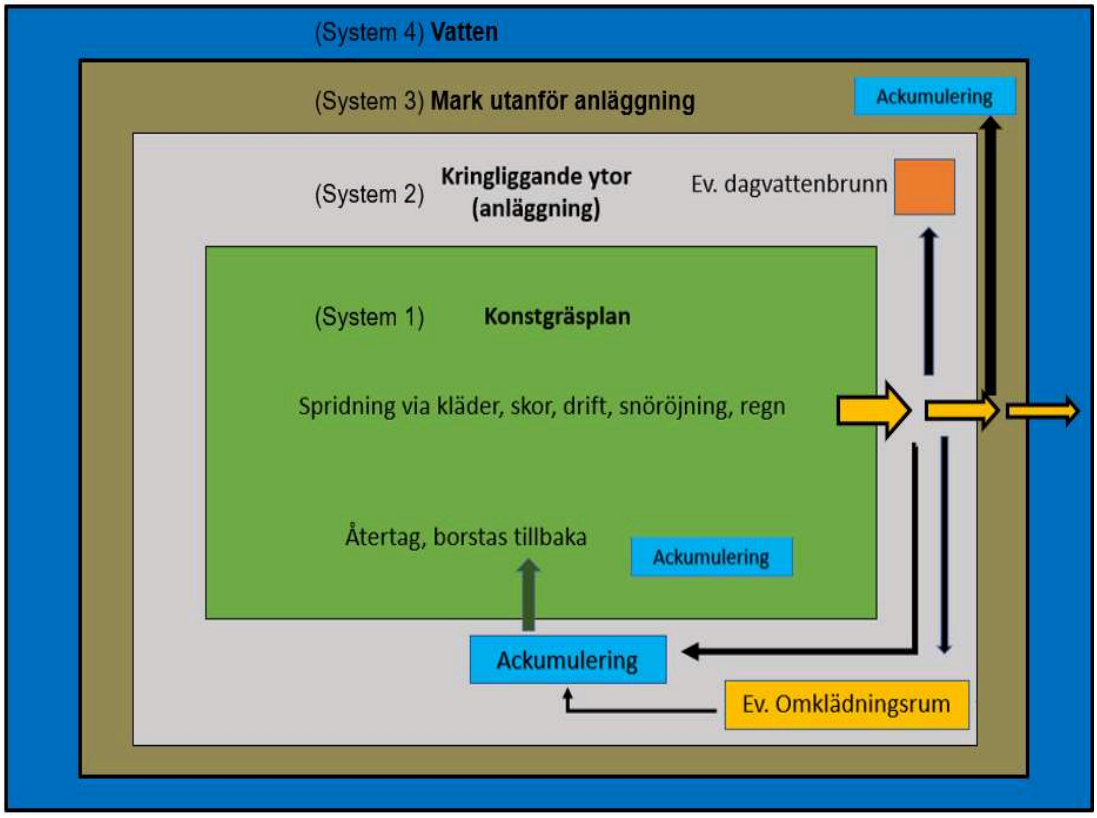

Figure 1. Causes of dispersal and inner and outer systems around the pitch. Based on Regnell (2017).

System 1 represents the actual artificial turf pitch.

System 2 is at sports grounds (e.g. Bergaviks IP) actual sports ground. The asphalt areas around the artificial turf pitch at Bergaviks IP belongs to system 2. At artificial turf pitches that are not sports grounds, system 2 is the immediate area around the pitch, inside the existing fence.

System 3 is all kinds of soil and environments outside system 2, besides aquatic environments.

System 4 is aquatic environments/recipient, for example watercourses, lakes and sea.

The protective object for microplastics is aquatic animals and organisms, which are found in system 4. The table below displays microplastics' environmental impact and effect in the different system levels.

Table 1. Microplastics' impact in different system levels.

System	Environmental impact	Comments
1	Not relevant	Here the microplastics fulfil their function and do not constitute any danger for the environment
2	Not relevant	The microplastics do not constitute any danger for the environment, but the accumulation here is a waste of resources and a possible littering problem
3	Causes	Microplastic which accumulates constitutes a waste of resources here, a littering problem as well as a potential detriment to the environment
4	Risk of adverse effects	This is the primary protective object. The microplastics constitute a risk for the aquatic environment

2.2. *Conditions and differences between suggested measure and initial situation without measures*

The study compares potential microplastic dispersal from one suggested measure, where dispersal prevention measures have been put in, with an initial situation without measures.

The suggested measure includes

- Granulate traps and filters in drains
- Brushing stations installed and players brush themselves off
- Work implements on site and maintenance vehicles that leave the facility are brushed off and blown with compressed air after each occasion

Initial situation without measures includes

- No granulate traps or filters
- No brushing station for players, players do not brush themselves off
- Work implements are on site, but maintenance vehicles leave the facility after each occasion without being brushed off

Common conditions for both cases are that:

- Comparison of the effect of brushing the artificial turf according to Svff's recommendations and at 50/50 dry/wet
- The pitch is maintained on 70 occasions over a period of one year
- The number of occasions when activities take place on the pitch per year is 16,154, which is equivalent to about 44 visitors every day throughout the year.
- Snow from the pitch is dealt with on site at the sports ground

2.3. *Dispersal prevention measures at Bergaviks IP*

The design of the artificial turf pitch at Bergaviks IP was based on the *Swedish Football Association's recommendations for installation of artificial turf pitches*. In addition to this, it was decided that the following measures would be installed in order to facilitate measurements and minimise microplastic dispersal;

- Surface water from the asphalt and drainage water from the artificial turf was separated, see figure 2 below
    - Enable measurements of separate water flows and microplastic dispersal via respective water route

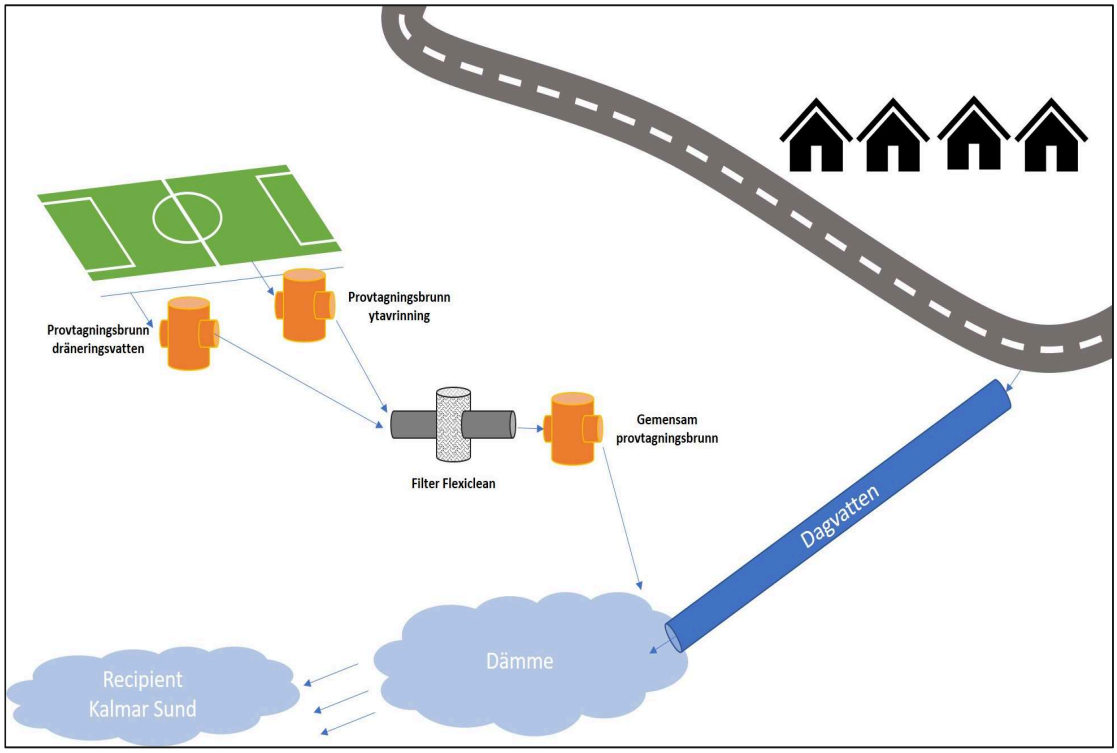

Figure 2. Simple sketch of the water's route from Bergaviks IP's artificial turf pitch

- A sealing layer was installed under the pitch to collect up all drainage water
    - Enable measurement of the drainage water flow

- Granulate traps were installed in all stormwater drains around the pitch (>200 µm), figure 3 below
    - Enable measurement of microplastic > 200 µm which reaches the open stormwater drains and is captured in the granulate traps

Figure 3. Granulate trap at Bergaviks IP

Figure 4. Granulate filter before installation in drain at Bergaviks IP

- Granulate filter which captures microplastic > 100 µm, figure 4 above
    - Prevents microplastic > 100 µm being dispersed with the surface water

- Winter lining to pile up snow on the pitch instead of hard surface
    - Minimise the spread of granulate from the pitch as a result of snow clearing

- Fence around the entire pitch with a board at the bottom against the ground
    - Minimise dispersal outside the fence along the ground

- A main entrance/exit with brushing station and information sign for players, figure 4 below.
    - Direct players to the exit and there prevent microplastics being spread from the pitch with players

Figure 5. Brushing station with info sign at entrance/exit of Bergaviks IP

- Operatives brush off vehicles (and implements) after operation/maintenance if they are to leave the ground
    - Prevents microplastic being spread from the pitch with maintenance vehicles and/or with the implements used

3. METHOD

3.1. *Dispersal routes identified*

The following dispersal routes for microplastic from the artificial turf pitch have been identified and quantified through continuous measurements and sampling:

A) Players
   a. Granulate and artificial turf that attaches to players during activity
B) Maintenance vehicle
   a. Granulate and artificial turf that attaches to vehicle during operation and maintenance
C) Stormwater drains
   a. Microplastics > 200 µm that are spread to the open stormwater drains are captured by granulate traps
D) Surface water from asphalted areas around the pitch
   a. Microplastics in the size interval mp < 200 µm are not captured by the granulate traps and are quantified in separate sampling wells
E) Drainage water
   a. Microplastics accompany the drainage water through the artificial turf and the superstructure. Particles > 10µm are then quantified in sampling wells
F) Collecting well
   a. Particles in the size interval 10 µm < mp < 200 µm are quantified in specific collecting wells
   b. The collecting wells are not dispersal routes, but rather samples in this well show how much microplastics are spread further out to the closest stormwater pool with existing dispersal prevention measures installed.

Another theoretically possible dispersal route is via wind. This dispersal route is not quantified in this project as it has not previously been established. If microplastics are spread by the wind, then the amount is judged to be very low in relation to all other dispersal routes. Microplastic that is < 10 µm in all drains and wells is not measured due to limitations in the analysis method selected and is therefore not included in the assessment.

3.2. *Comparison of environmental impact from other sources*

Sampling of metals, PAHs (so-called PAH16) and phenols was also conducted in order to obtain a better overall assessment of the artificial turf pitch's environmental impact. These samples were taken at the same sampling points and on the same occasions as the samples for microplastic.

To try to relate the discharge of microplastics, metals, PAH and phenols from the artificial turf pitch to other sources of discharge, water samples in the stormwater pool into which the water ran were also taken during the study.

Before construction of the artificial turf pitch started, three reference samples were taken in the stormwater pool to enable comparison of the contents in the pool before and after

installation of the artificial turf pitch. Analysis results are presented in Appendices 1, 6, 7 & 8.

3.3. *Method for quantification of microplastic dispersal*

3.3.1. Players

Execution & quantification

Players and coaches from various football teams have had to brush off clothes and shoes, and also empty their shoes, in a special tub. The amount of microplastics has subsequently been quantified through weighing. Based on this, an average per player and occasion has been calculated. The weather conditions on each occasion have been taken into consideration and an average for dry and wet conditions respectively has then been calculated. An average for dispersal per player and occasion has then been produced based on the anticipated weather conditions in Kalmar municipality over a period of one year (58% wet, 42% dry) (Source: My weather 2019). The average has then been multiplied by the number of occasions on which football activities have taken place in Sweden (21 million), to subsequently be divided by the number of artificial turf pitches in the country (approximately 1,300). (Source: Stff 2018).

This produces a total of 16,154 occasions in one year, which corresponds to about 44 visitors per day throughout the year. Any microplastics that occur on material, such as cones & balls, are not included. The results from dispersal via players are given in appendix 2.

Measurement occasions/Measurement period

Measurements were taken on 23 occasions during the period Oct 2018 – Apr 2019. 12 occasions were in dry weather conditions and 11 were in wet weather conditions. The total number of players included in the survey was 376 (an average of 16 per occasion).

3.3.2. Maintenance vehicle

Execution & quantification

Maintenance vehicle and implement (brush) were driven onto a tarpaulin before leaving the pitch. Measurement was then carried out in two different ways as below:

- On the first 5 occasions the vehicle and implement (brush) were routinely brushed off before they were driven up onto the tarpaulin. Compressed air was subsequently used to blow away dry microplastics.
    - 3 of these occasions were in dry weather and 2 in wet
- On the last 2 occasions the vehicle and implement (brush) were driven up onto the tarpaulin before routine brushing. The vehicle and implement were subsequently both brushed and blown off in order to collect up microplastics present.
    - 1 of these occasions was in dry weather and 2 in wet

The microplastics collected on the tarpaulin were then quantified by weighing.

According to Svff's recommendations, grooming or brushing should take place 1-2 times per week. However, brushing should not take place in rain or with a wet pitch. Kalmar municipality's operatives state that brushing the pitch when wet takes place on approximately half of all occasions. The results presented are therefore based on both 100% dry weather and 50/50 % dry/wet weather. Hardly any snow fell in Kalmar during the project period, so potential dispersal via vehicles in snow is not quantified.

Several pitches share a single brush in Kalmar municipality. The weight given in Appendix 3 therefore includes the amount of microplastic that has attached to both vehicles and brush. Two operatives employed by Kalmar municipality have stated independently of each other that about 90% of all granulate collected comes from the brush and about 10% from the vehicle. 10% of the figure measured has therefore been used for what has attached to the work vehicle on each occasion.

Kalmar municipality has registered 35 occasions on the pitch during the period Jan-Jun 2019. The number of occasions in one year has therefore been determined as 70.

The potential spread via maintenance vehicle was determined by multiplying the average for the dry occasions by 70, for the two different situations;

a) Potential dispersal in dry weather if the vehicle was *not* routinely brushed off before leaving the pitch, and the brush implement was left on the pitch
b) Potential dispersal in dry weather if the vehicle was routinely brushed off before leaving the pitch, and the brush implement was left on the pitch

Measurement occasions/Measurement period

The amount of microplastic from maintenance vehicles was quantified on a total of 7 occasions (Feb 2019 – Oct 2019).

3.3.3. Stormwater drains (granulate traps)

Execution & quantification

The granulate traps have been emptied on two occasion; March 2019 and September 2019. The amount of microplastics was determined by drying and weighing.

Measurement occasions/Measurement period

Granulate was collected in the traps on two occasions (Sep 2018 – Sep 2019). The total amount indicates the annual amount that was prevented from further dispersal.

3.3.4. Water routes - Surface water from asphalted area, Drainage water, Collecting wells and Stormwater pool

Execution & quantification

Anna Kärrman, Senior lecturer at Örebro University, has been included as quality reviewer for quantification of microplastics spread by water.

Sampling of water has taken place in the following sampling points;

a) Surface water from asphalt (surface water drain)
b) Drainage water from the artificial turf (drainage well)
c) Collecting wells (water from surface water drain and drainage well)
d) Stormwater pool (water from artificial turf and other indeterminate sources)

The area around the sampling well was cleaned prior to each sampling in order to minimise any contamination as a result of lifting the grating. Sampling took place about 5 cm below the surface of the water beside the drains' outlet pipe. An attempt was made to adapt the sampling occasions so that there would be a flow of water in the drains. This is because flowing water provides a better representation of what the spread of microplastics is actually like than stationary water, where particles may have been accumulating for an indefinite period.

Microplastic detected in respective water samples have been identified with the analysis methods SEM-EDX and FTIR, and presented as quantity, plastic type and approximate size. Microplastics identified in the water samples have been quantified using water flows measured (litre/period), size and number of particles/litre of water detected, as well as the particles assessed dry density. The analysis method does not detect microplastics < 10 µm.

The water flow for the drainage water has been continuously recorded during the period Dec 2018 – 3rd Oct 2019. The water flow for the surface water has, however, not functioned correctly, so instead the maximum potential water flow has been calculated based on precipitation and the run-off area that reaches the open stormwater drains. The run-off area is either

a) All asphalt areas around the pitch
b) The asphalt areas on the pitch's long sides
    a. There are no drains on the pitch's short sides and the asphalt slopes somewhat towards the pitch

The water flow is presented in Appendix 4.

As measurements always entail some uncertainty, a range from minimum to maximum, and most probable, dispersal of microplastics via water has been determined according to the following;

a) Minimum
    a. All microplastic particles present are of size 30x30x15 μm^3.
    b. Microplastics identified as *below the detection limit* have been counted as 0 (e.g. < 4 means 0 particles).
    c. Some of the water that reaches the asphalt infiltrates through the artificial turf instead of reaching open stormwater drains.
b) Maximum
    a. All microplastic particles present are of size 80x80x15 μm^3.
    b. Microplastics identified as *below the detection limit* have been counted as the detection limit/2 (e.g. < 4 means 4/2 = 2 particles).
    c. All water that reaches the asphalt ends up in open stormwater drains.
c) Most probable
    a. All microplastic particles present are of size 55x55x15 μm^3
    (Based on oral communication with E. Hålenius at ALS, who conducted all analyses)
    b. Microplastics identified as *below the detection limit* have been counted as 0 (e.g. < 4 means 0 particles).
    c. Some of the water that reaches the asphalt infiltrates through the artificial turf instead of reaching open stormwater drains.

The results in the next section present this range, where the figure that is regarded as the most probable is at the top and the range below is in brackets.

Measurement occasions/Measurement period

Sampling was conducted on 8 occasions during the period Sep 2018 – Oct 2019, plus three reference samples in the stormwater pool during May 2018 – Aug 2018.

In total, the following number of samples was taken at the four different sampling points;

Surface water from asphalt – 9 samples

Drainage water from the artificial turf – 8 samples

Collecting wells – 9 samples

Stormwater pool – 10 samples

4. RESULTS

4.1. *Microplastic dispersal to water*

Analysis results of microplastics are given in Appendix 1.

The potential spread of microplastics to water is based on the suggested measure and the initial situation without measures, described in section *2.2 Conditions and differences between suggested measure and initial situation without measures,* reproduced in table 2.

Table 2. Potential dispersal of microplastics to water

Dispersal route	Potential dispersal per year based on suggested measure	Potential dispersal per year based on initial situation without measures
A. Stormwater drains (mp > 200 µm)	~ 0 kg	~ 15.5 kg
B. Surface water from asphalt (10 µm < mp < 200 µm)	~ 0 kg	~ 0.01 kg
C. Drainage water from the pitch (10 µm < mp)	~ 0 kg	~ 0.07 kg
D. Collecting wells (10 µm < mp < 100 µm)	~ 0.1 kg	~ 0,1 kg *(0,030 – 0,225 kg)**
TOTAL	**~ 0.1 kg**	**~ 15.6 kg**

**Represents minimum and maximum possible dispersal of microplastics based on calculations in section 3.3.4*

The table clearly shows that the bulk of microplastic dispersal to water can be prevented with the right measures.

The diagram below shows the proportion of different plastic types that are dispersed to water from the pitch.

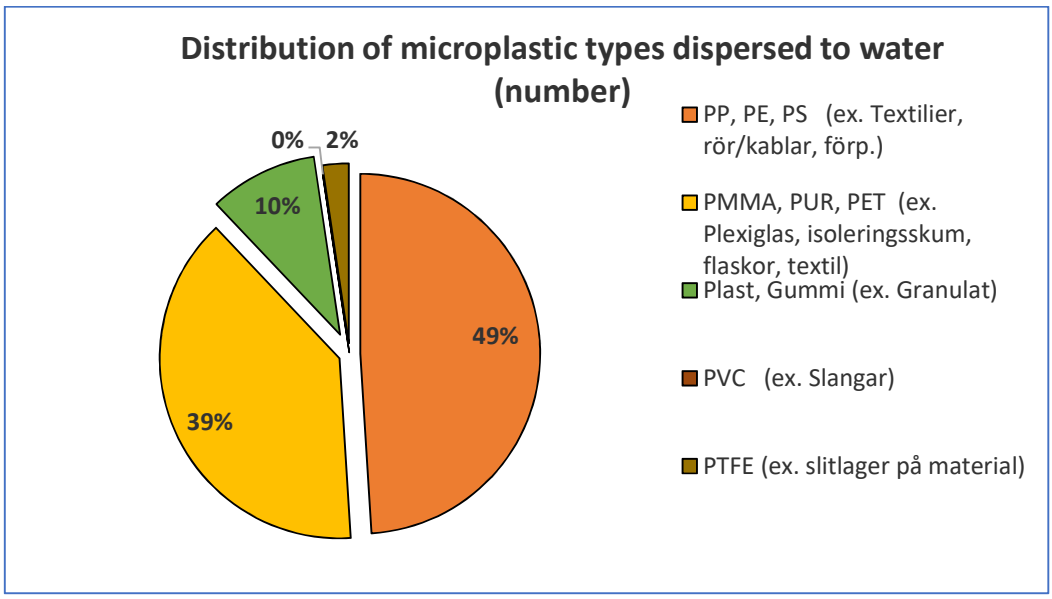

Figure 6. Distribution of microplastic types dispersed to water

The dispersal of microplastic to water that the project was not able to prevent amounts to about 100 grams, with around 10% judged to be rubber. To provide further clarity regarding the dispersal, the diagram below shows how large the spread was in the first and second six months respectively after the installation of the artificial turf pitch.

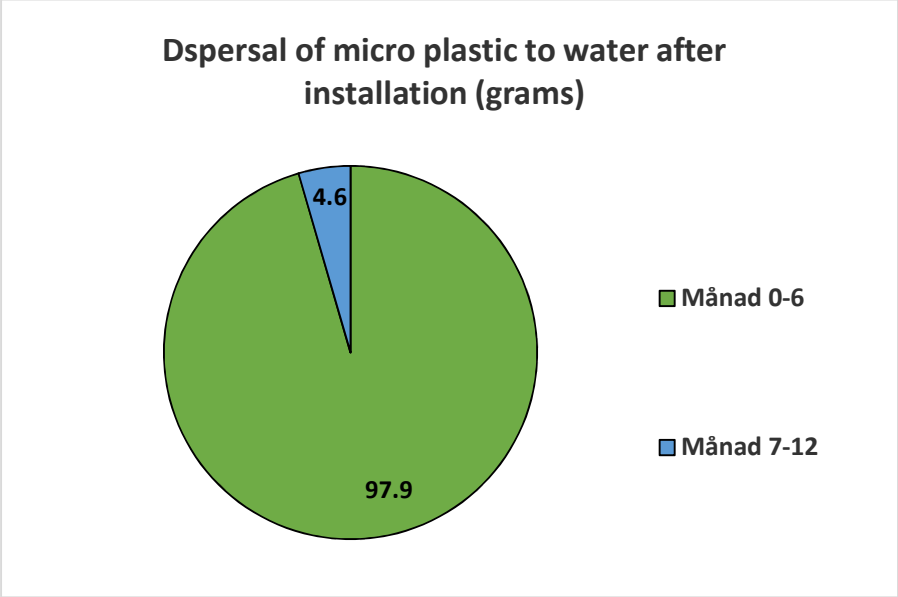

Figure 7. Dispersal to water biannually after installation.

It is clear that the dispersal of microplastics to water, which was not stopped by the granulate traps and filter, decreased over time. The proportion of microplastic which can be rubber also decreases, as shown in the table below.

Table 3. Dispersal of microplastic per six months after installation

Type of microplastic	Dispersal 0-6 months (g)	Dispersal 7-12 months (g)
All microplastic	97.9 g	4.6 g
Rubber	10.5 g	0.1g

The clear reduction in microplastic dispersal can be due to contamination of the water pipes as a result of the installation of the artificial turf pitch. About half of the microplastics identified were of the types Polypropylene (PP), Polyethylene (PE) and/or Polystyrene (PS), which can derive from pipes, cables, textiles and packaging. However, establishing the origin of all microplastics' requires more extensive research.

4.1.1. Microplastics in stormwater pool

Microplastics are present in the stormwater pool in generally higher concentrations than in the water that leaves the artificial turf pitch. Both in the reference samples before the artificial turf pitch's installation and during the course of the project. The exception is the two last samples when very few microplastic particles were found, which was due to the fact that it was only possible to filter a small amount of water as a result of a lot of organic material in the water.

In consultation with Anna Kärrman, Senior lecturer at Örebro University, it was established that more extensive studies are required to be able to draw clear conclusions on microplastic dispersal to the stormwater pool. Based on the samples that have been taken, it can however be observed that

a) The stormwater pool contains microplastics
b) The microplastics present are of a different origin and occur in different concentrations depending on sampling occasion
c) It is not possible to establish what the primary sources of microplastics in the stormwater pool are, but there is a low probability that the artificial turf pitch is a significant source

4.2. *Microplastic dispersal to surroundings*

Results for dispersal via players are provided in appendix 2 and for maintenance vehicle in appendix 3.

The potential spread to the surroundings based on initial situation without measures and with suggested measure, described in section *2.2 Conditions and differences between suggested measure and initial situation without measures,* is reproduced in table 3.

Table 4. Potential dispersal of microplastics to surroundings

Dispersal route	Potential dispersal per year based on suggested measure	Potential dispersal per year based on initial situation without measures
A. Players (shoes & socks)	~ 0 kg	~ 26.8 kg
B. Maintenance vehicle excl. implement (brush)	-----	-----
Brushing 100% on dry pitch	~ 0 kg	~ 12.4 kg [a] ~ 0.1 kg [b]
Brushing 50/50% on dry/wet pitch	~ 0 kg	~ 24.1 kg [c] ~ 6.2 kg [d]
TOTAL	**~ 0 kg**	**Maximum ~ 51 kg**

a) *The amount is from both brushing the vehicle and then blowing with compressed air. Based on 1 measurement in dry conditions.*

b) *The amount is from blowing off the vehicle with compressed air after routine brushing has taken place. Based on 3 measurements in dry conditions.*

c) *The amount is from both brushing the vehicle and then blowing it off with compressed air. Based on 2 measurements; 1 in dry conditions and 1 in wet.*

d) *The amount is from blowing off the vehicle with compressed air after routine brushing has taken place. Based on 5 measurements; 3 in dry conditions and 2 in wet.*

The results in appendix 2 & 3 show that in wet weather on average approximately 3 times more granulate attached to both players and maintenance vehicle as in dry weather. Brushing away microplastics is thus especially important if matches and maintenance take place in wet weather.

The diagram below shows how large a proportion the respective dispersal route constitutes of the total potential distribution.

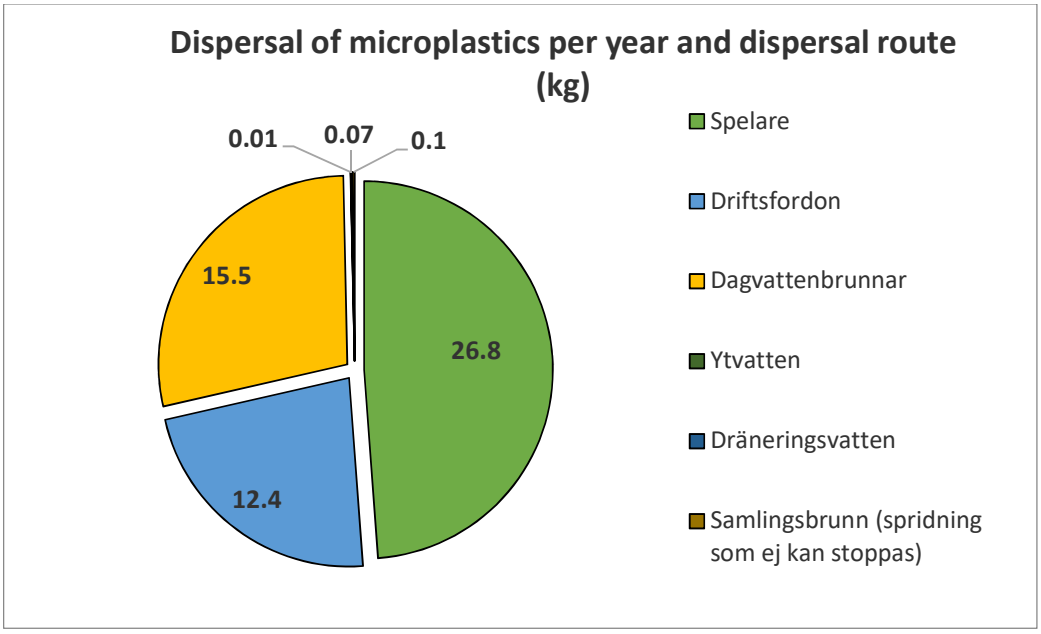

Figure 8. Microplastic dispersal for respective dispersal route

In connection with quantifying the different dispersal routes, it has been observed in the project that it is possible to prevent the bulk of microplastic dispersal with the right measures.

4.3. *Metals & elements*

Metals and elements were primarily analysed in order to identify potential leaching from the artificial turf pitch and the material from which it was constructed. Metals were analysed after filtration to identify metals dissolved in the water. The metals which stand out to some extent are copper and zinc. The analysis results are given in Appendix 5.

The table below gives the increased contents in respective sampling point. The contents are compared with Västerås' surface water policy (Surface water policy in Västerås, 2014), which set the following guidelines; Copper (Cu) – 40 µg/l & Zinc (Zn) – 150 µg/l.

Table 5. Increased metal contents in different sampling points.

Sampling point	Number of samples	Copper	Zinc
Surface water from asphalt	9	No sample with increased content, though approx. 20 microg/l on average	All 9 samples with increased content
Drainage water from artificial turf	9	1 sample with increased content, 8 samples well below guideline	No sample with increased content
Collecting well	9	1 sample with increased content, 8 samples well below guideline	1 sample with increased content, 8 samples well below guideline
Stormwater pool	11	No sample with increased content	No sample with increased content

Based on the table above, it is clear that the surface water from the asphalt contains higher contents of Zn and Cu than the water in the other sampling points. It has not been possible to establish the reason for this in this study, but it is judged to be due to, for example;

- Increased contents as a result of leaching from fence, galvanised posts and steel base beside the artificial turf pitch
- Leaching from granulate in granulate traps
- Leaching from other material in and around the artificial turf pitch
- Contaminants from maintenance vehicle

Establishing the source of the metals Zn and Cu will need more extensive sampling. However, it is noted that the water that leaves the artificial turf pitch, i.e. the sampling point *Collecting wells*, only has 1 sample with increased contents and 8 samples well below existing guidelines.

The zinc contents can theoretically be used to determine the highest theoretically possible dispersal of the rubber granulate SBR, which could also include particles < 10 µm. However, this cannot be used in this study as the metal contents identified are post-filtration, which means that the metals are dissolved in the water. Zinc can occur dissolved in water, bound in the rubber granulate SBR or in minerals. What the distribution at Bergaviks IP is like has not been determined in this project, more detailed tests are needed for this. Neither was reference sampling of rain water performed in the project, which would have clarified the picture of what is spread from the artificial turf pitch and what is already in the water.

4.4. *PaH*

All PaH-contents were either below the detection limit or well below the existing limit values, in all sampling points. Analysis results are given in Appendix 6.

4.5. *Phenols*

Phenols were below the detection limit in all sampling points, on all occasions. Analysis results are given in Appendix 7.

5. CONCLUSIONS & RECOMMENDATIONS

The study shows that the bulk of the potential microplastic dispersal from artificial turf can be prevented. The spread can be controlled by construction and maintenance, as well as by users of the pitch. Sampling and analyses carried out indicate that the spread of rubber granulate from the artificial turf pitch via water routes is limited provided that protective measure such as granulate traps and filters are installed, and that players and vehicles are exhaustively brushed off before leaving the pitch. The dispersal of microplastics to water which would currently *not* be prevented amounts to approx. 100g per year, approx. 10% of which is judged to be rubber granulate. It was, however, not possible to quantify microplastics < 10 µm with the analysis methods used and they are consequently not included.

The spread to water that could not be prevented was greatest directly after installation and decreased over time; approx. 96% of the spread occurred during the first six months after the artificial turf was installed and only 4%, (which corresponds to approx. 4 grams) has been spread during the second six months.

A comparison with other sources of discharge shows that microplastics are to be found in varying concentrations in the stormwater pool into which the water from the artificial turf pitch runs. More extensive sampling is needed to be able to draw conclusions on the stormwater pools' microplastic contamination from other sources.

The conclusions from the study are;

- Wet weather conditions contribute to higher potential dispersal of microplastic via players and maintenance vehicle. Protective measures are therefore particularly important in wet conditions. Protective measures are also judged to be important in snowy conditions, however, the lack of snow during the project period has meant that potential dispersal in such occasions has not been quantified
- The right protective measures in the right place can reduce an artificial turf pitch's microplastic discharge to a few grams per year

Recommendations for facility owners which intend to build are to follow the Swedish Football Association's recommendations. Dispersal prevention measures that have been identified and which are of importance to minimise microplastic dispersal from artificial turf are;

1) Operatives brush/blow off vehicle and implement from granulate and artificial turf after each operation, and that tools are left on the pitch
    a. Artificial turf should be maintained in dry weather, in accordance with Svff's artificial turf training.
2) Fence around the pitch as well as brushing station(s) are installed at entrances/exits and are supplemented with info signs
3) Granulate traps and/or filters are inserted into stormwater drains and maintained
4) Open stormwater drains should be kept to a minimum and, if possible, avoided altogether.
5) Strategically designated area for snow – the snow should preferably not leave the pitch, but if this is the case, it should be screened off and prevented from spreading outside the fence around the pitch

The dispersal prevention measures mentioned above can also be beneficially applied to existing facilities to the extent deemed to be necessary and feasible.

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