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# Determining the effectiveness of Risk Management Measures to minimize infill migration from synthetic turf sports fields

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# Content

# Preface

This report was prepared by Tech licentiate Simon Magnusson and Tech Dr Josef Mácsik. Simon Magnusson has worked for many years on issues related to environmental aspects of construction and building materials and for the past seven years Simon has conducted several studies on environmental aspects of synthetic turf fields, involving both life cycle assessment and assessment of local environmental impacts due to leaching and microplastic emissions. Simon Magnusson is an industrial PhD student at Luleå University of Technology within the area of environmental systems analysis and civil engineering.

Dr. Josef Mácsik works in the field of geotechnology / environmental chemistry for granular materials in construction. Josef Mácsik works with the development of methods and guidelines for assessing the environmental and geotechnical performance of construction with recycled materials.

Simon Magnusson and Josef Mácsik are employed by Ecoloop, a company that develops sustainable solutions for the societies needs together with academy, industry, and stakeholders.

The report was commissioned by the European Synthetic Turf Council (ESTC), with the brief that they wished to assess the effectiveness of Risk Management Measures in minimizing the risk of infill migration from synthetic turf sports fields into the natural environment.

# 1. Summary

The use of synthetic turf sports fields sports fields has grown significantly throughout Europe since the development of long pile, rubber infill surfaces in the early 2000s. The fields are used due to their ability to sustain far greater levels of use and in a much wider range of climatic conditions than natural grass.

Due to the huge popularity of football, this sport is the principle users of synthetic turf sports fields. Other sports that use these types of surface include rugby, American football, Gaelic games and hockey.  Synthetic turf fields are now used at the professional levels of sport in some countries and at the community level in all countries.  The fields may be full size or mini-pitches used for training and community participation.

The fields are made of synthetic turf carpet with a plastics pile that is designed to replicate the appearance and playing characteristics of real grass. The pile of the carpet is partly infilled with Elastic (performance) infill made of rubber/plastics granulate. The infill is used to improve player performance, ensure adequate comfort and protection to players when they fall, and to increase the longevity of the fields. The infill is usually in the size of 0.5-3 mm and therefore falls under the definition of a microplastics developed by the European Chemical Agency (ECHA).

The use of infill in synthetic turf fields has caused concern due to the risk of it spreading to the environment. To minimize this risk the ECHA are proposing that the use of these infills is either banned or fields are required to contain the infill on the fields and prevent its loss to the environment.

In a number of countries were communities have expressed concerns about infill migration Risk Management Measures (RMM), based on containing the infill have been developed. These techniques have subsequently been reviewed and formalized in a technical report published by the European Standards Committee (CEN Technical Report TR 17519).

The aim of this study is to present a way to monitor the effectiveness of turf infill containment. Literature was reviewed to describe the infills function and its properties and to gather data from field measurements of infill transported by maintenance equipment, surface water runoff, players etc. and used to quantify the extent of infill migration due to common activities on turf fields.

Activities during use and maintenance lead to transportation of infill, these include relocation on the fields and infill being carried off the fields mainly by shoes/clothes, maintenance equipment, or by water.

Due to large differences in how turfs are managed and maintained in Europe, it is difficult to quantify a pan-European mean infill loss from synthetic turf fields. Infill movement and migration occur at all fields. However, by having control over the infill movement the infill can be prevented from getting into zones where it cannot be controlled and maintained.

A field comprises three zones:

- The synthetic turf field (playing area and run-offs) where the infill is meant to be,
- Areas such as surrounding paving, storage compounds for maintenance equipment, shoe cleaning stations and storm water drains where the infill can accumulate but is still controlled as it is contained.
- Areas where any infill entering them is uncontrolled and this may lead to the infill contaminating the environment.

Despite the site-specific variety of maintenance practices undertaken on European synthetic turf fields, this study estimates that infill migration can be controlled by up to 97 % and uncontrolled infill transport can be reduced to below the 7g/m$^2$ proposed by ECHA's SEAC committee with relatively easy measures such as using containment barriers, good maintenance routines and improving player hygiene.

A risk management approach has been used to develop a methodology for improving infill containment efficiency. Activities and events that may cause infill loss during the life cycle of synthetic turf fields have been identified. The severity (quantity) of infill loss from each events/activity is evaluated. Containment measure effectiveness, and the responsibility for monitoring measures (maintenance personal, players, etc.) is identified and described for each event.

The risk management approach shows that for many events that may lead to infill loss, the risks can be eliminated, e.g. appropriate field boundary barriers, filters in surface water drains, handling of infill bags, and appropriate handling and storage of maintenance equipment. Other events such as infill being carried by shoes and clothes cannot be eliminated but can be controlled by the use of shoe cleaning stations and decontamination gates at entrance ways. It is recommended that as more field are built, they should incorporate the risk management measures detailed in CEN Technical Report TR 17519. Consideration should also be given to retro-fitting them to existing fields.

# 2. Background and problem definition

## 2.1. Football and synthetic turf in Europe

Football is one of the most popular sports in Europe. Football fields are used by both professional footballers but are also widely used by the public. Many football fields are now made of synthetic turf instead of real grass since synthetic turf is more durable. Higher durability means that synthetic turf fields can be used by more people than natural grass fields.

A conventional synthetic turf field consists of following components: A plastics carpet with plastic fibers, a sand material that stabilizes the carpet and an elastic rubber/ plastic infill material that provides softness and improves player performance so it is similar to natural grass fields.

## 2.1. Microplastics in synthetic turf fields

The rubber and plastic infill used in synthetic turf fields are intentionally added to the playing surface and are smaller than 5 mm so fall under the definitions of the microplastics restrictions being developed by ECHA. The use of such infill has raised questions regarding the potential spread of microplastics to the environment. Studies indicate that microplastics spreading are strongly connected to maintenance practices and containment measures and that there is potential for improving the management of many turf fields (Regnell 2019, IVL 2019). However, prior to this study there was limited compiled knowledge about how to control and monitor infill containment measures.

## 2.2. Aim and objective

The aim of this study is to present a way to monitor the effectiveness of turf infill containment. The objectives are:

- Define what are the typical conditions for the use of synthetic turf fields
- Describe the typical ways infill is transported from synthetic turf fields and the effectiveness of infill containment, in quantitative terms, can be to reduce this under typical conditions
- Develop and describe a methodology for monitoring the effectiveness of infill containment

## 2.3. Methodology

Methodologies for quantifying microplastics spreading from synthetic turf were reviewed. Data from estimations and measurements of microplastics spread were collected. A risk management method has been developed and used for sorting and prioritizing activities and events that may cause microplastics spreading. Literature was reviewed for identifying infill containment measures and how to monitor infill containment efficiency.

# 3. Introduction

## 3.1. Components of a synthetic turf surface

Most synthetic turf fields used today are third generations synthetic turf fields, so called 3G systems. An illustration is given in Figure 2. A 3G system consist of a long pile plastic carpet with sand infill providing stability of the carpet, and elastic, polymeric infill providing softness and player performance. The height of the carpet pile is typically between 50 and 60 mm but can be lower when a shockpad is used. Before the turf system is laid out, a subbase of aggregates and drainage is installed. This may include an asphalt layer. Sometimes an elastic mat, a shockpad, is installed on top of the base. The shockpad provides additional impact attenuation to protect players.

Infill is transported from the supplier to site in bags (normally 1 ton big bags). When it is being installed the infill, is spread using specialist infill spreading equipment, often pulled by a tractor.

The vast majority of synthetic turf fields are built for community use and therefore replace natural grass fields.  This means they are not surrounded by infrastructure such as spectator seating, etc. The fields can be full size (typically around 7125 $m^2$) or be small training or small-sided football areas.

A small number of synthetic fields are built indoors.  Likewise, a small number are located within professional stadia, in both cases the field is isolated from the surrounding environment and infill migration from these fields is much lower and easier to control.

In some regions of Europe paved areas are often constructed on the side edges of the turf field surface to keep the field clean from soil or mud. (Magnusson & Macsik 2017). In other regions the synthetic turf is laid up to the perimeter fence of the field, possibly with a maintenance strip outside the fence.

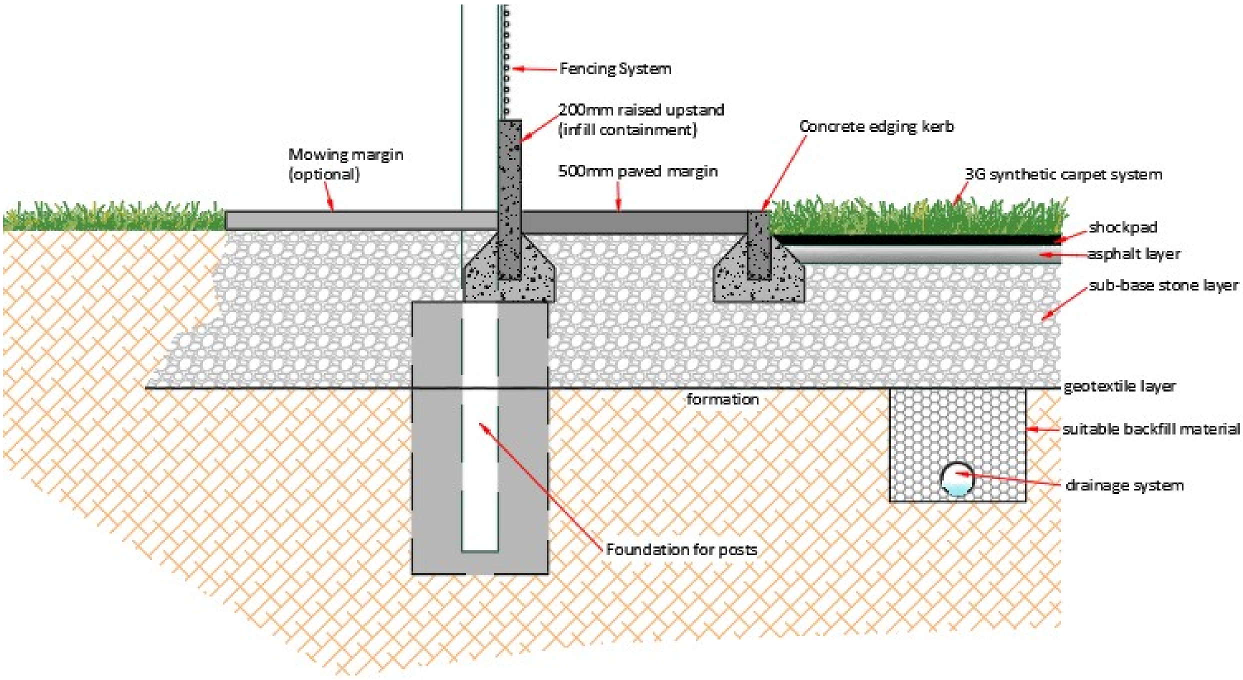


*Figure 1. Typical construction of a synthetic turf field*

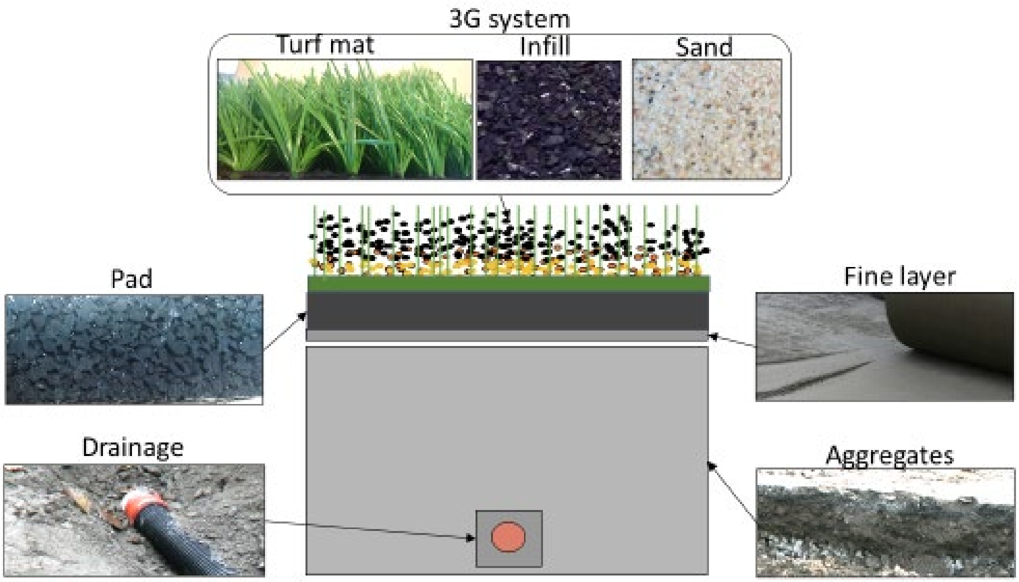


*Figure 2. Components of a synthetic turf surface. Modified from Magnusson & Macsik (2017)*

## 3.2. Maintenance for field performance

Maintenance is necessary to provide good player performance and increase the life span of the synthetic turf system. The physical impact on the turf field from players relocates and compacts the infill material in the turf mat, and the turf fibers (pile) tend to flatten and curve. These effects will be largest in frequently used areas of the field such as the goal areas. At frequently used areas of the fields the infill depth may decrease as the infill compacts, but it also tends to move towards the sides of the field, where it accumulates. (Forrester & Tsui, 2014)

The infill therefore needs to be loosened up, i.e., decompacted, and evenly redistributed over the field, and the turf fibers needs to be kept straight to keep player performance and prevent a shortening of the lifespan of the field. By decompacting, using tines (harrowing), the field, the infill is loosened and by brushing the infill is redistributed evenly. Infill that has moved and accumulated on the sides of the field is brushed back into the central portions of the field. If the pile fibers are let to flatten it will be difficult to restore them since the maintenance brushes will slide on the surface of flattened yarns rather than raising them. Flattened piles result in permanent damage of the field and it makes maintenance practices less efficient (Forrester & Tsui, 2014). Maintenance needs for most synthetic turf fields in Europe are brushing to remove litter and lifting the carpet pile, decompacting (harrowing) to loosen the infill and grooming to redistribute the infill.

The initial concerns about infill migration and contamination of the environment came to public attention in 2016, predominantly in Scandinavia, because of snow clearance, (which can lead to removal of infill from fields in large quantities (IVL 2016).

When the temperature is falling and moist sand and infill is freezing, turf fields become firm which increase the risk of injuries for the players. By using de-icing salt, the risk of freezing in many countries can be removed. Thin depths of snow from light snowfalls can be thawed with salt or by just playing on the fields (SvFF 2020).

Thicker layers of snow need to be cleared from the fields by ploughing. By adjusting the plough distance to the turf carpet, the amount of infill that gets removed with the snow can be reduced and abrasion on the turf fiber can be avoided (Magnusson 2015). Remaining snow can then be melted with salt or by players. Fields clearing snow usually store snow on the outer parts of the field or on designated areas close to the turf field (Ramboll 2017). When stored snow has melted, the infill can be put back to the field. To avoid the physical impact on turf carpet from ploughing tractors transporting snow, it is important to limit the weight of snow carried in tractor buckets.

In total, there are about 52 000 fields in EU (Eunomia 2018). Only 4 % are located in Finland (250 fields), Sweden (1190 fields) or Norway (800 fields) where snow handling may be a part of maintenance (ECHA 2017). From a study by Ramboll (2017) about 60% of Norwegian synthetic turf fields were cleared of snow. This indicates that snow clearing is a specific issue for a relatively small percentage of the European synthetic turf fields in general, probably around 2 % of all fields.

### 3.3. Typical field design and use

The design of synthetic turf fields varies depending on the intended user (schools, professional use, public use) and local conditions such as available space. Some design examples are given in Table 1 and Table 2.

*Table 1. Examples of current field constructions*

| | |
|---|---|
|  | Full size field. Synthetic turf laid to perimeter fence. |
|   | Full size field. Spectator zone between synthetic turf and field boundary |

| | |
|---|---|
|  | Field with narrow paved area between synthetic turf and field boundary |
|  | Pitch with synthetic turf laid to boundary, paved area outside fence line |
|  | Small sided football pitch, synthetic turf to boundary |

<table>
<tr><td></td><td rowspan="2">Semi-professional football club stadium</td></tr>
<tr><td>
</td></tr>
<tr><td></td><td>Dutch Premier league stadium</td></tr>
</table>

| | |
|---|---|
|  | Indoor pitch - frame fabric structure |
|  | Indoor pitch |
|  | Infill removed with snow |

*Table 2. Examples of field constructions with infill RMM (containment measures incorporated).*

<table>
<tr><td></td><td>Barriers preventing infill loss from field</td></tr>
<tr><td></td><td rowspan="2">Small sided pitch with barriers around perimeter</td></tr>
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| | |
|---|---|
|  | Decontamination grates and boot cleaning brushes at entrance |
|  | Decontamination grates at entrance |
|  | Boot cleaning brushes |

| | |
|---|---|
|  | Filter drain between synthetic turf and boundary<br><br>Accumulation zone between field and natural ground |
|   | Drain filters |
|  | Snow storage area with barrier adjacent to field |

## 3.4. Function and material properties of infill

A 3G synthetic turf surface will normally have between 15 and 20 mm of the carpet pile standing above the infill layers.  To keep turf fields in good condition, infill is added to the turf carpet. The thickness of the infill layer depends on turf carpet design and length of the turf fiber. To keep optimal player performance and field durability it is important to maintain the optimal infill layer thickness. Infill usually consist of rubber granulates of different sizes between 1-3 mm. The granulates are often made from recycled and shredded car tyres. Rubber infill have a specific density around 1,16 gram/cm3 which makes the material less mobile in water since it will sink (Løkkegaard et al 2019).

### 3.4.1. Infill compaction

With use, some granulates will relocate and the smaller granulates will fill the voids between larger granulates which results in a reduction of the total infill bulk volume. This phenomenon is called compaction. Lab studies of rubber infill compaction in long pile synthetic turf fields shows that the weight and load from players contribute to the infill material compacting. If synthetic turf fields are not maintained (i.e. no harrowing), the loss in infill depth due to compaction need to be compensated by refilling with more infill, see Figure 3, where 1 cycle equals the physical impact on the turf field from one football player passing by (playing). Infill depth is the thickness of infill layer. Data for compaction effect is gathered from Fleming et al (2015). Refilling needs were calculated by using a bulk density of rubber infill of 0,5 ton/ m3 and the area of a full-size football field. Even well-maintained field experience compaction. These results are in line with information from field owners who experience refilling need of about totally 10 ton infill during the first 3 years from installation (Norges Fotballforbund 2020). 10 tons of refilling increase the thickness of the infill layer by about 2,8 mm. These findings show that infill refilling quantities are not a useful measure for infill loss.

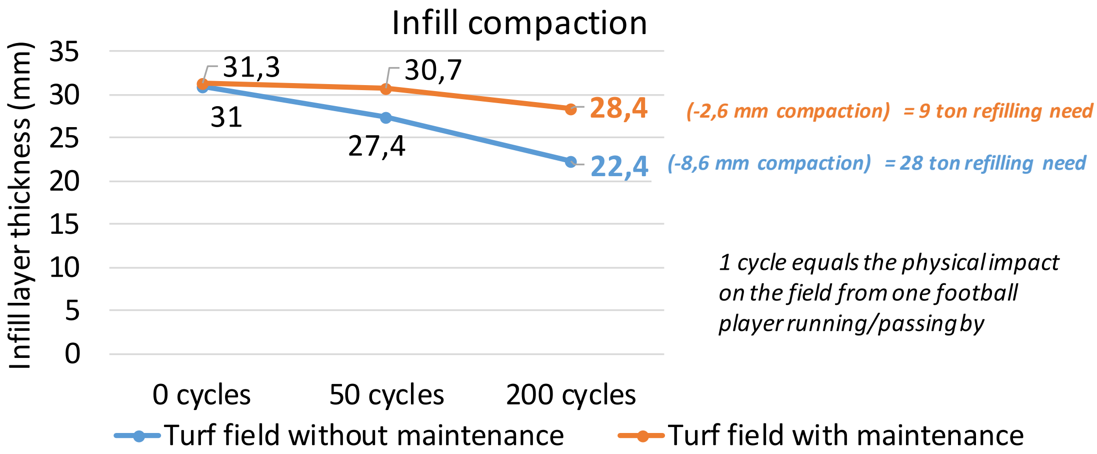


*Figure 3. Compaction and difference in refilling need on long pile synthetic turf field with and without maintenance after simulated use in laboratory.*

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# 4. Infill containment

## 4.1. System boundaries and definitions

Many football fields consist of the synthetic turf field and sometimes a paved margin surrounding the field. The simplest turf fields often now have a narrow-paved surface, while others have wider paved surfaces and fences. Well-equipped facilities may have stands, lighting, changing rooms, surfaces for operating vehicles, snow storage and more. (see pictures in table 1). The paved area around the turf field usually have drains to allow surface water to capture run off. Depending on how the fields are designed the potential for infill containment will vary. A general illustration is given in Figure 4.

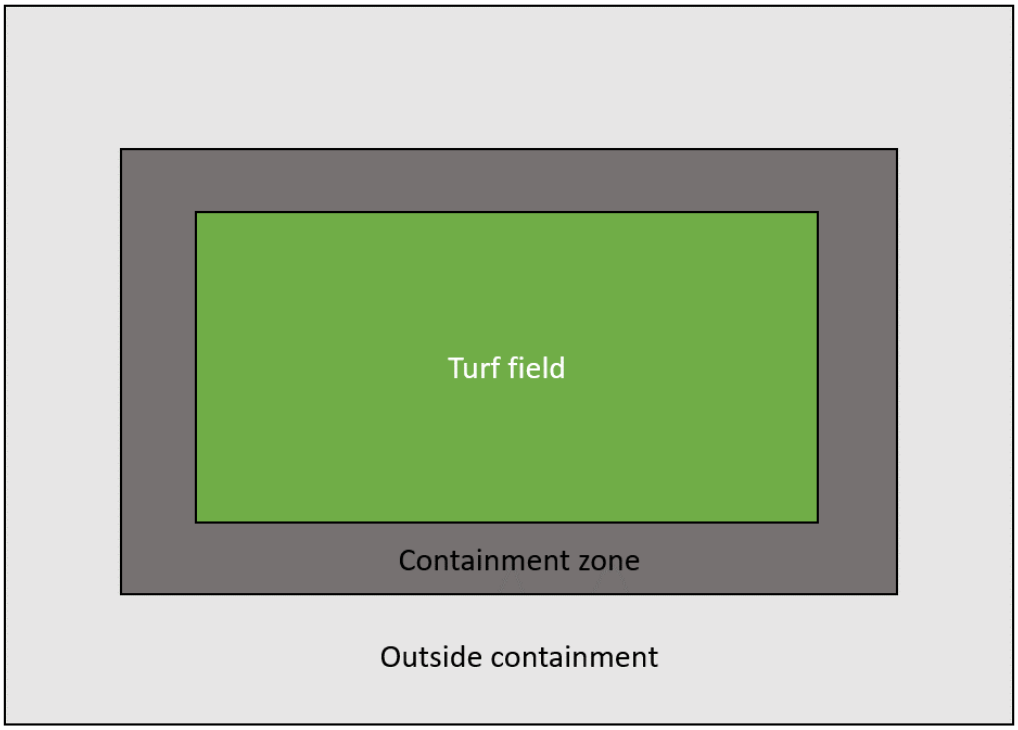



*Figure 4. Illustration of the turf field and the containment zone where it is possible to prevent infill loss and outside the containment zone where there is little possibility to prevent infill loss.*

Some definitions used in this report are listed below:

*Containment zone*
The containment zone is both the turf field itself and its surrounding zone where maintenance measures can prevent infill from spreading infill further. An efficient containment zone includes effective accumulation zones where infill is easily reclaimed.

*Outside the containment zone*

This uncontrolled zone is anywhere it is difficult for the field owner to reclaim the infill material, for example ditches, grass, soil and infill taken to private homes etc in players' clothing. Infill from these accumulation areas are exposed to further transport to the environment.

*Managed and uncontrolled infill transport*
Infill transport is defined as any relocation of infill from the turf field, such as infill transported by shoes, maintenance equipment, runoff, etc. Managed infill transport means that there are maintenance measures implemented to reclaim the infill to the field or to manage it properly as waste. Uncontrolled infill transport means that the field owner takes no measures to reclaim the transported infill.

*Infill containment efficiency*
The *efficiency* of infill containment will depend on how well infill transport is managed and kept in the containment zone.

*Accumulation zones*
Infill transported from the field will accumulate at different places such as player passages, at storage surfaces for maintenance and in well filters etc. These accumulation sites need to be under control to reclaim the infill to the turf field or handle it properly as waste. Infill accumulation zones can be both within and outside containment zone and are illustrated in Figure 5. Accumulation sites outside the containment zone is a source of further infill transport to the environment.

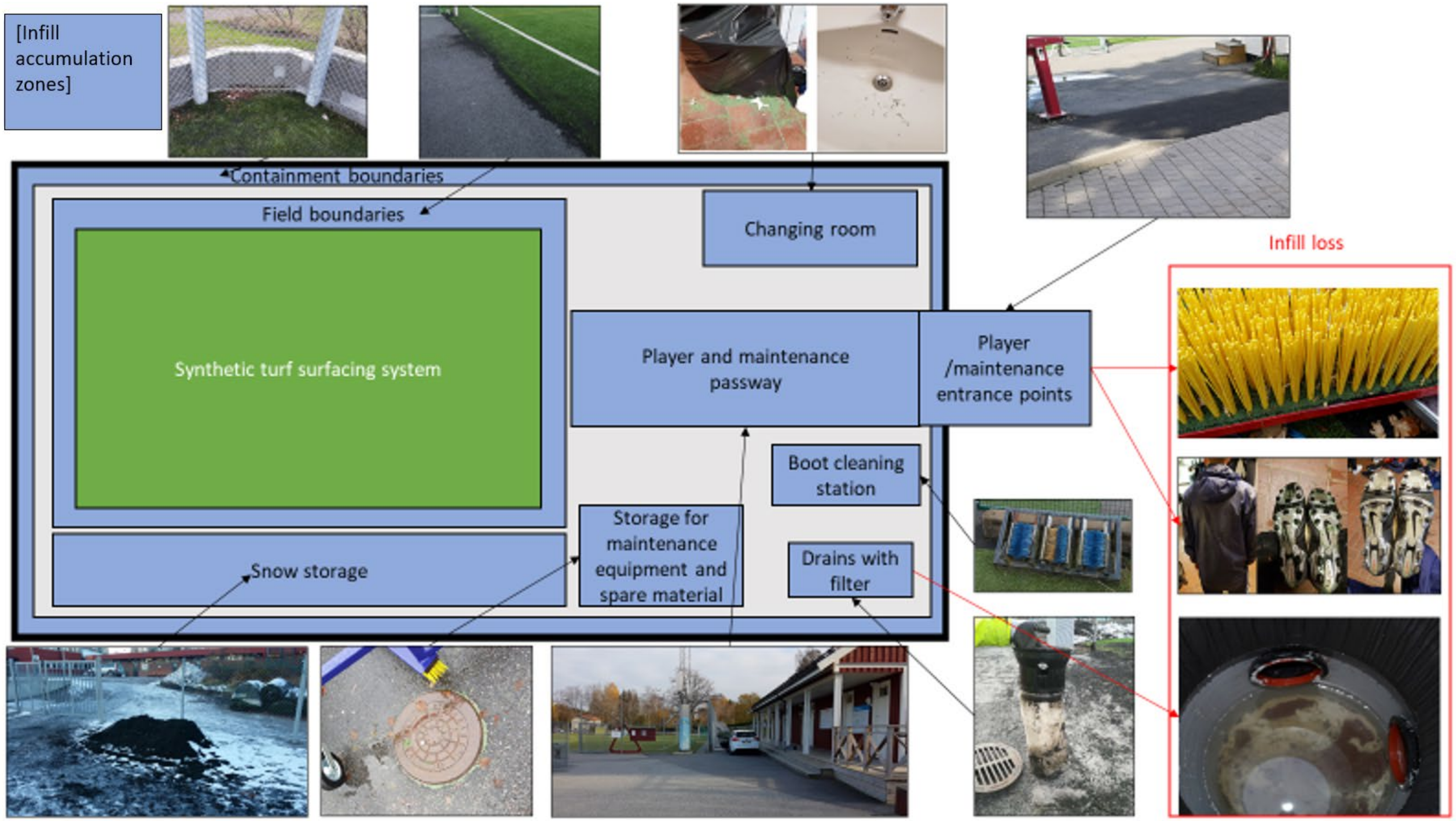



*Figure 5. Illustration of typical infill accumulation zones that can be relevant at a synthetic turf field.*

## 4.2. Early estimates of infill loss

Infill loss from synthetic turf was initially addressed in some of the early studies mapping sources of microplastic pollution in society. These studies identified potentially large land-based sources to microplastics and estimated the quantities of microplastics that could spread to aquatic ecosystems (Lassen et al 2015, Magnusson et al 2016, Verschoor et al 2017). Here synthetic turf was identified as a potentially important source among others such as road traffic, shoe abrasion, and plastic waste management. In these studies, rough estimates on microplastics emissions were used for almost all identified microplastics sources.

For infill in synthetic turf it was assumed that uncontrolled transport and spreading to the natural environment of infill from synthetic turf field is directly correlated and equal to the quantity of refilling required during the life span of the field. In these studies, the annual uncontrolled transport from synthetic turf was estimated to be around 3-5 tons per year, per synthetic turf field. This was based on information from field owners that stated a refilling need of 3-5 tons per year. Later studies specifically investigated the average uncontrolled transport of infill from synthetic turf by using a mass balance approach (Wallberg et al 2016). With the mass balance approach, it was assumed, like previous studies, that the sum of infill transported uncontrollably should be equal to quantity needed for refilling. The mass balance by Wallberg et al (2016) was broken down into activities that can lead to microplastics transport such as infill being carried by player shoes or carried by drainage, among others. Wallberg et al (2016) identified a potentially large error in the method used, since there was a large mismatch between how much is refilled and how much infill that was estimated to potentially be transported from the fields. It was suggested that compaction of infill could be a reason and that actual loss is probably lower than refilled amount. Other studies such as mass balance calculations by Krång et al (2019) are based on similar methodology and highlights that the compaction effect adds a large uncertainty to the method of quantifying infill loss.

## 4.3. Key indicators for quantifying infill containment

Estimates on infill transported from turf fields are of three types;

1) estimations based on refilling quantity during the life span of the field,
2) measurements of the accumulation of infill in uncontrolled zones such as nearby pavements, soil and grass
3) measurements of infill transport due to specific events/ activities such as players shoes and clothes, maintenance equipment, rain etc.

<u>Refilling</u>: Compaction is a major reason for refilling and can lead to a refilling need of several tons per year. Compaction is strongly correlated to how well maintained the fields are. Well maintained fields will thus have less refilling need. Refilling is thereby not a good measure of uncontrolled infill transport; however, it is a good indicator of maintenance efficiency.

<u>Infill accumulation outside the containment zone</u>: Infill accumulation studies are based on field measurements such as soil and sediment sampling in the local environment of turf fields. These studies give a good picture of the extent of microplastics spread and accumulation that have occurred historically. They can point out where most infill will

accumulate around the fields, such as drainage channels, grass and soil etc. However, these studies do not aim at identifying the relevance of activities causing uncontrolled infill transport.

<u>Infill transport measurements</u>: These studies include measurement of infill transport due to activities or events such as rain, player behavior, maintenance practices, among others. These studies give a good picture of what is causing infill to be transport uncontrollably from synthetic turf fields, the quantities, and which measures are the most relevant for minimizing infill loss.

In Table 3, pros and cons for each method is presented. Combining control of refilling, accumulation and transport gives conditions for monitoring infill containment.

*Table 2. Pros and cons of methods for quantifying infill transport*

| Method | Pros | Cons | Sensitivity |
|---|---|---|---|
| Refilling volumes | Indicator of potential infill transport<br>Indication on maintenance effectiveness.<br>Easy to follow up.<br>Indicator of cost efficiency.<br>Indicator of management efficiency. | Transport is indicated without pointing out the source of infill transport.<br>Compaction is a major reason for refilling, though it is difficult to estimate its contribution.<br>Winter maintenance are the largest contributors.<br>Not an indicator for user behavior. | tons/field and refilling frequency |
| Infill accumulation outside the containment zone: | Good indicator of accumulation volumes.<br>Indicator of maintenance effectiveness.<br>Follow up is possible.<br>Indicator of user behavior effectiveness. | Source must be well defined in advance.<br>Time dependent.<br>Needs good control of management, maintenance, events, construction, and drainage of the turf.<br>Not a direct indicator for user behavior.<br>Transport pathways and events are not indicated. | kg - gram /accumulation site |
| Infill transport measurements | Good indicator of infill transport for predefined spreading routes<br>Indicator of maintenance effectiveness.<br>Follow up is possible.<br>Indicator of user behavior effectiveness. | Spreading routes must be well defined in advance.<br>Event dependent.<br>Needs god control of management, maintenance, happenings, construction, and drainage of the turf.<br>Pathways and events can be missed. | grams/event |

# 5. Extent of infill transport due to activities

Infill will mainly be transported by players shoes and clothes, maintenance equipment, surface water runoff and snow removal. As described earlier, snow removal is mainly performed at some of the fields in the Nordic countries (estimated to 2 % of all European fields). It has been suggested that wind erosion also can transport infill, however the literature does not show that infill mobility is caused by wind.

Infill transport from players uncleaned shoes and clothes is 0,31- 2,7 gram after each player event which is a small amount but can be a relatively large sources for loss because the number of players is high. With cleaning equipment much of this infill on shoes/clothes can be reclaimed (Forskningskampanjen 2017; Regnell 2019).

Large variations can be seen for infill transport from maintenance. If the maintenance equipment is leaving the field uncleaned, infill can be carried by the tractor and on the maintenance brushes. The highest volumes occur when fields are maintained in wet weather. A limited number of measurements are available, and show that between 0,18-5,1 kg/ infill could get stuck to the equipment per maintenance event where the highest values is from measurements during wet conditions (Regnell 2019).

Where fields have adjacent surface water drainage channels measurements indicate that the total amount of infill ending up in drains is between 10-40 kg/ field and year (Lundström 2019). Similar measurements by Regnell (2019) indicated 15 kg/ field and year. If traps and filters are installed in the drains, measurements show that resulting runoff carries less than 10-gram infill per year from the field (Regnell 2019). The efficiency of such filters has also been showed in a study by Trinh (2019), where infill could not be detected in resulting runoff water.

Infill will be transported to the sides of the field due to maintenance and by players. If infill is not brushed back to the center of the fields and if there are no containment barrier, infill can be lost. Based on measurements of infill that has accumulated next to fields without proper maintenance routines and without containment barriers it was estimated that the potential loss could be 250 kg/ year (Hofstra et al 2017). Measurements at a sports center containing three synthetic turf fields in Norway without proper containment measures, showed that infill accumulated outside the containment zones such as pavements outside the turf fields was between 12 - 20 kg (NORCE 2017). These accumulation studies give little information about why infill has ended up in these zones.

**Snow removal**

Infill carried with snow removal is the single event that could lead to the largest transport of infill from a field. Snow sampling by Sund (2020) indicate that the amount of infill that could be carried with the snow is 44 - 213 kg / snow clearance event. However, if snow is stored at a designated snow storage site, the infill can be reclaimed to the field after the snow has melted. The measurements indicate a reduction in infill transport for each snow clearance event, since the first snow clearance of the winter transported 213 kg and the next snow clearance event 44 kg.

# 6. Estimation of infill transport and effectiveness of containment measures

Based on reviewed literature (se appendix) data from infill transport measurements have been used to estimate containment efficiency for synthetic turf fields. Uncontrolled transport can lead to - but does not have to lead to - infill loss and spread to the environment. For example, infill carried by shoes or maintenance brush can fall off and accumulate close to the synthetic turf carpet, within the containment zone of the field.

Conditions for south European and Central European climates have been used in the calculations as these regions account for the vast majority of synthetic turf fields throughout Europe. Northern Europe is a special case where a limited number of fields have snow clearance.

Wet weather increases infill transport by shoes and maintenance equipment. The number of days with dry and wet weather in central and southern Europe is therefore used in the calculations. Based on European precipitation data, a mean value of 120 wet days/year was considered (140 days/ year for central Europe and 100 / year for south Europe). A synthetic turf field with high usage was assumed. The number of users (players) was set to 30 users/hour for 1950 hours / year which gives 58 500 users/ year. It was assumed that maintenance brushing was conducted 2 times / week. Users was assumed to play on the field even during rainy days. Maintenance was assumed even under wet conditions. For the special case of snow removal, it was estimated that the field was snow cleared 5 times per winter. Estimated infill transport is presented in Table 4. Due to large uncertainties, it is not recommended to use data in Table 4 to calculate infill loss for synthetic turf fields in general since it is a mixture of high quality data and low quality data. However it can be used for a worst-case scenario to analyse the efficiency of containment measures.

*Table 3. Estimates of infill transport used in worst case scenario for infill transport*

| Activity | Quantity | Data quality | Reference |
|---|---|---|---|
| Infill carried to drain catchment pits | 15 kg/ year | High quality, high number of measurements | Regnell (2019), Lundström (2019) |
| Infill carried by maintenance brush and tractor | 239 kg/ year, where it is estimated that 90 % of this quantity is stuck to the brush and 10 % is stuck to the maintenance tractor | Low quality, few measurements | Estimate based on data from Regnell (2019) |
| Infill carried by shoes and clothes | 88 kg/year | High quality, high number of measurements | Estimate based on Regnell (2019), Forskningskampanjen (2017) |
| Infill carried to field sides | From 12 – 250 kg/ year. 131 kg/ year is used in the calculations. | Low quality, few measurements | NORCE (2017), (Hofstra et al 2017) |
| Infill carried by snow removal | 433 kg/ year. Assuming six snow clearance event per winter where first event carry 213 kg infill and the next four snow clearance events carry 44 kg infill each. | Low quality, few measurements | Sundh (2020) |

The effect of infill containment measures was analyzed in following management scenarios presented in Table 5

*Table 4. Uncontrolled infill transport in various potential scenarios*

| **Scenario** | **Situation** | **RMM implemented** | **Potential infill migration (loss from controlled zones)**<br>Based on the data in Table 4 | |
|---|---|---|---|---|
| | | | **Full size field on which snow removal is NOT undertaken** | **Full size field on which snow removal IS undertaken** |
| **Worst case scenario** | • There is no containment and no maintenance routines for reclaiming infill that is migrating to the field sides due to maintenance, playing, or due to any other possible reasons.<br>• Surface water drains located around field without filters<br>• The same maintenance brush and tractor is used for several synthetic turf fields and leaves the synthetic turf site twice a week always uncleaned.<br>• Player's shoes and clothes are never cleaned.<br>• There are no filters / traps in drains around the fields to capture infill. | None | 473 kg/ year | 906 kg/ year. |
| | | | Comment:<br><br>Total uncontrolled infill is calculated to be between 354-592 kg/ year. By using a mean value, total uncontrolled infill in this scenario is calculated as 473 kg/ year. | Comment:<br><br>If snow clearance is added and there are no maintenance routines for infill control or designated storage for snow, the worst-case scenario is 473 + 433 kg = 906 kg/ year. |

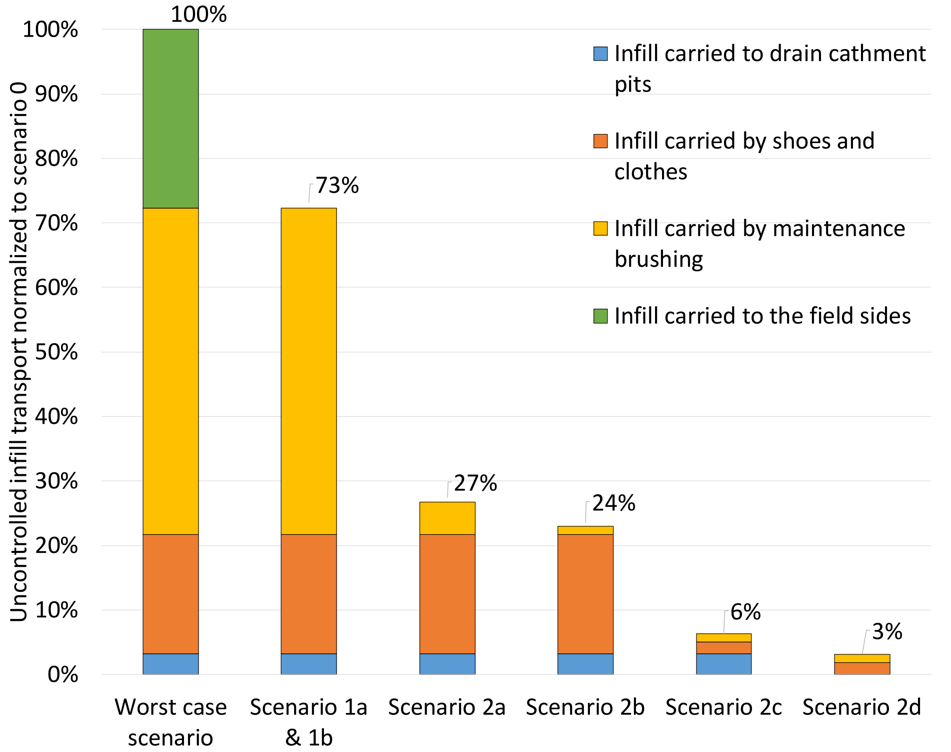
| | | | | |
|---|---|---|---|---|
| **Scenario 1a** | • The same maintenance brush and tractor is used for several synthetic turf fields and leaves the synthetic turf site twice a week always uncleaned.<br>• Player's shoes and clothes are never cleaned.<br>• There are no filters / traps in drains around the fields to capture infill. | • There is a perimeter barrier for preventing infill that is migrating to the field sides due to maintenance or due to any other possible reasons/events to spread any further. | 342 kg/ year<br><br>Comment:<br><br>A containment board has a reduction effect of 100 %. | 342 kg/ year.<br><br>Comment:<br><br>If snow clearance is added and there is a designated place for snow storage, the worst-case scenario is also 342 kg/ year since storage on fields with containment boards is 100 % effective. |
| **Scenario 1b** | • The same maintenance brush and tractor is used for several synthetic turf fields and leaves the synthetic turf site twice a week always uncleaned.<br>• Player's shoes and clothes are never cleaned.<br>• There are no filters / traps in drains around the fields to capture infill. | • There are wide accumulation zones (but no containment boards) preventing infill that is migrating to the field sides due to maintenance or due to any other possible reasons to spread any further. | 342 kg/ year<br><br>Comment:<br><br>Total uncontrolled infill in this scenario is calculated to 342 kg/ year, which is the same infill quantity as in Scenario 1a.<br><br>Accumulation zones also have a reduction effect of close to 100 %. | 342 kg/ year<br><br>Comment:<br><br>If snow clearance is added and there is a designated place for snow storage, the worst-case scenario is also 342 kg/ year. |

| | | | | |
|---|---|---|---|---|
| **Scenario 2a** | • Player’s shoes and clothes are never cleaned.<br>• There are no filters / traps in drains around the fields to capture infill. | • Perimeter barriers or accumulation zones<br>• One specific maintenance brush is used only for the synthetic turf field so that the brush never has to leave the containment zone | 127 kg/ year | 127 kg/ year |
| **Scenario 2b** | • Player’s shoes and clothes are never cleaned.<br>• There are no filters / traps in drains around the fields to capture infill. | • Perimeter barriers or accumulation zones<br>• One specific maintenance brush is used only for the synthetic turf field so that the brush never has to leave the containment zone.<br>• The maintenance tractor is brushed off before leaving site twice a week. | 109 kg/ year | 109 kg/ year |
| | | | Comment:<br>Brushing of tractor from infill has a reduction effect of close to 100% (Regnell 2019) however, to compensate for mistakes/behavior a 75 % reduction effect is assumed here. | |
| **Scenario 2c** | • There are no filters / traps in drains around the fields to capture infill. | • Perimeter barriers or accumulation zones<br>• One specific maintenance brush is used only for the synthetic turf field so that the brush never has to leave the containment zone.<br>• The maintenance tractor is brushed off before leaving site twice a week.<br>• Clothes/shoes are brushed off before leaving site. | 30 kg/ year | 30 kg/ year |
| | | | Comment:<br>Brushing/cleaning can provide close to 100% reduction effect from shoes/clothes is possible (Regnell 2019) however, to compensate for15mistakes/behavior a 90 % reduction effect is assumed. | |

| | | | | |
|---|---|---|---|---|
| **Scenario 2d** | • Full implementation of RMM | • Perimeter barriers or accumulation zones<br>• One specific maintenance brush is used only for the synthetic turf field so that the brush never has to leave the containment zone.<br>• The maintenance tractor is brushed off before leaving site twice a week.<br>Clothes/shoes are brushed off before leaving site.<br>Filters fitted to drains | 15 kg/ year | 15 kg/ year |
| | | | Comment:<br><br>Reduction benefit is > 99 % (Regnell 2019; Trinh 2019). | |

Further analysis is focused on the scenarios for the General cases and not the special case snow removal. By normalizing the estimated uncontrolled infill transport from Scenario 1a-2d against the worst-case scenario, it is possible to analyze the containment efficiency.

Uncontrolled infill transport and containment efficiency for each scenario have been normalized to the worst-case scenario and is presented in Figure 6. The analysis show that infill containment efficiency can be up to 97 % (Scenario 2d).



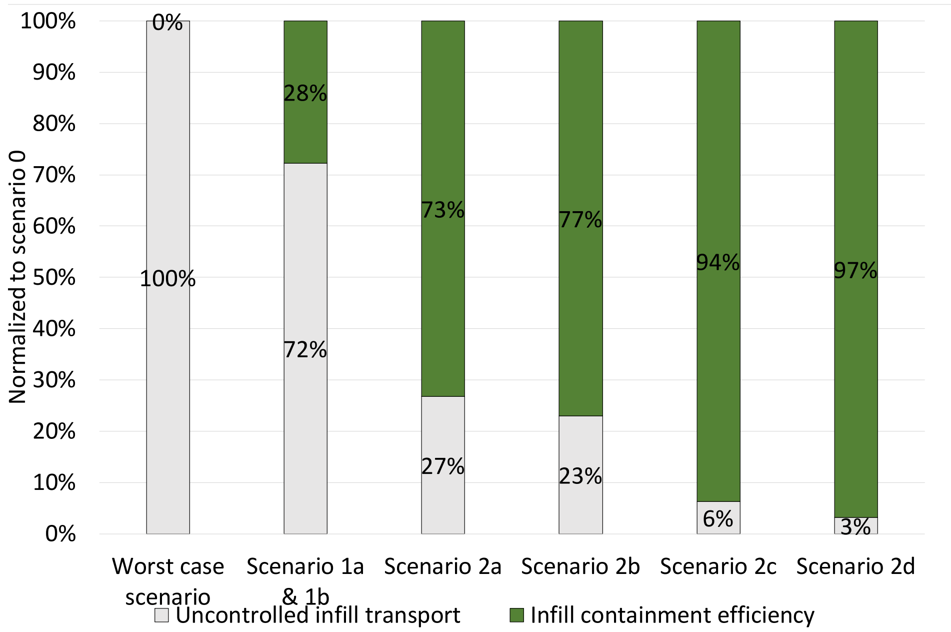




*Figure 6. Quantity of uncontrolled infill transport for each Scenario. Uncontrolled transport can lead to - but does not have to lead to - infill loss and spread to the environment. For example, infill carried by shoes or maintenance brush will partly fall off and accumulate close to the turf mat, within the containment zone.*

## 6.1. Sensitivity analysis

The sensitivity for possible mistakes in player hygiene and maintenance routines are analyzed further. Data from Regnell (2019) and Forskningskampanjen (2017) show that all infill can be brushed off from shoes, clothes, and maintenance tractors. It was assumed in the scenario analysis in this study that these measures may not work perfectly. It was therefore assumed that brushing efficiency is not more than 75 % for tractor and 90 % for shoes/clothes.

For the sensitivity analysis, it is assumed that in 25 % of cases the maintenance tractor is not brushed to remove all infill before leaving site and that in 25 % of cases, players will not clean their shoes and clothes of all from infill, see Figure 7. The sensitivity analysis show that even with failures in maintenance and player hygiene, the total amount of uncontrolled infill at the turf field is below 50 kg/ year.

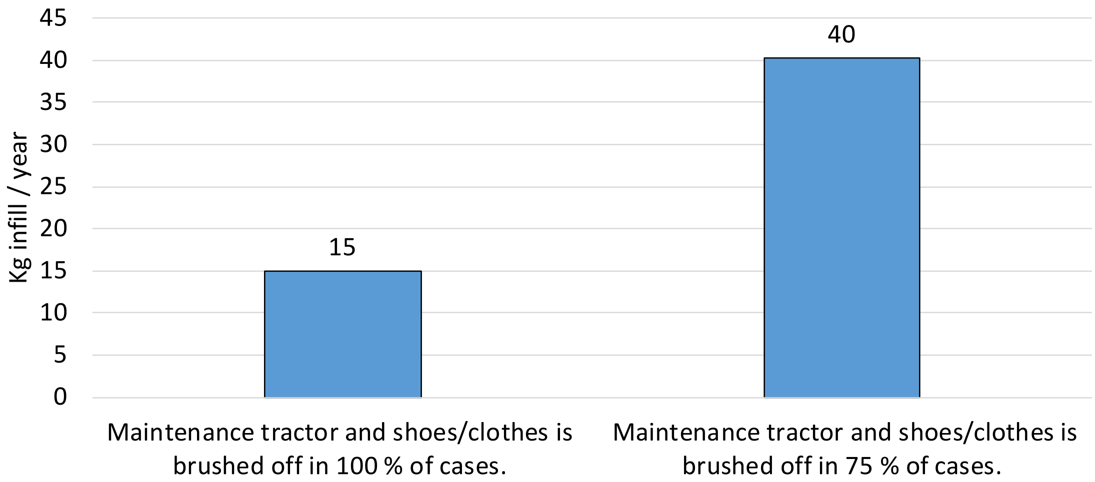



*Figure 7. Sensitivity analysis of failures in maintenance and player hygiene*

By implementing measures such as maintenance routines, containment barriers or introducing accumulation zones where infill can be reclaimed, uncontrolled infill transport/migration can be reduced by up to 97 %. Uncontrolled infill transport will then be about 15 kg/year [2 g/m$^2$]. which is below the 7g/m$^2$ proposed by ECHA's SEAC committee.

# 7. Risk analysis and risk management for infill containment

## 7.1. Theory

A risk management plan is based on a risk analysis carried out in steps. The first steps are to identify as many potential risks as possible in a risk inventory and then to sort and prioritize the most important risks. The next steps are to develop a risk management plan with measures including who is responsible for them. The working method is illustrated in Figure 7. In this risk analysis, the focus in this study have been on risk identification as a basis for a future risk management plan for monitoring infill containment.

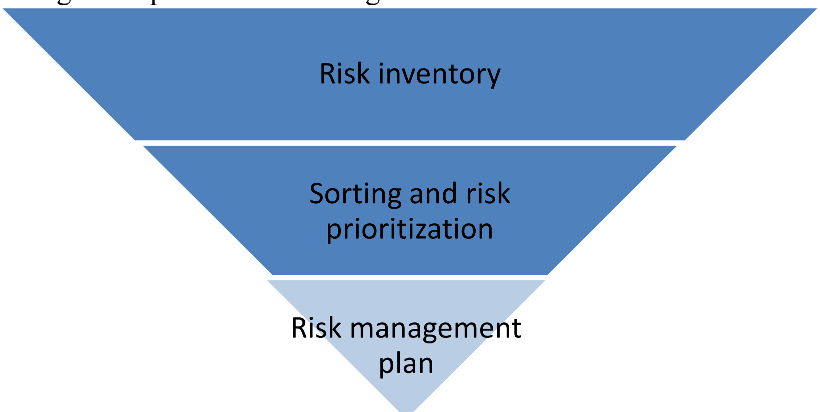



*Figure 8. Main steps for developing a risk management plan. The risk inventory can result in a high number of risks. These risks are sorted and prioritized based on the severity of the risk consequences. A net lest of the most important risks are then used as a basis for developing a risk management plan.*

The risk inventory aims to identify as many risks as possible. In this study risks have been identified by reviewing literature and from personal communication with field owners. The ”bow tie”-model (CGErisk 2020) has been used to describe casual relationships between risk and consequence, se Figure 8. Causes to risks can be prevented and minimized, however if an event is initiated, and barriers/risk protection does not work there is need for barriers/ measures that mitigate the effects of the event. Otherwise the event will lead to consequences.

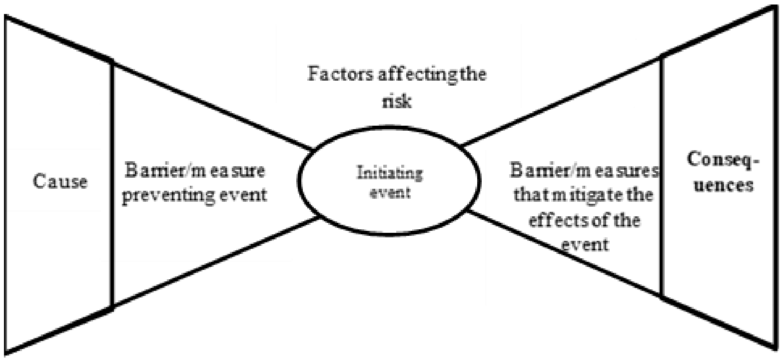



*Figure 9. The bow-tie model describes the causal relationship between risk sources and consequences, and is based on an initiating event*

## 7.2. Method

Information gathered from the literature review and personal communication with field owners was compiled into a list of initiating events in each work step/activity of the synthetic turf field's life cycle, where the severity of each event is highlighted by using color code. An event was assessed as high risk if it were highly likely to occur and would have major consequences for the quality of the final coverage. Events was listed in a table together with:

- Description of events,
- Consequences and its severity,
- Possible actions to prevent events
- Likelihood of risk after prevention measures taken.

The list also includes proposals for control measures and proposals for those responsible for quality assurance and is intended to be a basis for a risk management plan.

## 7.3. Risk inventory

The life cycle of a synthetic turf field is illustrated in Figure 10. The turf field will have a short time period of installation and a long period of use and maintenance before final replacement/ decommissioning. Event and activities during construction/installation and replacement/decommissioning are single events or few compared to events and activities during use and maintenance period.

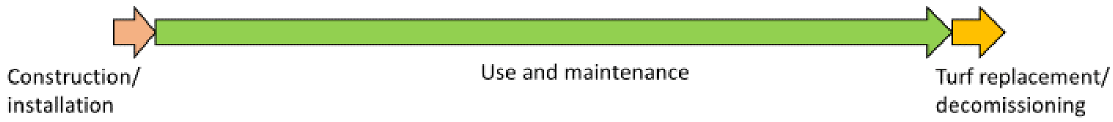



*Figure 10. Life cycle of a synthetic turf field.*

**Containment barrier**
For fields where the turf is laid up to the fence and there are no paths around the perimeter (so also no drains for the infill to enter), infill can fall out of the carpet into the surrounds. In addition, infill can be thrown out of the field when lifted by maintenance brushes.

**Installation / refilling**
Infill can leak from bags if they are damaged, vandalized, opened outside the field, or emptied bags are not disposed of correctly, or equipment used for filling leaves the site uncleaned. (CEN report TR 17519 2020)

**Maintenance**
Turf fields are sometimes excessively overfilled to protect the weaken backing of an old carpet and prolong the life of the surface. Uneven infill distribution can lead to infill being relocated to the sides of the field. Uncleaned maintenance equipment can transport infill from the field site. Inappropriate use of rotary brush and leaf blowers can result in infill spreading from the field site. Infill from cleared snow can spread from snow storages if snow piles get to high. Uncleaned boot cleaning stations can lead to reduced cleaning efficiency

and that infill is transported uncontrolled by shoes. Unfiltered surface water or from locker rooms can transport infill to water. Clogging of filters can lead to overflow and hence infill transport to water. (CEN report TR 17519 2020).

**Use**
Boots and clothes. Are not cleaned leading to uncontrolled infill transport This is relevant for, trainers, school student/children, public users, professional users. (CEN report TR 17519 2020).

**Turf replacement / Decommissioning at end of life**

Loss due to poor handling of use turf infill at installation site.
Loss due to poor handling of infill during transport. (CEN report TR 17519 2020).

## 7.1. Sorting and prioritizing risks

It is decided to include all risks identified in the inventory. A risk management spread sheet is presented in the table below.

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| RISK MANAGEMENT SPREAD SHEET FOR SYNTHETIC TURF INFILL CONTAINMENT | | | | | | | |
|---|---|---|---|---|---|---|---|
| Activity | Nr of Activities during a 10 year period | **Event and Probability of event**<br>Green = Small probability<br>Blue= Medium probability<br>Red= high probability | **Consequence from event**<br>Green = Small infill loss (<10kg)<br>Blue= Medium infill loss (10's of kgs)<br>Red= Large infill loss (100's of kgs) | **Proactive measure & infill containment efficiency**<br>**Risk for infill loss after proactive measure:**<br>Green= Eliminated risk<br>Blue= Medium risk<br>Red= High risk | **Quantification of containment efficiency** | **Responsibility** | **Monitoring and follow up** |
| **1. Containment barriers** | | | | | | | |
| Infill falling off the field due to migration to the sides | | Infill spread due to absence of containment zone around the field | Infill can spread by players and maintenance equipment. Infill spreading to environment increases. | Install boards around the field | ~ 100% | Responsible for field design | If boards do not work as intended, take action to prevent infill spreading |
| Infill thrown off the field due to maintenance | | Infill spread due to absence of containment zone around the field | Infill can spread by maintenance equipment. Infill spreading to environment increases. | Install boards around the field | ~ 100% | Responsible for field design | If boards do not work as intended, take action to prevent infill spreading |
| Infill carried by wind from the field | | Infill spread due to absence of containment zone around the field | Infill can spread by wind. Infill spreading to environment increases. | Install boards around the field | ~ 100% | Responsible for field design | If boards do not work as intended, take action to prevent infill spreading |

| 2. Infill installation and refilling | | | | | | | |
|---|---|---|---|---|---|---|---|
| Order infill bags | 10 | Infill leakage from damaged infill bags | Infill can leak out every time the bag is handled, from production plant to turf field. Infill spreading to environment increases. | Infill materials should be supplied to site in suitable heavy–duty bags that are not torn or open. Check that there are no holes in the bags and that correct type of bags is used. | ~ 100% | Responsible for ordering infill bags | If there is damaged bags, take action to prevent infill spreading |
| Storing inflll bags | 10 | Infill bags is vandalized | Vandalism of infill bags can lead to infill leakage. Infill spreading within field area increases. | Infill materials should be stored in secure compounds. Check that infill bags are not damaged. | ~ 100% | Responsible for storing infill bags | If there is damaged bags, take action to prevent infill spreading |
| Opening infill bags | 10 | Infill bags are opened outside field | Infill can leak out every time the bag is handled. Infill spreading to environment increases | Only open bags within the confines of the field, do not transport loose infill from outside the field to the installation equipment. | ~ 100% | Responsible for handing infill bags | If there is open bags outside the field, take action to prevent infill spreading |
| Handling emptied bags | 10 | Emptied infill bags are not contained | Infill can leak out every time the bag is handled. Infill spreading to environment increases | Collect and contain emptied infill bags before they leave the field area | ~ 100% | Responsible for handling infill bags | If there is uncontained emptied infill bags, take action to prevent infill spreading |
| Transporting filling equipment from field | 10 | Uncleaned filling equipment leaves the field | Infill can be carried by filling machines and brushes for infill distribution and fall off. Infill spreading to environment increases | Thoroughly clean equipment before they leave the field area | ~ 100% | Responsible for filling/refilling | If there is uncleaned filling equipment, take action to prevent infill spreading |

| 3. Maintenance | | | | | | | |
|---|---|---|---|---|---|---|---|
| Transporting maintenance equipment from site | 1 000 | Uncleaned maintenance equipment leaves the field | Infill can be carried by maintenance equipment and fall off. Infill spreading to environment increases | Thoroughly clean maintenance equipment before they leave the field area | ~ 95% * | Responsible for maintenance | If maintenance equipment is not thoroughly cleaned, take action to prevent infill spreading |
| Storing maintenance equipment | 1 000 | Maintenance equipment is not stored at designated area | Infill can be carried by maintenance equipment and fall off. Infill spreading within field area increases. | Store maintenance equipment at designated paved location, remove accumulated infill back to field | ~ 100% | Responsible for maintenance | If maintenance equipment is not stored at designated area, take action to prevent infill spreading |
| Using rotary brushes and leaf blowers | 30 | Rotary brushes and leaf blowers is used incorrectly | Infill can be flicked up and thrown off the field containment. Infill spreading to environment increases | Adjust brushing / leaf blowing pattern so that splashing infill does not falls outside the field containment | ~ 100% | Responsible for maintenance | If rotary brushes and leaf blowers are used incorrectly, take action to prevent infill spreading |
| Clearing snow | Special case | Inadequate snow clearing routines | Cleared snow is transported outside the field or leaked outside the containment due to snow falling over fencing. Infill spreading to environment increases | Store snow inside a designated containment area and limit the height of snow piles so that infill cannot fall over fencing | ~ 100% | Responsible for maintenance | If snow clearing routines are inadequate, take action to prevent infill spreading |
| Filtering surface water | Continous | Leakage of unfiltered surface water from field area | Surface water from rain and snow can carry infill to drainage where it is accumulated or lost outside the containment. Infill spreading to environment increases | Assure that surface water is leaving the field by ground infiltration or by wells with filters | ~ 100% | Responsible for maintenance and design | If unfiltered surface water is leaking from the field, take action to prevent infill spreading |
| Filtering shower/sink water | Continous | Leakage of unfiltered water from locker rooms | Water from showers and sinks can carry infill to drainage where it is lost outside the containment. Infill spreading to environment increases | Install filters in showers and sinks | ~ 100% | Responsible for maintenance and design | If unfiltered shower/sink water is leaking from the locker room, take action to prevent infill spreading |
| Filtering surface or shower/sink water | Continous | Leakage of unfiltered water due to clogging | Filters around the field and in showers can be clogged with sediment, hair and infill etc which reduce filtering efficiency. Infill spreading to environment increases. | Ensuring that all filters around the field and in locker rooms are regularly checked and emptied to ensure they remain operational | ~ 100% | Responsible for maintenance | If filters are clogged, take action to prevent infill spreading |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **4. Use** | | | | | | | |
| Relocation of infill due to playing | Continous | Overfilling | Too thick layer of infill makes top infill layer more mobile which can increase infill accumulation on the sides of the field. Infill spreading within field area increases. | Reset infill depth through maintenance. Brush back infill to field | ~ 100% | Responsible for maintenance | If the field is overfilled, take action to prevent infill spreading |
| | Continous | Inadequate distribution of infill | Infill disperse from higher center of field to lower field sides where it accumulates. Infill spreading within field area increases. | Reset infill depth through maintenance. Brush back infill to field | ~ 100% | Responsible for maintenance | If infill is unevenly distributed, take action to prevent infill spreading |
| Users leaving field | 585 000 | Boot cleaning stations are not cleaned or not working | Infill can accumulate at cleaning stations. Worn out brushes can lead to reduced efficiency when cleaning boots. Infill spreading to environment increases | Remove accumulated infill and replace worn out brushes | ~ 100% | Responsible for maintenance | If boot cleaning stations are uncleaned or does not work adequately, take action to prevent infill spreading |
| | | Inadequate or ignored boot/clothes cleaning routine | Infill can be carried by shoes/ clothes and fall off. Infill spreading to environment increases. | Informing players and trainers how to use boot cleaning stations | ~95%* | Users | If users does not brush of shoes and clothes, take action to prevent infill spreading |
| Visitors /spectators /staff leaving field | 10 000 | Inadequate or ignored boot/clothes cleaning routine | Infill can be carried by shoes/ clothes and fall off. Infill spreading to environment increases. | Informing visitors, spectators, and staff how to use boot cleaning stations. | ~95%* | Visitors/ spectators/ staff | If visitors/spectators/staff does not brush of shoes and clothes, take action to prevent infill spreading |

| 5. End of life disposal | | | | | | | |
|---|---|---|---|---|---|---|---|
| Removing turf mat and infill | 1 | Leakage during turf removal | Leakage from inadequate turf mat handling when unrolled from field and loaded on truck. Infill spreading to environment increases. | Loading to truck should be done on the turf field so leakage stays at the turf field. | ~100% | Responsible for decomissioning | If loading to tucks is taken place outside the field, take action to prevent infill spreading |
| Transporting turf mat/ infill by truck | 1 | Leakage during transport to disposal/ recycling | Infill is not contained properly when transporting infill to disposal /recycling. Infill spreading to environment increases. | Decommissioned turf and infill should be transported to recycling/disposal in suitable heavy–duty bags that are not torn or open.<br>Check that there are no holes in the bags and that correct type of bags is used | ~100% | Responsible for decomissioning | If there is damaged bags, take action to prevent infill spreading |

*Assumption based on measurements by Regnell 2019

# 8. Conclusions and recommendations for how to improve of infill containment

The aim of this study is to present a way to monitor the effectiveness of turf infill containment. Literature was reviewed to describe typical use of synthetic turf fields in the EU and to describe the infills function and its properties. In addition, data from field measurements of infill transported by maintenance equipment, runoff, players etc. was gathered and used for quantifying the extent of infill transport due to common activities on turf fields. Activities during use and maintenance lead to transportation of infill such as relocation on the fields, infill carried by shoes, or carried by maintenance equipment.

Due to great variety in how turfs are managed in Europe, it is difficult to simply quantify the mean infill loss from synthetic turf fields. Infill transports occur at all fields. However, by having control over infill movement/migration, infill can be prevented from moving outside zones that can be controlled and maintained. These zones include surrounding paving, storage areas for maintenance equipment, shoe cleaning stations and drain filters that are used as accumulation zones within the controlled zone. By adding containment barriers around the field, the risk for infill spreading is reduced even more.

A risk management approach was used to develop a methodology for improving infill containment efficiency. Activities and events that may cause infill loss during the life cycle of synthetic turf fields were identified. The severity (quantity) of infill loss from each events/activity was evaluated. Containment measure, its effectiveness, and responsibility for monitoring measures (maintenance personal, players, etc) was identified and described for each event.

The risk management approach showed that for many events that may lead to infill loss, the risks can be eliminated, e.g. appropriate field boundary barriers, filters in surface water drains, handling of infill bags, and appropriate handling and storage of maintenance equipment. Other events such as infill being carried by shoes and clothes cannot be eliminated but can be controlled by the use of shoe cleaning stations and decontamination gates. It is recommended that as more field are built that incorporate the risk management measures detailed in CEN TR 17519.

Despite site specific variety of maintenance practices at European turf fields, it is estimated that infill migration into uncontrolled zones on fields in common use in the EU can be controlled by up to 97 %. This means that uncontrolled infill migration can be limited to about 15 kg [2 $g/m^2$] with relatively easy measures such as using appropriate field design, good maintenance routines and improving player hygiene, all as detailed in the CEN Technical Report TR17519. Uncontrolled infill transport will then be below the 7$g/m^2$ proposed by ECHA's SEAC committee.

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# Appendix

Previous measurements of infill transport due to activities

| Infill transport route | Result | Measuring method | Scope / reference |
|---|---|---|---|
| Infill carried by uncleaned shoes and clothes | 2,7 gram / player with football shoes and clothes | Brushing of shoes and emptying shoes. Weighting of dried infill | 376 players and 23 occasions (Regnell 2019) |
| | 0,62 gram/ player without football shoes<br>0,31 gram/ player with football shoes | Brushing of shoes and emptying shoes. Volume measurement. | Players from 379 games on 11 manna fields (Forskningskampanjen 2017) |
| Infill carried by uncleaned maintenance equipment | *Tractor leaving site uncleaned* (maintenance brush is left on site)<br>Dry field: Ca 178 gram/ event<br>Wet field: Ca 161-510 gram/ event<br>*Tractor and maintenance equipment leaving site uncleaned:*<br>Dry field: Ca 1 780 gram/ event<br>Wet field: Ca 1613-5100 gram/event | Infill removed with brushes and compressed air. Drying and weighting. | 7 maintenance events (Regnell 2019) |
| Infill carried to surrounding wells without filters | 10–40 kg/field and year | Emptying filters in Drying and weighting | 4 fields and totally 12 wells (Lundström 2019) |
| Infill from field without containment measures carried to uncontrolled zones | 0,3-7,5 gram/ m2 pavement (Maximum: about 12-20 kg/ year for 3 fields) | Sampling on paved sidewalks/ small roads | 3 fields (NORCE 2017) |
| | About 250 kg/ year | Sampling next to fields | |

| | | | |
|---|---|---|---|
| Infill in surface water from fields with filters in wells | Total annual microplastics spread was estimated to ca 97 grams. Microplastics from rubber infill could not be identified. | Sampling of water followed by FTIR, SEM and EDX analysis (Detection limit: Ca 10-20 µm) | 1 field, 3 sample stations and 3 sampling occasions. (Regnell 2019b) (Västerås) |
| | Total annual microplastics spread was estimated to about 5 grams. Microplastics from rubber infill was < 20 % . | | 1 field ,1 sample station 2 occations (Magnusson 2019) (Järfälla) |
| | Total annual infill spread was estimated to about 10 grams/ year. About 15 kg was stopped with filters. | | (Regnell 2019) |
| | Total annual microplastics spread was estimated to about 62 grams. Microplastics from rubber infill could not be identified. | Sampling of water followed by visual analysis in stereo microscope (Detection limit: Ca 100 µm) | I field, short time and long time water sampling Uppsala (Trinh 2019) |
| Infill carried by snow clearing | 213 kg at first clearing event and 44 kg at second clearing event | Sampling of infill at snow clearing storage after snow clearing events | One field, sampling of snow from two snowfalls/snow clearing events (Sund 2020) |

| | | | |
|---|---|---|---|
| Calculation for Worst case scenario | | | |
| | | | |
| Users per hour | 30 | | |
| User hours per year | 1 950 | | |
| **Users per year** | **58 500** | | |
| | | | |
| Maintenance brushing per year (twice a week) | 104 | times/ year | |
| | | | |
| | Days (mean for South and Central europe) | % of year | |
| Wet days/ year | 120 | 0,329 | |
| Dry days per year | 245 | 0,671 | |
| | | | |
| Infill carried by shoes and clothes | | | |
| Wet field | 2,7 | gram/player | |
| Dry field | 0,91 | gram/player | |
| | | | |
| Infill caried by shoes and clothes during one year | | | |
| Total for the wet days | 0,329*58500*2,7= | 51966 | gram |
| Total for the dry days | 0,671*58500*0,91= | 35721 | gram |
| **All year** | | **87686** | **gram/year** |
| | | | |
| | | | |
| Infill carried by maintenance brushing (of which 90 % is stuck on the brush, 10 % is stuck on tractor) | | | |
| Wet field (mean of 1613 to 5100 gram) | 3357 | gram/ maintenance event | |
| Dry field | 1780 | gram/ maintenance event | |
| | | | |
| Infill carried by maintenance brushing during one year (of which 90 % is stuck on the brush, 10 % is stuck on tractor) | | | |
| Total for the wet days | 0,329*104*3357= | 114863 | gram/year |
| Total for the dry days | 0,671*104*1780= | 124215,52 | gram/year |
| **All year** | | **239079** | **gram/year** |