Environmentally friendly substitute products for rubber granulates as infill for artificial turf fields

CONTENT

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1 SUMMARY

Artificial turf covered by crumb rubber from used tires constitutes a significant source of micro-plastic in Norway. With this project, the Norwegian Environmental Agency wishes to identify and review the characteristics of alternative infill materials for artificial turf. The present report provides an overview of alternative infill materials that may, in whole or in part, replace the tire granules as infill for artificial turf – based on a review of more than 50 references and more than 25 interviews.

Artificial turf consists of a synthetic 'grass mat' added small rubber granules to get the 'grass' to stand upright, providing damping and grip. The Norwegian Environment Agency estimates that ten per cent of the rubber granules are removed from the turf fields each year due to snow clearance, cleaning, and stapling on shoes and clothes, resulting in a total discharge in Norway of about 1,500 tons of rubber granules per year in the form of micro plastic.

The alternative infill materials, their performance as turf infill, and their impact on human health and the environment are not yet well studied, documented, or proven. The report presents findings from a comprehensive literature study and consultations with a series of stakeholders, including international suppliers of artificial turf and material-oriented research institutions. It should however be emphasized that artificial turf is an area of constant development; the environmental and health challenges of crumb rubber are still being thoroughly investigated all over the world[1], but independent investigations of the characteristics and performance of the alternative infill materials are sparse.

The following alternative infill materials have been included in the literature review and survey:

- SBR rubber and Coated SBR rubber
- Thermoplastic Elastomers, TPEs
- Ethylene Propylene Diene Monomer, EPDM
- Sand / silica
- Organic materials – cork, sugarcane
- Other, less relevant materials - recycled sneakers and zeolite

SBR crumb rubber is the traditional infill material and the infill product that is most uniform across the EU; there are certain standards for the product and it is regularly checked and examined in independent studies.

There are vast differences between the alternative products also within the same product category: ‘EPDM’, ‘TPE’, ‘and organic infill’ are generic terms embracing a range of product types that vary greatly depending on the manufacturer in terms of fillers and substances - and with different characteristics on usability, availably, health aspects, and environmental impact. Each of the alternative infill materials for artificial turf has its specific advantages and disadvantages as compared to the traditional crumb rubber infill.

Based on the present study it is not possible to identify an alternative infill material that is significantly superior to the rubber crumb when combining the key characteristics: Usability, environmental and health performance, price and operation costs, maintenance requirements, and aesthetics.

Disregarding the type of infill material it is apparent that the maintenance procedures have significant importance for the removal of infill material from the field and hereby for the potential formation of micro plastics, and an ongoing study (2017) financed by the Norwegian Environmental Agency aims at identifying best maintenance procedures. Other factors also influence the environmental impact of a turf

[1] As an example, the Office of Environmental Health Hazard Assessment (OEHHA) in 2015 launched a very comprehensive, three-year long study, Health Impacts of Synthetic Turf Fields 2015-2018, among others investigating the types and amounts of chemical emissions from synthetic turf and the related health effects.

field but to a lesser degree, including the type of shock pad (reducing the needed amount of infill material), the actual use, and the waste treatment possibilities.

2 SAMMENDRAG

Kunstgress med granuat laget av bildekk utgjør en betydelig kilde til mikroplast i Norge. Med dette prosjektet ønsker Miljødirektoratet å identifisere og vurdere egenskapene til alternative fyllmaterialer til kunstgress. Denne rapporten gir en oversikt over alternative fyllmaterialer som helt eller delvis kan erstatte dekkgranulatene som fyllmateriale i kunstgress, basert på en gjennomgang av mer enn 50 referanser og mer enn 25 intervjuer.

Kunstgressbaner består av en syntetisk ”gressmatte” som er tilsatt små gummigranulater for å få gresset til å stå oppreist, samt gi demping og grep. Miljødirektoratet anslår at 10 % av gummigranulatene havner utenfor banen hvert år grunnet snørydding, rengjøring og via sko og klær, hvilket gir et samlet utslipp på ca 1,500 tonn gummigratulat per år i form av mikroplast.

Alternativene, deres ytelse som fyllmateriale og hvilken helse og miljøinnvirkning de har er ennå ikke tilstrekkelig studert, dokumentert eller bevist. Rapporten presenterer funn fra en omfattende litteraturstudie og konsultasjoner med en rekke interessenter, blant annet internasjonale leverandører av kunstgress og materialeorienterte forskningsinstitusjoner.

Følgende alternative fyllmaterialer har blitt undersøkt igjennom litteraturstudier og undersøkelser:

- SBR-gummi
- Krysset SBR-gummi
- Termoplastiske Elastomerer, TPE
- Etylenpropylendienmonomer EPDM
- Sand/silika
- Organiske materialer – kork, sukkerrør
- Andre, mindre relevante materialer – resirkulerte joggesko og zeolitt

SBR gummigranulat er det fyllmaterialet som er det produktet som er mest homogent, da det er visse standarder for produktet og det kontrolleres jevnlig og undersøkes gjennom uavhengige studier.

Det er store forskjeller mellom de alternative produktene også innenfor samme produktkategori: ”EPDM”, ”TPE” og ”organisk fyllmateriale” er generiske vilkår som omfatter en rekke produkttyper med store variasjoner, avhengig av produsenten, når det gjelder fyllstoff og substans – og med forskjellige egenskaper i brukbarhet, tilgjengelighet, helseaspekter og miljøpåvirkning. Hvert av de alternative fyllmaterialene for kunstgress har fordeler og ulemper sammenlignet med det tradisjonelle gummigranulatfyll.

Det er ikke mulig å identifisere alternative fyllmaterialer som er betydelig bedre enn gummigranulat basert på foreliggende studie, når man kombinerer nøkkelegenskapene: brukbarhet, helse og miljøpåvirkning, pris, driftskostnader, vedlikeholdskrav og estetikk.

Uavhengig av type fyllmateriale er det åpenbart at vedlikeholdsprosedyrene har særlig stor betydning for fjerning av fyllmateriale fra feltet, herved for potensiell dannelse av mikroplast. En pågående studie (2017) finansiert av miljøstyrelsen har til hensikt å identifisere de beste vedlikeholdsprosedyrene. Andre faktorer har også betydning for miljøpåvirkningen av kunstgressbaner, men i mindre grad, inkludert typen støt dempere (som reduserer den nødvendige mengde fyllmateriale), den faktiske anvendelse og avfallsmulighetene.

3 BACKGROUND

On December 20th, 2016, the Norwegian Environment Agency published an overall assessment of sources of and measures against micro-plastic. The Agency identifies artificial turf covered by crumb rubber from used tires[2] as a significant source of micro-plastic in Norway.

Artificial turf consists of a synthetic 'grass mat' added small rubber granules to get the 'grass' to stand upright, providing damping and grip. The rubber granules have a size of approx. two millimetres and since the bulk is made of recycled car tires, the granules can contain pollutants like PAH, phthalates, heavy metals, and phenols. The Norwegian Environment Agency study estimates that ten per cent of the rubber granules are removed from the turf fields each year due to snow clearance, cleaning, and stapling on shoes and clothes, resulting in a total discharge in Norway of about 1,500 tons of rubber granules per year in the form of micro plastic. The rubber crumb thus constitutes an increasing pollution problem in Norway (and in other countries) and alternative materials are slowly gaining terrain. An indication of a slightly increased focus on alternative turf infill and the environmental aspects is found in the program for this year's congress of the International Association for Sports and Leisure Facilities in November, where natural, hybrid, and synthetic turf systems and their environmental impacts are on the agenda[3].

Due to the wet and cold climate in the Nordic countries, artificial turf fields are popular in all countries and especially in Norway where 1,600 artificial fields have been established[4,5]. The high number of fields in Norway together with the increased focus on micro-plastic underlines the need for further knowledge about the impacts of the fields on the surrounding environment.

3.1 Aim and scope of study

With this project, the Environmental Agency wishes to identify and review the characteristics of alternative infill materials for artificial turf to assess the possibility of phasing out the traditional infill material based on rubber crumb from recycled tires. The present report provides an overview of alternative infill materials that may, in whole or in part, replace the tire granules as infill for artificial turf.

Generally, the alternatives, their performance as turf infill, and their impact on human health and the environment are not yet well studied, documented, or proven. The report presents findings from a comprehensive literature study and consultations with a series of stakeholders, including international suppliers of artificial turf and material-oriented research institutions) to obtain more in-depth understanding of the market and potentials for alternative materials.

For each of the relevant replacement materials[6] the present report provides to the degree possible (depending on the information available in literature):

- A description of the material's properties
- A review of the usability as infill
- An estimation of costs and availability
- An account of reported health risks
- An overall account of the positive and negative environmental characteristics.
- A list of potential suppliers arranged according to location.

[2] Mepex 2016: Primary microplasticpollution: Measures and reduction potentials in Norway

[3] IAKS 2017

[4] The number of artificial turf fields is around 400 in both Denmark and Sweden.

[5] Interview with Bjørn Aas, the Norwegian University of Science and Technology, 2017

[6] Replacement products that have a poor utility, accessibility, or are environmentally ineffective, are only described briefly.

The key findings are summarised in a table to provide an overview of the report, and a separate summary indicates the key findings from the overall environmental assessment of the different materials.

3.1.1 Available literature

A substantial body of literature is concerned with the health and safety characteristics of crumb rubber infill made from recycled tires and the literature also lists health concerns of some of the alternative infill options. However, the literature survey has identified only a few references[7] on the environmental aspects of crumb rubber[8], and for alternative materials very few peer reviewed references have been identified[9, 10]. Much of the information compiled in this report on the alternative materials is therefore relying on vendor information, unpublished studies from universities and other institutions, and raw data from institutions currently managing sports fields. Throughout the present report, it is sought to distinguish between information provided by independent sources and information from commercially involved stakeholders respectively.

The literature review has been carried out systematically on each specific infill material through databases, google searches, and additional reference material identified through interviews. Some of the literature and information available has been published by American authors and vendors of synthetic turf and infill materials. Differences in the amount of testing, the testing procedures, and the qualification criteria for crumb rubber in Europe and America have been taken into consideration during the literature review and following analyses.

The market for alternative infill for artificial turf is immature with many and changing producers[11], the information about the products are often limited, and there is a lack of official environmental standards for the artificial fields. The declarations on the substances and materials are often lacking and can be untrustworthy Bjørn Aas declares[12]. The present study has shown that not all manufacturers are willing or capable of providing detailed information on the specific content of the infill materials, some have not (yet) carried out an independent analysis, and some are just not willing to provide the information. As in addition the analyses of infill materials that have been identified have used different test methods, comparison of the materials' environmental profile is very difficult. To overcome this problem, the Norwegian University of Science and Technology has the ambition to develop a methodology for the declaration of products for artificial turf fields[13].

A few articles, reports, and other documents explicitly undertake a multifactorial comparison among turf options, with some structural similarities to the assessment undertaken by this project[14,15]. These studies are included in the overview of references. The Football Association of Norway have recently analysed six different infill products and the main impression is that the granules content of hazardous substances

[7] Nilson et al 2008; Mepex 2016; Dye et al 2006; NIVA 2007; FIFA 2017; Hofstra 2007.

[8] The Norwegian University of Science and Technology is initiating a project to identify the amount of microplast and chemicals derived from artificial turf fields. Interview Bjørn Aas, The Norwegian University of Science and Technology

[9] Cheng et al 2004; Fifa 2017; Mount Sinai 2017.

[10] According to a biologist and specialist in artificial grass not much research has been done about the environmental effects of crumb rubber in the last decade and research about alternatives to SBR crumb rubber is lacking as well – especially for the organic materials. Interview with Anne Mette Dahl Jensen, University of Copenhagen, 2017.

[11] Information provided by Bjørn Aas, vice president of the Nordic section of International Association for Sports and Leisure Facilities (IAKS)

[12] Ibid

[13] Interview Bjørn Aas, the Norwegian University - Science and Technology, 2017

[14] Gale Associates has developed a table that compares multiple types of infill options based on "online data, manufacturers literature and conversations with turf and infill distributors," (Gale Associates 2015).

[15] A study published in Environmental Science and Technology provides a comparison among multiple types of infill covering advantages, limitations, cost, recyclability, and field performance (Cheng et al. 2014).

has not been reduced since 2004. The granules made of car tires tested in 2004 have almost the same content of hazardous substances as we find in the same granulate type today. The same applies to granules based on newly manufactured rubber TPE and EPDM. A summarisation of the analysis is listed in Annex, but the names of the producers have been replaced with the infill type as requested by Ole Myrhvold from NFF[16].

[16] Interview, Ole Myrhvold, Field Manager, The Football Association of Norway (NFF), 2017

4 ARTIFICIAL TURF WITH TRADITIONAL INFILL

Synthetic or artificial turf is a multi-layer product used as a surface on athletic playing fields, playgrounds, golf courses, and residential lawns. It typically consists of[17]:

- a top layer of fibres usually made from nylon, polypropylene, polyethylene designed to mimic natural grass blades
- infill to provide cushioning and serve as a base for the blades
- a backing layer to which the blades are sewn
- a drainage layer
- additional padding layers

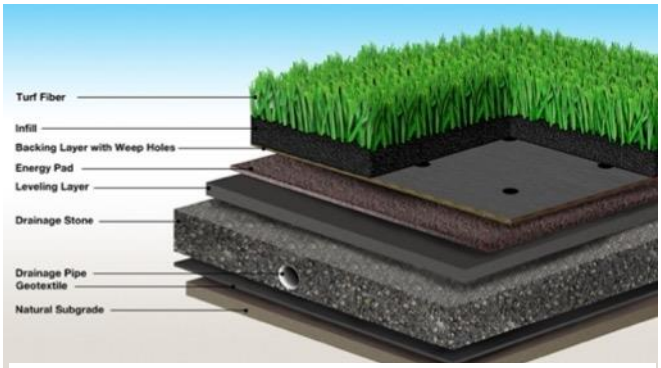

Illustration 1: Artificial Turf Counsel

As a landscape cover, artificial turf provides a low maintenance, weed-free surface that doesn't need to be watered or fertilized (however irrigation can be necessary for some infill materials).

The infill is applied between the turf fibres to help the 'grass blades' stand upright and to protect the artificial turf's backing layer. An artificial turf field's surface shall provide the playing characteristics that the sport requires and also provide the level of comfort and protection required by athletes running, falling, and sliding on the surface. The infill layer creates the right shock absorption, ball bounce, torsion and affects the sliding performance. Also, it aids the fibers in bending back to their original position and contributes to a consistent performance. The infill layer should also help the studs of the players' shoes to find their foothold.

4.1 Crumb rubber – standard infill material in artificial turf

Crumb rubber is derived from scrap car and truck tires that are ground up and recycled. The rubber's scientific name, *styrene-butadiene rubber* (SBR), covers a general-purpose synthetic rubber material, produced from a copolymer of styrene and butadiene. Far exceeding all other artificial rubbers in consumption, SBR is used in great quantities in automobile and truck tires, generally as an abrasion-resistant replacement for natural rubber[18].

The wide spread use of crumb rubber as a cushioning agent on artificial turf fields began in the mid-1990's based on an abundant supply of very cheap crumb rubber materials. Today, an estimated 90 % of the existing fields in Europe and USA use recycled rubber infill exclusively, whereas the remaining use a mixture of crumb rubber with sand or alternative infills, or contain only alternative infills[19]. 90 % of the Norwegian fields are made with SBR crumb rubber infill[20]. In 2016, 56,000 tonnes used and discarded tires were collected in Norway[21], and an amount of rubber corresponding to 1/3 of those tires were used as crumb rubber in artificial grass fields[22]. Industry estimates that 80.000-130.000 t/year SBR rubber infill

[17] http://www.syntheticturfcouncil.org/page/FAQs#synthetic

[18] Federal Research Action Plan on Recycled Tire Crumb Used on Playing Fields and Playgrounds - status report

[19] Ibid.

[20] Bodø commune: Miljøhensyn ved etablering og drift av kunstgressbaner

[21] http://www.dekkretur.no/nyheter/vi-tar-miljoeansvar/

[22] http://www.dekkretur.no/gjenvinning/materialgjenvinning

is used on European sport fields[23], primarily made from tires produced within EU. The quantity of tires and recycled rubber granules imported into the EU is reported to be small[24].

Usability

SBR is the most widely used infill product worldwide. It is free flowing homogenous and uniform black rubber granulate derived from specified sources of car tires[25] It has a high durability and comes in a variety of sizes[26]. The size of the SBR rubber granules must not be too fine or too coarse in order to ensure optimum ball behaviour. Too fine infill rubber compact and the playing surface will not be elastic enough; on the other hand, too coarse infill absorbs too much energy from the ball, resulting in poor rebound performance and splashing. Genan Holding A/S, the largest supplier of SBR rubber in Scandinavia, recommends the use of 0.8-3 mm granules.

Illustration 2: Genan Fine SBR

Because artificial turf is typically dark and does not vaporize water, the surface can reach temperatures up to 20-30°C higher than for natural grass with measurements as high as 70° C on a 40° C summer day.[27] The rubber has a distinct smell that is especially predominant in hot weather; the smell can be suppressed by irrigation – which also reduces the temperature of the field[28].

Crumb rubber from recycled tires are only available in black colour (unless they are coated – see 4.1.1.) and an obvious disadvantage is that the granules stick to cloth, footwear, and skin (especially in wet weather) and has a substantial splash during play[29]. The lifespan of crumb rubber infill is approximately 10 years[30], after which the complete field will be replaced.

Costs

The price for SBR rubber granulate is vendors stated to be 1.900 – 2.500 NOK/ton[31,32]. The use of recycled tire crumb is by many sources stated to be significantly cheaper than the alternative infill options[33].

An artificial grass soccer field typically needs 90-120 tonnes of crumb rubber[34], but with great variations according to the type of field system, chock pad, grass length/type etc.[35]. The amount of required refilling during the lifetime of the field is a question of the type of field system, the number of use-hours, and the maintenance[36].

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[23] ECHA 2016: Call for evidence on the use of recycled rubber granules used as infill material in synthetic turf

[24] However, ECHA cannot verify this information from an independent source; ECHA 2017, Annex XV Report.

[25] Genan Technical Data Sheet

[26] ibid.

[27] Cowi 2012: Omfanget av bruken, bruksområder og framtidig bruk av gummigranulat basert på bildekk og ny gummigranulat

[28] Nilson et al 2008: Mapping, emissions and environmental and health assessment of chemical substances in artificial turf

[29] Ibid

[30] Cowi 2012: Omfanget av bruken, bruksområder og framtidig bruk av gummigranulat basert på bildekk og ny gummigranulat

[31] Interview, Poulsen, Nordisk Kunstgræs, 2017

[32] Interview with Christian Steen, ProTurf AS

[33] Ibid and, for example, Cheng H, Hu Y, Reinhard M. (2014) Environmental and health impacts of artificial turf: a review

[34] http://www.dekkretur.no/gjenvinning/materialgjenvinning

[35] Interviews, Pål Lydersen, Lars Offenbach 2017

[36] Interviews, Pål Lydersen, Lars Offenbach, Dennis Andersen 2017

The total price for SBR rubber in a standard field would be between 170.000-250.000 NOK. The total cost of a standard soccer field (60*100 meter) with artificial turf lies between 2-5.5 million NOK (2017-prices)[37].

Health Risk

In recent years, the intensive use of tire crumb rubber infill has led to public concern for potential health risks. Since tire rubber is a complex material, containing many naturally-occurring and man-made chemicals, there is a risk that the crumb rubber granulate may release a variety of chemicals and particles into the air. As athletes and children dive and play on artificial turf surfaces, crumb rubber particles have been found to cling to clothing, hair, and skin. This could lead to breathing, unintentionally ingesting, and skin contact with tire crumb or chemicals that leak out of the rubber[38].

Many studies have been conducted on the topic, all concluding that the potential effect on human health is very low. However, a Norwegian study in 2006 found that SBR rubber crumb in artificial turf in gym halls could lead to a considerable impact on the *indoor* environment. The study therefore recommends use of alternative materials in indoor areas[39]. The NFL study shows that the two SBR products contained di-n-butyl phthalate (DBP) and diisobutyl phthalate (DIBP) which are harmful to reproduction.

In June 2016, The European Commission requested The European Chemical Agency ECHA to carry out a preliminary evaluation on the potential health risk of certain substances in recycled rubber granules used as infill on artificial turf sports grounds. The ECHA meta-evaluation of studies and literature from state health departments, universities, and other independent entities in the United States and Europe have not lead to declaration of crumb rubber as a public health concern or serious environmental concern, but many studies recognize the need for further scientific study of the topic[40].

In the US, further research has been initiated by (among others) a multi-agency[41] Federal Research Action Plan on Recycled Tire Crumb Used on Playing Fields and Playgrounds, studying key environmental and human health questions[42]. At the point of time of the present study, the exposure characterization of tire crumb is underway. The Dutch National Institute for Public Health and the Environment (RIVM) has in 2016 submitted research underpinning the conclusions of previous research: *The effect on human health of substances contained in rubber infill is "virtually negligible" – and there is no cause for concern*[43].

Chemical substances in SBR

SBR rubber contains carbon black, aromatic oils, zinc oxide, stearic acid, antioxidants and anti-ozonants, as well as Sulphur and accelerators that can contain nitrogen.

In addition to zinc, SBR rubber can emit copper and chromium originating from the steel cord used to reinforce the tires - and many more chemical substances and compounds, refer to appendix 1.

Environmental impact

The rubber granulate contains metals capable of entering the environment and in particular zinc has been found to be released from the granulate. Zink metal is not hazardous to humans, but can have consequences for organisms in the soil or surface water[44,45]. Many of the concerns raised by the public

[37] Interview, Poulsen, Nordisk Kunstgræs, 2017

[38] Vidair 2010.

[39] Dye et al 2006: Measurement of air pollution in indoor artificial turf halls

[40] ECHA 2017: Bilag XV-Rapport;

[41] The U.S. Environmental Protection Agency (EPA), the Centers for Disease Control and Prevention/Agency for Toxic Substances and Disease Registry (ATSDR), and the Consumer Product Safety Commission (CPSC)

[42] https://www.epa.gov/chemical-research/federal-research-recycled-tire-crumb-used-playing-fields

[43] RIVM 2016

[44] http://www.rivm.nl/dsresource?objectid=13f47f90-ca4e-4b43-a87c-4cdf39797379&type=pdf&disposition=inline

[45] Miljøstyrelsen: Miljøvurdering af zink ved tilladelse eller miljøgodkendelse af husdyrbrug; 2016.

focus at the potential leaching of metals and organic chemical substances from recycled rubber into drainage water and water recipients especially zinc, PAHs, and dissolved organic carbon. According to Bjørn Aas from the Norwegian University of Science and Technology it is documented that there is a higher leach of metals from rubber granules that have been placed in water; a study not least relevant for the Nordic countries where the climate is generally wet[46]. However, none of the studies examined present evidence to support claims that leaching of chemical substances from infill used in artificial turf will cause environmental problems.

During vulcanization, the rubber is heated with vulcanizing agents under pressure, which causes profound chemical changes at the molecular level, altering the initial composition of the tire and giving it its elasticity. There is some concern, but also uncertainty, about whether rubber material in vulcanized tires might undergo chemical transformation over time. The rubber could serve as a sorbent for chemicals in the air and in dust that falls onto the field.[47] The leaching of zinc is seen as perhaps the most relevant parameter, as some scientists claim that emission of zinc to the soil over time can exceed the environmental limit values[48]. The 2008 study from The Danish Technological Institute states that it *cannot be ruled out that there may be an environmental risk with the leaching of some substances from crumb rubber*[49]*,* and the number of chemical substances and compounds that can be released from crumb rubber calls for attention (see appendix 1). However, no identified scientific study documents the impact[50].

The actual concentrations of chemical substances in the drainage water from third-generation fields are probably significantly lower than those measured in the laboratory because it has been recognised that the contact with water is not as 'efficient' as in the laboratory tests.

The maintenance of the fields and especially the winter maintenance clearly is a very important factor in terms of spread of micro plastic. The best indicator for this is the fact that for Norwegian artificial turf fields there are large variations in the need for refilling of the rubber granulates, depending on whether the field is placed in a colder or warmer region. Pål Lydersen from Unisport in Norway says: *"From the football association, we know that in-land fields up north are losing granules, but coastline fields have less snow and lose fewer granules. The different climate is very important to consider regarding the guidelines for maintenance.*

We have had four fields recycled in recent years and they have not had any refilling during the ten years they were used; still, they weighted the same as a new field. It is a question on how to keep the granules inside the pitch area, and on some cases very little granules disappears from the pitch. But the fields which require winter maintenance need much more refill – 10-20 times during a 10 years period. A solution is to get more control of the snow"[51].

The traditional waste handling of SBR has been incineration or landfilling[52]. Recycling of SBR can be difficult because the infill is contaminated with sand. However, recycling of the complete turf is now possible with 99 % recycling of the turf materials[53]; development of this system has been supported by the Danish EPA. If recycling is not possible it is unsure whether a secondary market for a lower quality

[46] Interview med Bjørn Aas, Norwegian University of Science and Technology

[47] EPA 2016: Federal Research Action Plan on Recycled Tire Crumb Used on Playing Fields and Playgrounds

[48] Hostra 2007

[49] Nilsson et al 2008: Mapping, emissions and environmental and health assessment of chemical substances in artificial turf

[50] ECHA 2017: Bilag XV-Rapport

[51] Interview, Pål Lydersen, Unisport 2017

[52] Landfilling not allowed within EU

[53] A Danish recycling concept for artificial turf with an alleged 99 % recycling rate of the materials will in 2017 be documented by an independent EU Environmental Technology Verification (ETV) https://ec.europa.eu/environment/ecoap/etv/about-etv_en

product exists. If the crumb rubber is cut into smaller sections it is unlikely for it to be recycled after its second use. Instead it will presumably end up in incineration[54].

Supplier examples
Genan (DK); Ragn Sells (NO); Sport surface (NO); Unisport (NO)

4.1.1 Coated Rubber Infill

Material properties

SBR Crumb rubber can be coated with polyurethane (PU) film[55]. Coated rubber provides additional aesthetic appeal, can reduce the dust during the manufacturing process, and the encapsulation of the rubber particles can and reduce or eliminate the unwanted effects typical of traditional black rubber[56]. The coated crumb rubber is marketed as safer and more heat resistant than standard crumb rubber, however, the coatings may contain additional chemicals of concern and their effectiveness in sealing off the toxins in crumb rubber has not been well studied[57].

Only one European supplier of coated SBR rubber has been identified during this study. The 'Infillpro X Tre' from Limonta Sport has a granule size of 0.5 - 2.5 mm and the granules are equilibrated, spherical, elongated, and fibre shaped. The goal with the equilibrated and heterogeneous fragments is to minimize the spread as the rubber granulate binds together. Colours are black, brown and green[58].

Usability

The elastic granule is advertised as having high use durability: Excellent resistance against UV, ageing, and wearing trample, no dust on the field, and high stability[59]. The rubber is fibrillated in the granulation and the supplier states that better bond is obtained in the filler material and spreading as well as splash is minimized compared to traditional SBR infill. The minimization of spreading has been observed with control measurements on field sides, but there is no scientific proof yet[60].

Illustration 3: Limonta Sport X-Tre

Literature states that this type of product has not been on the market long enough to prove that the coatings will remain intact for the lifetime of the field[61]. The recycler of artificial turf fields ReMatch has experienced that the coating typically lasts 4-5 years, thereafter the granulate will potentially leak the same chemicals as SBR rubber[62]. This is confirmed by the infill vendor ProTurf AS stating that the coated material is very seldom sold and that the SBR coating has a minimal effect that vanishes over time[63].

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[54] FIFA 2017: Environmental impact study on artificial football turf

[55] Literature states that SBR also can be coated with EPDM, colorants, sealers, and anti-microbial substances (Artificial Turf: A Health-Based Consumer Guide, 2017), however no examples have been found from suppliers in this study.

[56] Artificial Turf: A Health-Based Consumer Guide, 2017

[57] Delaware Riverkeeper Network: Alternative Infills for Artificial Turf Fact Sheet,

[58] http://www.limontasport.com/en-us/products/infill/x-tre/

[59] Ibid.

[60] Interview, Poulsen, Nordisk Kunstgræs, 2017

[61] Activitas 2014): Turf Study Memorandum prepared for the City of Marlborough, Massachusetts.

[62] Poulsen, Nordisk Kunstgræs, interview.

[63] Interview Christian Steen, ProTurf AS, 2017

Costs, access and availability

The InfillPro X-Tre is part of the FIFA Quality and FIFA Quality Pro systems, it is a new product but already applied in artificial turfs in Scandinavian countries[64]. The X-Tre infill product costs around 5.000 NOK/ton[65], more expensive than the standard SBR infill but a lower price than other alternative infill solutions such as TPE, Virgin EPDM and organic compounds.

Suppliers further state that the infill has up till three times lower mobility of granules in the playing area than other products in the market as well as higher performance in weight/volume: 10 % less infill in artificial turf with Infillpro X-Tre will be necessary compared to other products[66]. There is a 10-year guarantee on the durability of the enclosure for the InfillPro X-Tre product[67].

Environmental effects

The INFILLPRO X-Tre is stated to fulfil the EN71 requirements and all ecological and environmental parameters requested by international regulations[68]. Due to the coating of the SBR rubber with polyurethane, the discharge of metals into drainage water from InfillPro X-Tre is below the detection limit, apart from Zink with a 50% discharge compared to plain black SBR[69]. However, if the polyurethane coating is not completely intact throughout the life of the granule, leakage may occur in subsequent years[70] .

According to the supplier the spreading of micro plastic should be minimized because of the equilibrated and heterogeneous fragments[71].

The 'Infillpro X Tre' form Limonta Sport use a pigment advertised as 'not toxic and environmental friendly'[72]. No independent, specific studies on these substances have been identified during the literature review

Supplier examples

Sport Surface (NO) INFILLPRO X-Tre (Limonta Sport (IT)

[64] Ibid.

[65] Interview, Poulsen, Nordisk Kunstgræs, 2017

[66] http://www.limontasport.com/en-us/products/infill/x-tre/

[67] ibid.

[68] http://www.limontasport.com/en-us/products/infill/x-tre/

[69] Danish Technological Institute: Elution of metals from infill material

[70] Interview, Dennis Andersen, ReMatch 2017.

[71] Interview, Poulsen, Nordisk Kunstgræs, 2017

[72] Supplier information: http://www.limontasport.com/en-us/products/infill/x-tre/

5 REVIEW OF ALTERNATIVE INFILL MATERIAL

Due to the increasing health and environmental concerns over the crumb rubber infill used in artificial turf, more and more manufacturers of artificial turf are marketing alternatives to the traditional infill. There are many new and emerging variations in the different products' composition with some aimed at reducing the release of toxic substances, some focusing on heat concerns, and others again targeting other improvements. Each of these materials offers its own apparent advantages, disadvantages, and issues for consideration. Some of the alternative fill materials have been used all over Europe for a decade and the use in the United States is increasing.

5.1 TPE infill

Material properties

TPE (Thermoplastic Elastomers) is a generic term for extruded plastic pellets made from a rubber and plastic polymer. TPE is often composed of ethylene, butadiene, and styrene copolymers[73]. While TPEs are often advertised as made from virgin (not recycled) materials, there is wide variability on the quality and chemical composition of the many TPEs on the market[74,75].

Illustration 4: Limonta Sport TP

TPE is distinct from EDPM rubber in that the material is not vulcanised. Instead, the mesh structure of the product is created by the styrene segments forming crystalline domains[76]. The structure of TPE is maintained without addition of reinforcing agents and stabilizers[77]. The TPE is heated and compressed into grains or other shapes and afterwards cooled down to preserve its shape[78,79].

The TPE infill may contain substances such as UV-stabilizer (e.g. benzotriazole[80]), anti-oxidants, chalk, pigments (e.g. TiO_2[81]) and flame retardants (e.g. $Mg(OH)_2$[82])[83]. If the product do not contain ultraviolet stabilizers it may undergo degradation relatively quickly[84]. TPE is sold in many different colours, mostly brown and green.

Usability

TPE is characterised by good weather resistance[85] and is advertised to be long lasting[86,87], and TPE fields are in general less warm to play on[88]. The TPE material can harden over time[89,90]. Cheaper TPE infill

[73] Artificial Turf: A Health-Based Consumer Guide, 2017

[74] Montgomery County Review of Fields, 2011

[75] Delaware Riverkeeper Network: Alternative Infills for Artificial Turf Fact Sheet

[76] Nilsson et al 2008: Mapping, emissions and environmental and health assessment of chemical substances in artificial turf

[77] http://www.toxipedia.org/display/toxipedia/Crumb+Rubber

[78] http://sturf.lib.msu.edu/article/2012jan36.pdf

[79] Smart Connection Consultancy: The smart guide to synthetic sports fields rubber infill

[80] Wypygh, Anna & Georg 2015: Databook of UV stabilizers, 1. Edition, June 2015

[81] dyes-pigments.standardcon.com, "Types of Pigments"

[82] L. Van Wabeeke 2001: Flame retardant plastics: a general review.

[83] Artificial Turf: A Health-Based Consumer Guide, 2017

[84] Cheng H, Hu Y, Reinhard M. (2014) Environmental and health impacts of artificial turf: a review

[85] Nilsson et al 2008: Mapping, emissions and environmental and health assessment of chemical substances in artificial turf

[86] SportsTurf: Guide to synthetic infill products

[87] Smart Connection Consultancy: The smart guide to synthetic sports fields rubber infill

materials may be more likely to melt at high temperatures which will compromise the performance of the system[91], and reports show that many TPE fields have been replaced due to melting of the material resulting in a gum-like substance that sticks to cleats and makes the grass fibres glue together[92].

Costs, access and availability

The TPEs are quite expensive to fabricate[93,94] and have a high market price compared to crumb rubber. The price of TPE is approximately 15.000 NOK/ton for TPE from ProTurf AS[95] and 16.000-17.000 NOK/ton for the TPE product from Stargum[96].

Approximately 7-10 kg/m^2 granules are necessary if a shock pad is used (50-70 tonnes for a standard field)[97]. Refilling is estimated to be between 6-8 % a year[98].

Health risk

The Norwegian study from 2006 states that the chemical composition of the thermoplastic elastomer is very unlike SBR rubber, but there is little information available on this elastomer in literature. The 2006-study also states that rubber granules produced from thermoplastic elastomer generate less pollution compared to SBR rubber on the parameters that were measured (concentration of polycyclic aromatic hydrocarbons (PAH), volatile organic compounds (VOC), and phthalates)[99].

While many TPEs are advertised as free of lead, zinc, and other toxic metals and materials, some have been shown to in fact contain heavy metals[100] (see also appendix). Others do not have crush resistance, flexibility, and softness. Some TPEs may not have UV stabilizers. The shape of the material will have an impact on the playability and safety[101].

Styrene and butadiene are classified as carcinogens by the World Health Organization. The effects of human exposure to these substances from turf infill are not yet known as specific studies have not yet been conducted.[102] However the Danish Technological Institute report from 2008 states that the emission of chemical substances from TPE is predicted to be limited, because no vulcanisation chemicals are used as is the case for rubber[103].

Environmental effects

TPEs are recyclable and reusable as infill[104] (except if the product has hardened over time[105]). Some TPEs are free of heavy metals. TPE breaks down more quickly than SBR and cannot typically be reused in a

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[88] Montgomery County Review of Fields, 2011

[89] Ibid

[90] Delaware Riverkeeper Network: Alternative Infills for Artificial Turf Fact Sheet

[91] Smart Connection Consultancy: The smart guide to synthetic sports fields rubber infill

[92] Activitas. (2014) Turf Study Memorandum prepared for the City of Marlborough, Massachusetts.

[93] Montgomery County Review of Fields, 2011

[94] Cheng H, Hu Y, Reinhard M. (2014) Environmental and health impacts of artificial turf: a review

[95] Interview med Christian Steen, ProTurf AS

[96] Interview, Urszula Stankiewicz, Stargum 2017

[97] Interview, Lars Poulsen, NKI 2017

[98] Ibid

[99] Dye et al 2006: Measurement of air pollution in indoor artificial turf halls

[100] Mount Sinai Hospital Children's Environmental Health Center 2017

[101] Montgomery County Review of Fields, 2011

[102] Artificial Turf: A Health-Based Consumer Guide, 2017

[103] Nilsson et al 2008: Mapping, emissions and environmental and health assessment of chemical substances in artificial turf

[104] Montgomery County Review of Fields, 2011

[105] Interview, Dennis Andersen, ReMatch, 2017

future field - unlike SBR, that can actually be reused[106]. The TP product from Limonta Sport has been tested for migration of certain elements to show that the TP materials is complying with the limit values[107]. The report is attached as appendix.

The TPE granules have the same risk of ending up as micro plastic in the nature as SBR rubber[108].

Supplier examples

Sport Surface (NO): TP (Limonta Sport, IT); Unisport (NO): TPE; ProTurf: TPE infill from multiple suppliers; Polytan (DE): BionPro; Mondo (IT): EcoFill; Stargum (PL): TP granules; SO.F.TER.(IT): holo, terra, forgrin; Target Technologies International Inc (CA): FutrFill; Field Turf (US/int.): EcoGreen, Eco Max

5.2 EPDM infill

Material properties

EPDM (Ethylene Propylene Diene Monomer) is a synthetic vulcanized rubber polymer. The advantage of this polymeric structure is good weather resistance, making it unnecessary to add anti-ozonants to EPDM rubber[109].

Most sources state that EPDM is only generated from virgin rubber, but according to Mount Sinai (2017) EPDM might also be generated from recycled rubber[110]. EPDM has the same grain size as SBR crumb rubber.

EPDM is a generic term and the source, formulation, and quality of the material can vary greatly[111,112] with only limited possibility for a layman to see the difference[113]. Cowi reports in 2012 that the quality of rubber granulates based on EPDM differs: Good quality EPDM is well suited for use in artificial turf, but some suppliers use a lot of chemical fillers or recycled EPDM, which can cause the rubber granulates to crumble, resulting in poor quality granulates. Only (expensive) testing of the granulate can show the quality[114].

Illustration 5: Gezofill

Usability

EPDM is by suppliers advertised as a polymer elastomer with high resistance to abrasion and wear and without changing its solid form under high temperatures. EPDM creates a surface that strongly resembles a natural grass playing surface.

EPDM is available in many colours but is typically marketed in light green and tan colours to reduce heat concerns. Compared to rubber infill, EPDM supposedly absorbs less heat when exposed to the sun[115]; the material is odourless in contrast to SBR crumb rubber that has a significant smell[116].

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[106] Activistas 2014

[107] LCQ MD standard report 1331937a, 2013

[108] FIFA 2017: Environmental impact study on artificial football turf

[109] Nilsson et al 2008: Mapping, emissions and environmental and health assessment of chemical substances in artificial turf

[110] Mount Sinai 2017: Artificial Turf: A Health-Based Consumer Guide

[111] Gale Associates Inc. (2015). Alternative Infills for Synthetic Turf.

[112] Cowi 2012: Omfanget av bruken, bruksområder og framtidig bruk av gummigranulat basert på bildekk og ny gummigranulat

[113] Kulturdepartementet 2015: Veileder: Kunstgressboka

[114] Cowi 2012: Omfanget av bruken, bruksområder og framtidig bruk av gummigranulat basert på bildekk og ny gummigranulat

[115] Ibid.

[116] Smart Connection Consultancy: The smart guide to synthetic sports fields rubber infill

Studies show that several manufacturers in Europe have had to replace a large number of EPDM-filled fields due to a reaction between the EPDM and the carpet fibre causing a breakdown of the fibre. There are reports of premature aging and degradation of the infill due to high levels of chemical fillers[117].

Costs, access and availability

EPDM is very expensive in comparison with crumb rubber[118]. According to ProTurf AS the price of virgin EPDM is about 15.000 NOK/ton. Recycled EPDM has a price of 7.000 NOK/ton[119]. A rough price indication of the Gezofill product is 13.000-15.000 NOK/ton and 12.000 NOK/ton for the EPDM product from Stargum[120].

Approximately 7-10 kg/m^2 granules are necessary if a shock pad is used (50-70 tonnes for a standard field)[121]. The consumption per square meter strongly depends on the height of the infill and the carpet used[122]. Refilling is estimated to be between 6-8 % a year[123].

Health risk

There are insufficient data on chemical exposures due to limited studies that evaluate the composition, off gassing, leaching, and associated potential health effects[124].

The NFF analysis concludes that the EPDM product shows no content of the hormone disrupting phthalate (DEHP) but has the highest emissions of volatile organic compounds to the indoor environment.

Vulcanisation of EPDM

Zinc can be a constituent in both peroxide and sulphur vulcanization. In sulphur vulcanisation, the typical accelerators are based on nitrogen and sulphur. For the peroxide vulcanised types, organic peroxides are used, typically dicumyl peroxide which splits off acetophenone during vulcanisation. Other types may split off tert-butyl alcohol. The softeners used for EPDM are predominantly naphthenic oils with a relatively low aromatic content. Triallyl cyanurate is used in peroxide vulcanised EPDM rubber as a cross-linking regulator.

Environmental effects

The EPDM is in studies stated to be durable, non-toxic, and more environmentally friendly than tire rubber[125,126]. A 2004 Byggforsk study reports that apart from the chromium and zinc content, the EPDM granules contained less environmentally dangerous substances than the granules from recycled rubber. EPDM also emitted smaller amounts of volatile substances than the traditional infill[127]. However EPDM granules has the same risk of ending up as micro plastic in nature as SBR rubber and the production of virgin EPDM has a higher environmental impact (total climate gas emission) than reused EPDM or SBR[128].

EPDM made from virgin material does not contain hazardous additives[129]. However, EPDM can be subjected to either peroxide or sulphur vulcanisation. EPDM can contain UV stabilizers, anti-oxidants, chalk, pigment, flame retardants, and volcanic agents such as zinc oxide[130] (see box[131]). According to

[117] Montgomery County Review of Fields, 2011

[118] Cheng H, Hu Y, Reinhard M. (2014) Environmental and health impacts of artificial turf: a review

[119] Interview with Christian Steen, ProTurf

[120] Interview, Urszula Stankiewicz, Stargum 2017

[121] Interview, Lars Poulsen, NKI 2017

[122] Interview Michael Karpe, Sales Director, Gezolan 2017

[123] Interview, Lars Poulsen, NKI 2017

[124] Artificial Turf: A Health-Based Consumer Guide, 2017

[125] Cheng H, Hu Y, Reinhard M. (2014) Environmental and health impacts of artificial turf: a review

[126] Montgomery County Review of Fields, 2011

[127] Plesser et al 2004: Potensielle helse- og miljøeffekter tilknyttet kunstgressystemer, Byggforsk in Nilsson et al 2008.

[128] FIFA 2017: Environmental impact study on artificial football turf

[129] Cheng H, Hu Y, Reinhard M. (2014) Environmental and health impacts of artificial turf: a review

[130] Mount Sinai 2017: Artificial Turf: A Health-Based Consumer Guide

[131] Nilsson et al 2008: Mapping, emissions and environmental and health assessment of chemical substances in artificial turf

Cheng H, Hu Y, Reinhard M. (2014) studies has shown that new turfs as EPDM are more toxic to aquatic life than crumb rubber[132]. Furthermore, chemicals used in the manufacturing might leak into the nearby water[133].

EPDM granules are more difficult to recycle because of the vulcanization in the production[134].

Supplier examples

ProTurf (NO): Melos Bionic EPDN – APT (Melos, DE); Unisport (NO) Gezofill (Gezolan, EU); Stargum (PL): EPDM granules; Polytan (DE): Gmbh

5.3 Sand Infill

Material's properties

Pure silica sand is one of the earliest alternative infilling materials. Silica sand is derived from quartz eroded by wind and water. This product is a natural infill, with tan, off-tan, or white colour and round or sub-round in particle shape (compared to other more edgy sand types). Silica sand is abrasive and relatively hard, especially under cold or frozen conditions.[135]

Usability

Silica sand is commonly used as infill in artificial turf in lawns, playgrounds, and recreational areas. It is a very good stabilizer to keep the fibres standing, but can get compacted when wet[136]. Silica sand has a higher density than other infill products but still need to be replaced over time because it has been removed by wind or usage[137]. Silica sand is widely used in the second-generation artificial turf[138], normally with a high purity (greater than 90%) to resist crushing and absorption of bacteria and other field contaminants[139].

Silica sand can be coated with different materials as a standalone product (see 5.6.1) or used in combination with traditional crumb rubber infill systems[140]. Silica sand can be mixed with other types of sand in a 50/50 ratio, and a mixture of silica sand and rubber infill is known to provide a better playing surface than rubber alone, i.e., a better field safety and playability[141]. Segregation of the rubber and sand particles in the turf can occur and the mixed infill needs to be loosened periodically [142].

Before year 2000, most or all artificial pitches in Norway were filled purely with sand. This led to sliding injuries and the fields became hard, so when the SBR infill came on the marked in 2000 it was seen as a revolution for player usability, and the building of artificial fields with SBR rubber increased dramatically[143].

According to Etne Municipality that still primarily uses pure sand as infill, the sand gets worn out and need to be replaced over a period of time. Apart from that the players are satisfied with the sand

[132] Mount Sinai 2017: Artificial Turf: A Health-Based Consumer Guide

[133] Cheng H, Hu Y, Reinhard M. (2014) Environmental and health impacts of artificial turf: a review

[134] FIFA 2017: Environmental impact study on artificial football turf

[135] Gale Associates: "Alternative Infills for Synthetic Turf."

[136] http://www.heavenlygreens.com/blog/comparing-artificial-turf-infill-zeofill-vs-silica-sand

[137] ibid.

[138] Cheng H, Hu Y, Reinhard M. (2014) Environmental and health impacts of artificial turf: a review

[139] Delaware Riverkeeper Network: Alternative Infills for Artificial Turf Fact Sheet,

[140] Smart Connection Consultancy 2017: The Smart Guide To Synthetic Sports Fields Rubber Infill

[141] http://www.heavenlygreens.com/blog/comparing-artificial-turf-infill-zeofill-vs-silica-sand

[142] Cheng H, Hu Y, Reinhard M. (2014) Environmental and health impacts of artificial turf: a review

[143] Ole Myrhvold, Field Manager, The Football Association of Norway (NFF), 2017

fields[144]. However, according to The Football Association of Norway (NFF) the football players are generally not satisfied with artificial fields with purely sand infill[145].

Costs, access and availability

According to literature silica sand is inexpensive (less expensive among the alternative infill materials) and easily found[146,147]. Specific prices have not been found during this project. Etne municipality were not able to describe the supplier used or prices, but stated that there are many local suppliers[148].

Health risk

Sand dust may cause respiratory irritation if inhaled[149]. Canadian studies indicate that the dust from silica sand might cause silicosis or even cancer when inhaled. Standards exist for occupational use but not for non-occupational use[150]. During the mining of silica sand small dust-sized particles of sand are produced and the smallest of these can be emitted with air (eg. crystalline silica). Workers in the mines are exposed to the airborne dust, people living close to the mines to a lesser extent[151].

Environmental effects

Mining of silica sand can affect the ground water due to the use of heavy machinery, spills and leak of fuel, oil or chemicals, runoff from contaminated sources, or illegally dumped waste. The use of flocculants in the cleaning of the sand might also present a risk. Though being environmentally safe the flocculants contain small amounts of chemicals of concern (acrylamide[152] and cleaning agents) [153]. The mining may cause groundwater in the area to become more acid, which might again cause dissolution of minerals such as iron and manganese. Mining activities can cause comprehensive ground water removal that may affect nearby wells [154]. Less energy and processing is required for production compared to materials based on fossil fuel[155]. Silica sand can be recycled or disposed of with little restriction[156]. In mixed infills the rubber crumb can be separated from sand and subsequently recycled[157].

Supplier examples

Unisport (NO)

5.4 Organic materials

Materials' properties

There are several organic infills available in the North American and European market, utilizing different organic components in combinations with one or more of the following: Coconut fibre, coconut husk,

[144] Interview Kristin Hagla, Etne municipality, 2017.

[145] Ole Myrhvold, Field Manager, The Football Association of Norway (NFF), 2017

[146] http://sturf.lib.msu.edu/article/2012jan36.pdf

[147] Cheng et al (2014)

[148] Interview Kristin Hagla, Etne municipality, 2017.

[149] Artificial Turf: A Health-Based Consumer Guide, 2017

[150] Delaware Riverkeeper Network: Alternative Infills for Artificial Turf Fact Sheet

[151] Minnesota Department of Health: Silica Sand Mining & the Environment, 2014

[152] Usually polyacrylamides; Guezennec et al 2014: Transfer and degradation of polyacrylamide based occulants

[153] Minesota Department of Health: Silica Sand Mining & the Environment, 2014

[154] Minesota Department of Health: Silica Sand Mining & the Environment, 2014

[155] FIFA 2017: Environmental impact study on artificial football turf

[156] Cheng H, Hu Y, Reinhard M. (2014) Environmental and health impacts of artificial turf: a review

[157] Ibid

coconut peat, cork, rice husks, walnut shells, etc. The literature states that as a general rule the products are treated with an antimicrobial application to prevent deterioration of the infill[158]. The drawback of these products is that they have no track record for durability and there are concerns about break down of the organic material, insects, and compaction of the material over time[159].

Usability

Cold weather can impact playability of turf filled with organic materials as the infill may become saturated and freeze. There are reports of early degradation and compaction. Organic infills require irrigation and regular maintenance, including de-compaction twice a year and replacement of 10% of infill every 2-3 years because of loss through decomposition and wind throw. Especially infill of coconut requires an expensive irrigation system [160]. The organic materials harden, blow and float away, leading to migration and accumulation in waterways, reduced performance capability of the turf court, and higher potential for injury. There is potential for weed and mould growth and decomposition[161].

The organic infill is less heat absorbing and absorbs more humidity than crumb rubber infill[162]. The infill is reported 10-25C cooler than crumb rubber, though still higher than natural grass. The infill resists wear and ultraviolet rays[163].

Costs, access and availability

The procurement cost of organic infill is relatively low compared to other alternative infill components[164], however varies according to the product in question. Reportedly there is limited availability of organic infill[165].

Health risk

There is a risk that when the organic turf infill material gets wet, favourable conditions for fungus can be created with potential health risk. Dahl Jensen from Copenhagen University states that organic material on top of a rubber shock pad *can* be a problematic combination[166]. However she also informs that no studies either prove or disprove this assumption. Organic material can be seen as less suitable in Norway than in US or Australia with the latter countries' typically warmer and dryer climates.

Environmental effects

Plant-based/organic infill is non-toxic and has a lower environmental impact (total climate gas emission) than polymer infills[167,168]. Long transportation of organic materials such as coconut should be considered when looking at environmental effects; however, bulky transport by ship means limited transport emissions. New alternatives could be developed from organic materials found in the Nordic countries, such as waste wood fibres[169].

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[158] Montgomery County Review of Fields, 2011

[159] Cheng H, Hu Y, Reinhard M. (2014) Environmental and health impacts of artificial turf: a review

[160] http://loudoun.granicus.com/MetaViewer.php?view_id=68&clip_id=4389&meta_id=96276

[161] Gale Associates Inc. (2015). Alternative Infills for Synthetic Turf

[162] Artificial Turf: A Health-Based Consumer Guide, 2017

[163] Cheng H, Hu Y, Reinhard M. (2014) Environmental and health impacts of artificial turf: a review

[164] Ibid

[165] Gale Associates Inc. (2015). Alternative Infills for Synthetic Turf.

[166] Interview with Anne Mette Dahl Jensen, Copenhagen University

[167] FIFA 2017: Environmental impact study on artificial football turf

[168] Montgomery County Review of Fields, 2011

[169] Interview Bjørn Aas, the Norwegian University of Science and Technology, 2017

At the end of its life cycle the organic material can be recycled directly into the environment through composting but cannot be reused as infill for new artificial turf fields[170]. The resources used on separation of the organic infill from the turf may outweigh the gain of using the infill as compost. If recycling is not possible, incineration is less environmentally harmful for organic infill compared to other types of infill when looking at lifecycle climate gas emissions[171].

5.4.1 GeoPlus

Sports Surface/Limonta Sport offers an organic infill product called Geoplus that "consists exclusively of a mixture of organic plant material, derived from defibration of woody plants, that have been carefully chosen and processed with an innovative process"[172]. According to the suppliers the composition and density of the Geoplus' special blend enable it to perfectly fit into the artificial turf system, avoiding any kind of infill splash effect. The product is 100% natural and recyclable by end of the field's life for agricultural use or gardening. The product is compatible for indoor courts[173].

Only two fields with GeoPlus infill are established in Norway, one of which is located in Etne Municipality in the southwest of Norway. The field was established in 2014 in order to avoid negative effects of rubber infill[174]. The infill has been supplemented two or three times since the establishment in 2014 with varying amounts of added infill. The maintaining procedures have been corrected in cooperation with the supplier and the field is now raked with a tractor three times a week. Compared to the artificial turf fields with sand infill[175], where maintenance has been done manually, this process is more resource efficient[176].

Illustration 6: Limonta Sport Geoplus

In dry summers the Geoplus infill can become dry and has to be irrigated. In very wet weather a good drainage system is necessary.

5.4.2 Cork

Material's properties

Cork is the outer bark of the cork oak tree and the structure and composition of the membranes make it very strong and waterproof. Cork is used for all kinds of purposes such as energy conservation, flotation, insulation, polishing, sealing, sound dampening, and vibration control. Since 2007, granulated and most often heat treated leftover material from bottle cork production[177] have been used as an infill in artificial turf systems to an increasing extent.

Usability

Cork is advertised to keep the turf cool because of the low thermal conductivity; the material has good shock absorbing properties and is completely recyclable. Cork has some positive properties when used as an infill such as a low density, high strength, low wear, and low heat absorption when exposed to

[170] Montgomery County Review of Fields, 2011

[171] FIFA 2017: Environmental impact study on artificial football turf

[172] http://www.limontasport.com/en-us/products/infill/geo-plus/

[173] ibid.

[174] Interview Kristin Hagland, Etne Municipality, 2017

[175] In Etne Municipality they have no fields of rubber granules, but only sand infill and one field with Geoplus

[176] The artificial turf fields with sand infill has to be maintained manually because of the construction of the field with a metal edge that does not allow the tractor to enter.

[177] IAKS: Pros and cons of cork as an infill for artificial turf pitches

sunlight. The material has a high elasticity because of its large share of air-filled cell structure, a high fire resistance, it is slow to react to a large number of acids and other chemical substances, and it is almost odour-neutral.[178] Cork has been successfully applied in Australia with good court performance in the hot, dry Australian climate[179].

On the other side, cork tends to bind water by absorption; it may harden at frost and get frost damage and defragmentation[180] and dry out in the summer with resulting dust emission, lack of elasticity and a tendency to sticking to shoes and clothes in dry weather – why generally irrigation is needed during hot periods[181,182,183]. In the past ten years several fields in Scandinavia have been installed with cork infill[184,185]. The Norwegian municipality of Etne is very satisfied with the installed cork field and considers using cork in other fields[186]. Only one field with cork infill has been installed in Denmark, FC Nordsjællands Premier League field in Farum in 2012, but the infill material was switched back to SBR rubber infill in September 2016[187] since the infill froze to ice at winter and made it impossible to play on the pitch[188].

The durability of cork is less than of rubber and the material must be replaced in 3-4 years[189]. There is also a risk that crumbled cork might seal the drain of the field[190].

The quality of the cork varies a lot, depending on where it has been taken from the bark[191]. Good quality cork supposedly absorbs less water and thus should be more suited for the Scandinavian climate, however, it has not been tested or confirmed yet[192]. According to the infill supplier DOMO, the difference between good and poor quality cork is the density; cheap cork is heavy and good quality is light weight. According to DOMO good quality cork must not exceed 130 kg/m3 and the cork infill from DOMO is between 90-120 kg/m3. The DOMO cork infill is 100% natural, the only process has been boiling. It has not yet been installed in Scandinavia, but have been installed in Germany with good results[193].

There are still several unresolved issues concerning granulated cork as infill material; the material has not been standardised or certified and it has not proven itself being a serious alternative on the market and in practice. Taking into account the matter of cost-effectiveness, these issues still have to be critically assessed[194].

[178] IAKS: Pros and cons of cork as an infill for artificial turf pitches

[179] Smart Connection Consultancy: The smart guide to synthetic sports fields rubber infill

[180] Interview Bjørn Aas, Norwegian University of Science and Technology, 2017

[181] Ole Myrhvold, Field Manager, The Football Association of Norway (NFF), 2017

[182] Interview, Martin Mogensen, DBU (Danish Football Union), 2017

[183] IAKS: Pros and cons of cork as an infill for artificial turf pitches

[184] Interview, Pål Lydersen, Unisport Norge, 2017

[185] Interview, Leif Torvestad Sportsurface Norge, 2017

[186] Interview Kristin Hagland, Etne municipality, 2017

[187] Interview, Kristoffer Skadhauge, FC Nordsjælland

[188] Interview, Martin Mogensen, DBU (Danish Football Union), 2017

[189] ibid.; Ole Myrhvold, Field Manager, The Football Association of Norway (NFF), 2017

[190] Moss Avis: Om kunstgressbaner og gummigranulat

[191] Ole Myrhvold, Field Manager, The Football Association of Norway (NFF), 2017

[192] Interview, Martin Mogensen, DBU (Danish Football Union), 2017

[193] Interview, Stef Oliviers, sales manager DOMO, 2017

[194] Interview Bjørn Aas, Norwegian University of Science and Technology

Costs, access and availability

There are many suppliers of cork granules, however, stakeholders claim that the amount of high quality cork is too limited to meet the global demand[195,196,197,198]. The supplier DOMO does not recognise this problem, and states that they have no problem with availability.

The cork infill from DOMO is approximately 19.000-24.000 NOK/ton. The quantity needed is 1,7-2 kg/m^2 at a 15 mm infill high with the use of a shock pad[199]. The total price for the cork infill at a standard field (160 m^2) would be approximately 230.000-290.000 NOK. Unisport's 'eCork' product is approximately 5.000 NOK/ton[200].

Suppliers states that cork generally has a lower overall cost considering total cost of the turf field than other organic infills due to less compaction and less need for irrigation[201]. NFF however has experienced that artificial fields with cork infill must be watered to obtain a good playing characteristics[202].

Suppliers of cork infill states that cork is a more durable infill granule (less infill compaction) than other organic infill materials[203]. However, suppliers also states that cork will need to be maintained and refilled more often than non-organic granules due to its low density. Uniport estimates 10% refill every year[204]. Because of the low density (< 1g/cm3) cork will float on water and therefor the material will discharge with water and wind (erosion).[205] A pilot study in Hamburg showed that by heavy rainfall the light granulated cork was lifted out of the fibres and migrated from the fields; if the grains do not migrate after being lifted by heavy rain they stay on top of the fibres and must be worked back into the field. The study showed that dense and high artificial turf systems are less likely to lose the infill, and it further indicated that the dense fields did not need refill after three years as for the less dense fields. The pilot study from Hamburg found the cork to be a suitable alternative for rubber crumb under the given circumstances[206].

Health risk

If not frequently and properly maintained the cork infill can compact and become hard which will affect field performance and safety[207]. Same possible health problems as stated about organic infill. However suppliers states that the cork components are naturally? anti-microbial and anti-allergenic and therefor able to repel pests and mould and last long before rotting[208].

Environmental effects

Cork is a renewable raw material derived from the bark of the cork oak - by independent sources seen as a sustainable process[209,210]. Despite of the long transportation distances (as cork is only grown in the

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[195] Interview: Bjørn Aas, Norwegian University of Science and Technology

[196] Interview, Pål Lydersen, Unisport Norge, 2017

[197] Interview, Dennis Andersen, Rematch 2017

[198] Moss Avis: Om kunstgressbaner og gummigranulat

[199] Interview, Stef Oliviers, sales manager DOMO, 2017

[200] Interview, Pål Lydersen, Unisport Norge, 2017

[201] http://www.fieldturf.com/en/purefill

[202] Ole Myrhvold, Field Manager, The Football Association of Norway (NFF), 2017

[203] http://www.fieldturf.com/en/purefill

[204] Interview, Pål Lydersen, Unisport Norge, 2017

[205] IAKS: Pros and cons of cork as an infill for artificial turf pitches

[206] Ibid

[207] Activistas 2014

[208] http://www.fieldturf.com/en/purefill

[209] IAKS: Pros and cons of cork as an infill for artificial turf pitches

[210] The Cork Quality Council and the WWF: Cork Oak Landscapes. https://www.corkqc.com/pages/sustainable-practices

Mediterranean), the overall environmental impact of cork is low due to the sustainable production and straightforward processing[211]. Because of a low bulk density cork can be removed from the fields when raining, which will require refill[212].

Supplier examples

Unisport (NO): eCork; Fieldturf (EU): PureFill; Domo Sports Grass (BE): Naturafill; GreenPlay (US): Pure Cork Infill;; Cork-shop (DE): Eco Cork.

5.4.3 Sugarcane granules[213]

Unisport in Norway is working on an organic infill type based on the sugarcane plant. The testing shows good technical prospects with two smaller outdoor fields and one indoor field. The granule will be in more different sizes than cork and will be unlimited supply. Unisport is waiting for approval to put the product on the market. The product is in the test phase and an independent study is being conducted at the moment, to be published 2018. Further information regarding the specific content of the infill product is not available at the moment.

Among the challenges are: The material is much lighter than rubber and therefore creates some problems on the field; when becoming wet it tends to get sticky, and the material is much more expensive than other materials (among others since it is in low volume). Other challenges include CSR in the production phase and the ethical/resource-related issue about using 1st generation food or by-products that could otherwise be used as livestock feed[214].

According to NFF Stavanger Municipality had installed a trial field with sugercane granules which had to be replaced, mainly because the granules sticks to shoes and clothes and was vulnerable to rain and wind[215].

Limonta Sport is also working on a new organic product with a secret recipe, but not based on cork or coconut; more information will be available early 2018[216].

Supplier examples of other organic infill products

ProGeo (US) – Geoturf; Shaw Sports (US): GeoFill.

5.4.4 Wood fibres

According to NFF, a new infill product based on wood fibres may be on the way, however there is little knowledge about the product at this stage[217]. Bjørn Aas also suggests that new alternatives could be developed from organic materials found in the Nordic countries, such as wood fibres[218].

5.5 Non-infill systems

It is possible to establish an artificial turf field with no infill. There are several options, one Norwegian supplier Sport Vest AS has introduced the TRINIDAD Non-Infill system, a yarn-based, carpet-like product,

[211] FIFA 2017: Environmental impact study on artificial football turf

[212] Norsk dekretur 2017

[213] Interview, Pål Lydersen, Unisport Norge, 2017

[214] Interview Bjørn Aas, Norwegian University of Science and Technology, 2017

[215] Ole Myrhvold, Field Manager, The Football Association of Norway (NFF), 2017

[216] Interview, Angelo Redolfi, Eksport manager, Limonta Sport, 2017

[217] Ole Myrhvold, Field Manager, The Football Association of Norway (NFF), 2017

[218] Interview Bjørn Aas, the Norwegian University of Science and Technology, 2017

from the Turkish supplier HATKO. Toxicology and flammability of the product are tested by FIFA accredited laboratories[219]. This specific non-infill type is most commonly used in smaller fields and enclosed mini-fields and for indoor use and is not recommended over 40 meters in length[220].

However other non-infill products can be installed in full size, and several full size artificial fields (64 x 100 meters) have been installed in Norway[221]. The Belgian supplier DOMO has two types of non-infill fourth generation carpets. Both can be used for professional use but they do not meet FIFA quality since they cannot pass the skin abbreviation tests[222]. The non-infill field are generally harder to play on than infill fields[223].

UNISPORT also has a no-infill artificial grass system, tested in (among others) Haslum IL in Bærum with three installed fields over the last two years, functioning to the satisfaction of Haslum IL. The fields are used for children and youth[224] and do not meet the requirements for FIFA quality or FIFA pro, mainly because the fibres lie down during use (since there is not enough support around the straw), causing the ball to roll too fast. There is a shorter guarantee on these fields, depending on how frequent they are used and the extent of maintenance[225].

Prices for the TRINIDAD product in 2018 will be NOK 280-290 per m^2, with the turf delivered as standard in 4m width and length as desired. According to the sales manager of the TRINIDAD product the turf does not need to be replenished or maintained since it does not contain granulate; only raking in the spring when the snow has melted is needed[226]; NFF states, though, that an artificial pitch must be maintained, even if there is no infill[227].

Illustration 7: Sport Vest Trinidad

Prices for the DOMO products are 160 NOK/m2 for the 20 mm carpet and 190 NOK/m2 for the 25 mm carpet.

It has not been possible to obtain a price indication from Unisport on their products.

The lifespan of the field is stated to be five years (compared to standard turf ten years)[228]. There are no special limitations on the production of this artificial turf[229].

Bjørn Aas from the Norwegian University of Science and Technology perceives the no-infill system as a relevant alternative to the infills and regards the FIFA-requirements as an obstacle for the use of this solution[230].

Supplier examples

Sport Vest AS (NO): Trinidad; Unisport (NO); Domo (BE); Greenfield

[219] HATKO Trinidad technical description

[220] Interview Sport Vest AS 2017

[221] Interview, Ole Myrhvold, Field Manager, The Football Association of Norway (NFF), 2017

[222] Interview, Stef Oliviers, sales manager DOMO, 2017

[223] ibid.

[224] Interview, Knut Guldbrandsen, Haslum IL.

[225] Interview, Jan Lyngemark, Unisport 2017

[226] Interview Sport Vest AS 2017

[227] Interview, Ole Myrhvold, Field Manager, The Football Association of Norway (NFF), 2017

[228] Interview Sport Vest AS 2017

[229] ibid.

[230] Interview Bjørn Aas, The Norwegian University of Science and Technology

5.6 Materials not deemed suitable

The following infill materials have in this study been deemed unsuitable for use in Norwegian context.

5.6.1 Acrylic/Polymer Coated Sand

This class of infill consists of coated silica sand with either a soft or rigid coating. The chemical contents of the polymer coatings vary by manufacturer.

Both the acrylic coating and the sand are very hard materials requiring a shock pad and are therefore recommended to be combined with a softer infill material. The coatings are either elastomeric or acrylic in nature; a bond with the sand grain seals it from bacteria and provides superior performance and durability over the lifetime of a field. The coating may according to reports dissolve in water and not last as long as manufacturers state[231], and the sand particles can gel together[232]. For some product types the silica sand used under the coating is reported to be of bad quality and reports state that the coating does not always adhere to the sand and may break down over time[233].

According to NFF a few Norwegian artificial fields were installed with coated sand infill some years ago but due to complaints from the players right from the beginning the infill or the whole field where changed after 2-3 years[234]. NFF's experience with coated sand infill in indoor areas is unsatisfying especially due to green dust emissions from the infill materials[235].

Coated sand is not a common alternative in the Nordic countries and not available among the European vendors identified in the present study[236]. Filcom, a German manufacturer, some years back produced a product called Flexsand made of calibrated (dried and sieved) sand with a synthetic rubber coating[237], but this production has stopped[238]. According to literature coated sand is more expensive than uncoated sand infill, however no more exact price information has been found[239].

The polymers used to coat the silica sand vary greatly and only limited data on the actual chemical recipes is available; some coating agents are believed to contain chemicals of concern[240] but acrylic coating is a well-known material and does typically not contain heavy metals and toxins[241]. No specific studies on the environmental impact of coated sand in artificial turf have been identified. The heavy sand material is to a minimum extent spread from the field, but there is a risk that the coating agents are released through worn and weather influence. The same environmental aspects as regular sand must be expected.

American supplier examples

Envirofill (US); Synthetic grass Warehouse: Durafill (US); Purchase Green: HeroFill (US, CA)

[231] Delaware Riverkeeper Network: Alternative Infills for Artificial Turf Fact Sheet

[232] Ibid.

[233] Ibid.

[234] Interview, Ole Myrhvold, Field Manager, The Football Association of Norway (NFF), 2017

[235] ibid.

[236] Neither Bjørn Aas from the Norwegian University of Science and Technology or ProTurf AS are familiar with coated sand. Interview Bjørn Aas, the Norwegian University of Science and Technology, 2017; Interview Christian Steen, ProTurf AS, 2017

[237] http://www.filcom.nl/en/products/flexsand-action-en-flexsand-mix

[238] Interview, Filcom 2017.

[239] Cheng H, Hu Y, Reinhard M. (2014) Environmental and health impacts of artificial turf: a review

[240] Gale Associates Inc. (2015). Alternative Infills for Synthetic Turf

[241] Montgomery County Review of Fields, 2011

5.6.2 Recycled Sneakers – Nike Grind

Ground athletic shoes and leftover materials from sneaker manufacturing are marketed as an infill material safer than crumb rubber because it meets restricted substance standards set for wearable consumer goods[242]. The material can be mixed with sand infill.

The actual composition of the rubber and other materials in the sneakers used is not actually known but is presumed to be very similar to that of crumb rubber[243], and play characteristics of the pitch is reported as similar to a SBR crumb rubber field[244]. The material has a high cost compared to SBR crumb rubber and the availability is very limited[245]. The material is not considered as a useful substitute for crumb rubber since the only difference is the potential of less chemical exposure but the same amount of spreading of micro plastic.

Supplier examples

Nike Grind (US); Field Turf (US): Eco grind

5.6.3 Zeolite products

Zeolite is a volcanic infill material also sold in health stores for natural detox. There are many types of zeolites with each offering different amounts of quartz[246]. ZeoFill is a form of zeolite that - according to vendors - can help to secure and stabilize the blades of artificial turf and make water disperse easily through to the permeable fabric underneath. Zeofill is made of natural volcano ash that can help to control the surface temperature of the artificial turf.[247] Zeolite products are most commonly for absorbing pet animal discharges because of its ability to control pet odours[248] and the material is not a product normally associated with sport activities[249].

Supplier examples

ZeoFill inc (IS): Zeofill

[242] http://www.nikegrind.com/surfaces

[243] Gale Associates Inc. (2015). Alternative Infills for Synthetic Turf

[244] https://www.tamdistrict.org/cms/lib/CA01000875/Centricity/Domain/1149/Alternative%20Infill%20Comparison.pdf

[245] Gale Associates Inc. (2015). Alternative Infills for Synthetic Turf

[246] http://www.heavenlygreens.com/blog/comparing-artificial-turf-infill-zeofill-vs-silica-sand

[247] http://www.heavenlygreens.com/blog/comparing-artificial-turf-infill-zeofill-vs-silica-sand

[248] https://www.beegreen.green/products/sod-synthetic-turf/landscape-grass-infill-50lb-bag-1/

[249] NFF and DBU

6 COMPARISON OF INFILL MATERIALS

The traditional rubber crumb infill material is technically well described in literature, but the initiation of many new, comprehensive research programs on the topic clearly demonstrates that many aspects are still not sufficiently investigated or clarified, especially in terms of environmental and health impacts.

The review of internationally available references on alternative turf infill materials and more than 30 interviews, have provided a broad overview of key characteristics of alternative materials. Technical and performance factors are to some extent accounted for, but very few independent studies have investigated the potential environmental and health impacts of alternative materials. Nor do they specifically address the risk of emissions of micro plastics to the natural environment associated with each material.

There are vast differences between the alternative products within the same product category, and the products within a product group contain different fillers and substances and have different characteristics within usability, availably, health aspects, and environmental impact. A generic price comparison between the different infill materials is hampered by the fact the actual price for a specific artificial turf field is influenced by factors such as the market situation, the type of field system, purpose of field, chock pad, and the length of grass fibres.

The FIFA Quality Programme for Football Turf aims to endorse products that meet strict quality requirements[250] to improve the game and to protect the players, clubs, and associations[251]. FIFA claims that all requirements are built on scientific findings from a number of relevant disciplines identifying players' needs, various aspects of safety, performance, durability, quality assurance, and playing comfort[252].

If a product (artificial pitch) proves to be compliant with the requirements, the product can be certified by FIFA and will be awarded one of the "FIFA QUALITY" labels: FIFA Quality Pro for the elite level and FIFA Quality for community level. In total more than 3,400 fields in 149 countries and 3,000 infill materials and material combinations have been certified since 2006[253].

- All of the infill material categories mentioned in this report have been certified FIFA Quality Pro, which means that they all comply with basic quality and usability requirements.
- The non-infill systems cannot be FIFA certified since they will not pass the skin abbreviation tests. Non-infill systems are harder than fields with infill and therefor risk causing more skin abbreviations when played on[254].

Specific considerations on the actual use of the pitch may allow more use of non-fill technology, reducing the risk of emission of micro plastics. For example, pitches for children do not necessarily need to reach the level necessary for achieving an international certificate[255]

As part of this study, the consultant has inquired a large number of key actors about an 'objective' assessment of the different infill materials in terms of playability, with only one concrete answer: The NFF considers TPE to be the best alternative infill type because of usability and for environmental concerns. The organic materials are of too poor quality to be played on the many hours required for

[250] Besides technical requirements, the FIFA Quality Programme also includes ethical standards with focus on ethical business practices in terms of child labour, working hours, health and safety requirements, and environmental responsibility.

[251] Football-technology.fifa.com, "FIFA Quality programme"

[252] The requirements and test methods can be found in the "FIFA Quality Programme - Handbook of Requirements for Foot Ball Turf"

[253] Football-technology.fifa.com, "Resource Hub"

[254] Interview, Stef Oliviers, sales manager DOMO, 2017:

[255] Bjørn Aas, Norwegian University of Schience and Technology, interview, 2017

professional use, EPDM is a product that varies a lot and can be of very poor quality, and sand is two hard to play on[256]. In Denmark, the different alternative materials have at this point of time not been tested sufficiently to conclude on the playability[257].

The following table summarises the characteristics of the different infill materials; environmental characteristics are accounted for in the next section.

[256] Interview, Ole Myrhvold, Field Manager, The Football Association of Norway (NFF), 2017

[257] Interview, Martin Mogensen, DBU (Danish Football Union) 2017: 'It is extremely hard to assess the benefits and disadvantages of the many different kinds of alternative infill products'

Type	Variation	Material properties	Usability	Availability	Costs	Health aspects
SBR	**Crumb Rubber SBR**	Crumb rubber is derived from scrap car and truck tires that are ground up and recycled. The rubber's scientific name, *styrene-butadiene rubber* (SBR), covers a general-purpose synthetic rubber, produced from a copolymer of styrene and butadiene.	The most widely used infill product worldwide. High durability. Many different sizes. The infill can reach very high temperatures, but only in countries with warmer climate. Only comes in black colour, whish can be an aesthetic issue and has a distinct odour.	Very high availability	1.900 - 2.500 NOK/ton The amount of refilling of infill needed depends on maintenance.	The preponderance of studies show no negative health effects associated with crumb rubber in outside fields but some studies found the rubber causing a considerable impact on the indoor environment. Many studies recognize the need for further scientific study of the topic – and many comprehensive study programs have been initiated during the last years.
	Coated SBR	A reticulated SBR polymer, encapsulated with polyurethane (PU) film to enhance its durability and eliminate the unwanted effects typical of traditional black rubber. Equilibrated and heterogeneous granules between 0,5 – 2,5 mm.	Coated SBR provides additional aesthetic appeal (different colours), can reduce dust and splash on the field. Advertised as having high use durability: Excellent resistance against UV, ageing, and wearing trample, and high stability. 10-year warranty on the coating. Stakeholders states that the coating may vanish over time.	Medium availability	5.000 NOK/ton Advertised as needing 10% less infill than SBR	Can reduce discharge of chemicals and metals (compared to traditional SBR) if encapsulation of the rubber particle is not deteriorated during the lifespan.
TPE		Crosslink of plastic and rubber, can be virgin or recycled. Can be shaped like SBR crumb rubber or any other shapes; pellet shaped, cylindrical, hollow inside.	Good weather resistance and long lasting if UV stabilizers are used and available in a variety of colours that should resist fading. Less warm to play on than SBR. Good quality TPE creates a soft surface playing field. Poor quality TPE can harden over time and melt at high temperatures.	Limited availability however if demand increases more can be manufactured.	15.000-17.000 NOK/ton Approximately 7-10 kg/m2 granules are necessary if a shock pad is used (50-70 tonnes for a standard field). Refilling is estimated to be between 6-8 % a year	Chemical composition is very unlike SBR rubber, generates less pollution. Advertised as free of lead, zinc, and other toxic metals and materials, but not all is in fact according to studies (see appendix). The emission of chemical substances from TPE is predicted to be limited, because no vulcanisation chemicals are used as is the case for rubber
EPDM		EPDM has the same grain size as SBR crumb rubber. Can be virgin or recycled. EPDM is a generic term and the source, formulation, and quality of the material can vary greatly. Good quality EPDM is well suited for use in artificial turf, but some suppliers use a lot of chemical fillers or recycled EPDM, which can cause the rubber granulates to crumble, resulting in poor quality granulates. Only (expensive) testing of the granulate can show the quality.	A cleaner and cooler material with less odour compared to SBR. Many different colours available. Quality of EPDM granulates differs greatly. EPDM is by suppliers advertised as a polymer elastomer with high resistance to abrasion and wear and to resemble the surface of natural grass. Reports of premature aging and degradation due to high levels of chemical fillers . Several manufacturers in Europe have had to replace a large number of EPDM-filled fields due to a reaction between the EPDM and the carpet fibre.	Limited availability however if demand increases more can be manufactured	Virgin EPDM 12-15.000 NOK/ton. Recycled EPDM 7.000 NOK/ton Approximately 7-10 kg/m2 granules are necessary if a shock pad is used (50-70 tonnes for a standard field). Refilling is estimated to be between 6-8 % a year	There are insufficient data on chemical exposures due to limited studies that evaluate the composition, off gassing, leaching, and associated potential health effects. EPDM is in studies stated to be non-toxic, and more environmentally friendly than tire rubber. In the NFF analysis the EPDM product shows no content of the hormone disrupting phthalate (DEHP) but the highest emissions of volatile organic compounds to the indoor environment.

Sand		One of the earliest alternative infilling materials. Silica sand is derived from quartz eroded by wind and water. Silica sand can be mixed with other types of sand in a 50/50 ratio, and a mixture of silica sand and rubber infill is known to provide a better playing surface than rubber alone, i.e., a better field safety and playability	Natural infill, with tan, off-tan, or white colour and round or sub-round in particle shape. Silica sand is abrasive and relatively hard, especially under cold or frozen conditions Can be recommended for less intensive use.	High availability	Silica sand is inexpensive and easily found.	Risk of sand dust causing respiratory irritation if inhaled, some studies indicate that the dust from silica sand might cause silicosis or even cancer when inhaled.
Organic	**Mix**	Several types of infills available with different organic components; Coconut fibre, coconut husk, coconut peat, cork, rice husks, walnut shells, etc. All are treated with an antimicrobial application to prevent deterioration of the infill	Weather can impact playability of turf filled with organic materials as the infill may become saturated and freeze. Less heat absorbing No track record for durability and there are concerns about break down of the organic material, insects, and compaction of the material over time	Limited availability	High material and maintenance costs	Favourable conditions for fungus can be created when wet. No studies about the problem.
	Cork	Cork is the outer bark of the cork oak tree and the structure and composition of the membranes make it very strong and waterproof.	Cork is advertised to keep the turf cool because of the low thermal conductivity, have good shock absorbing properties, and being completely recyclable. Players are usually content with the cork infill however problem can arise with cold weather if the cork is poor quality. The durability of cork is less than rubber and the material must be replaced in 3-4 years. There is a risk that crumbled cork might seal the drain of the field.	May be of limited availability.	DOMO cork is 19.000-24.000 NOK/ton. Approximately 1,7-2 kg/m^2 needed. Unisport's 'eCork' product is approximately 5.000 NOK/ton .	Cork can be 100% natural with no additives only a boiling process. If not properly maintained the cork infill can compact and become hard which can affect safety. Favourable conditions for fungus can be created when wet. No studies about the problem.
Non-infill		A yarn based, carpet like product. There are several different options. Can be installed indoor and outdoor in different sizes.	The non-infill field are generally harder to play on than infill fields and the ball will tend to roll faster. The non-infill can be used for professional use but they do not meet FIFA quality since they cannot pass the skin abbreviation tests.	High availability	Approximately 160-290 NOK/m^2 Minimal maintenance required.	No available literature in health effects.

7 ENVIRONMENTAL SCREENING

The literature review illustrates that each of the alternative infill materials for artificial turf has its specific advantages and disadvantages as compared to the traditional crumb rubber infill. The literature review has also documented that only little research has been conducted on the environmental characteristics and performance of alternative infills.

The infill material constitutes the main part of an artificial turf field's total weight and the type of infill material is an important factor in the total picture of an artificial turf's environmental footprint; other factors of importance are first of all the maintenance procedures on the individual pitch with significant importance for the removal of infill material from the field – a study on the environmentally most sound maintenance procedures is presently carried out on behalf of the Norwegian Environmental Directorate and expected finalised by end 2017. Other factors of environmental importance include the type and use of shock pad (reducing the needed amount of infill material); the piles; the use patterns; and the waste treatment practices (although many manufacturers claim their products to be recyclable this does in reality not happen because of lacking technology and systems)[258].

Climate impact from waste handling of turf infill materials

FIFA has carried out a study showing the climate change impact from different waste handling methods (not including manufacturing and use phases) for artificial turf fields. As the figure on the next page illustrates FIFA found huge differences in the climate impact from the waste handling – with TPE having the largest impact and the organic materials the lowest.

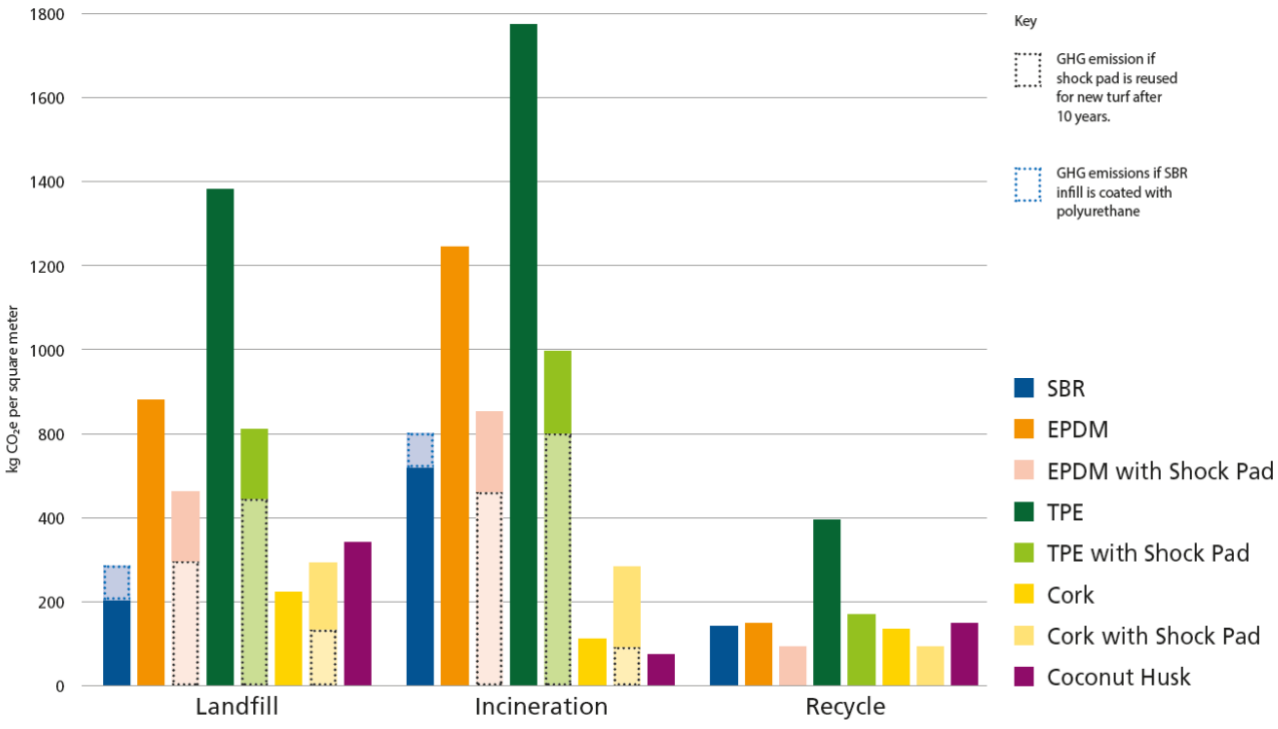

Illustration 8: FIFA 2017: Climate Change Comparison of waste handling of different infill materials.

The achievable information on the environmental characteristics is summarised in the below table.

[258] FIFA 2017: Environmental Impact Study on Artificial Football Turf

	MANUFACTURING	USE	WASTE TREATMENT
CRUMB RUBBER SBR	The material stems from shredded car tires that would alternatively either be recycled as rubber powder and granulates for other purposes; incinerated with heat extraction; or deposited at landfills (not allowed within the EU).	An artificial turf field requires annual supplement of 0-5 tons rubber granulate, depending mainly on the winter maintenance procedures (in cold and snowy regions more rubber is removed during maintenance). The rubber supplement substitutes removed/migrated rubber granules that may contribute to micro plastic pollution. The turf does not require water, fertilizers, pesticides or other chemicals for maintenance.	The traditional waste handling has been incineration or landfilling. Recycling of SBR can be difficult because the infill is contaminated with sand. Recycling of the complete turf is now possible with 99 % recycling of the turf materials. If recycling is not possible it is unsure whether a secondary market for a lower quality product exists. If the crumb rubber field is cut into smaller sections there is little change for it to be reused. Instead it will presumably end up in incineration
COATED SBR	Rubber materials as above. A long list of coating agents are being used, depending on the supplier; no environmental review has been identified and the impact from manufacturing processes is unknown.	As for SBR. The coating reduces spreading/ leaking/emission of rubber, micro plastics, and chemical substances during use. No reference on environmental pollution caused by the coating materials has been identified, but coating materials are to a certain extent emitted during use. Spreading of micro plastic could be less than from uncoated SBR rubber because of the equilibrated and heterogeneous fragments.	As above. If incinerated the total greenhouse gas emissions from the coated SBR is higher than from the non-coated SBR.
TPE	The product is produced from virgin fossil materials and therefore has a relatively higher environmental impact (use of virgin fossil materials as compared to recycling of tyre materials) than the products based on reused rubber	As for SBR	A thermoplastic that can be re-melted. Recyclable and reusable as infill.
EPDM REUSED	Less environmental impact than virgin EPDM.	As for SBR	EPDM is a thermoset plastic that cannot be melted into other products.
EPDM VIRGIN	Higher environmental impact (total climate gas emission) than reused EPDM[1]	Can have less leaking of chemicals than reused EPDM.	EPDM is a thermoset plastic that cannot be melted into other products.
SILICA SAND	Less energy and processing is required compared to materials based on fossil fuel There is a risk of environmental impact from mining, groundwater removal, and processing of the virgin materials.	Silica sand is a heavy material that will only to a small extent be removed/spread from the artificial turf field during use and maintenance.	Silica sand can be recycled and resold for many purposes.
ORGANIC	Lower environmental impact than for polymer infills (natural fibre as opposed to material based on fossil fuels, lower total climate gas emission). Use of antimicrobial substances and flame retardants may affect the environmental performance negatively.	No references	Recycling with composting might be possible. However, the resources used on separation of the organic infill from the turf can outweigh the gain of using the infill as compost. If incinerated the organic infill has a better total lifecycle greenhouse gas emission picture than the polymer infill materials.

CORK	Cork is a renewable source and the harvesting and processing is seen as sustainable. The forestry of cork has some environmental benefits because of a high biodiversity in the cork landscapes. Use of antimicrobial substances and flame retardants may affect the environmental performance negatively.	No environmental toxicity as cork contains and binds the pollutants because of its natural protective function for the cork oak. Because of a low bulk density cork may be unintentionally removed from the fields when raining, which will require refill. Can require irrigation.	As for organic.

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8.1.1 Suppliers

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NKI Nordisk Kunstgræs https://www.kunstgraes.dk/nordisk-kunstgraes-import

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8.2 Stakeholder survey

List of stakeholders contacted

- Anne Mette Dahl Jensen, Senior Consultant Copenhagen University
- Dennis Andersen, CEO, Re-Match A/S
- Lars Offenbach Poulsen, Sales and Marketing manager, NKI Nordisk Kunstgræs
- Angelo Redolfi, Eksport manager, Limonta Sport
- Leif Torvestad, CEO, Sportsurface Norge
- Jacob Ask Hansen, Teknologisk institut
- Pål Lydersen, Sales Manager, Unisport Norge
- Jan lyngemark, Country Manager & Sales Manager Outdoor, Unisport Danmark
- Kristoffer Skadhauge, Pres manager, FC Nordsjælland
- Bjørn Aas, Senter for Idrettsanlegg og Teknologi, NTNU Trondheim
- Kristin Hagland, Etne Kommune
- Eldar Meek, Sport Vest AS Norge
- Bjørn Åge Berntsen Senterleder, Senter for idrettsanlegg og teknologi, Institutt for bygg- og miljøteknikk
- Christian Steen, ProTurf AS
- Knut Guldbrandsen, field manager in Haslum IL,
- Flemming Lauenborg, Sales Manager, Polytan
- Lars Hjorth Bærentzen, The Danish Foundation for Culture and Sports Facilities, Denmark (chairman IAKS group)
- Michael Karpe, Sales Director, Gezolan
- Urszula Stankiewicz, Marketing Manager, Stargum
- Hatko, about non-infill systems.
- Filcom, A Sibelco Company, about coated sand infill.
- Ole Myhrvold, field manager, Norges fotballforbund
- Uhja Meertinen, Sales Manager, Saltex
- SO.F.TER Group Germany
- Roberta Ragonesi, Marketing Manager, SO.F.TER Group Italy
- Stijn Rambour, Department of Materials, Textiles and Chemical Engineering, Ghent University.
- Martin Mogensen, DBU (Danish Football Union)
- Stef Oliviers, sales manager, DOMO.

APPENDIX

	Aluminium (Al)	Antimony (Sb)	Arsenic (As)	Barium (Ba)	Boron (B)	Cadmium (Cd)	Cr (Chromium)	Zn (Zinc)	Cobalt (Co)	Copper (Cu)	Lead (Pb)	Magnesium (Mg)	Mercury (Hg)	Tin (Sn)	Selenium (Se)	Strontium (Sr)	Nickel (Ni)
SBR (can contain) (mg/L)	-	-	-	-	-	<0.001	<0.008	<0.2	-	-	<0.02	-	<0.001	<0.02	-	-	-
Requirements						*≤0.005*	*≤0.05*	*≤0.5*			*≤0.025*		*≤0.001*	*≤0.04*			
Gezolan Green EPDM (mg/L)	-	-	-	-	-	<0.002	<0.002	<0.188	-	-	<0.003	-	<0.0001	<0.002	-	-	-
Requirements						*≤0.005*	*≤0.05*	*≤0.5*			*≤0.04)*		*≤0.001*	*≤0.05*			
Limonta TP (mg/kg)	<50	<10	<5	<50	<50	<2	<10	<50	<10	<50	<10	<50	<10	<50	<10	<50	<10
Limonta X-tre (mg/kg)	<50	<10	<5	<50	<50	<2	<10	51	<10	<50	<10	<50	<10	<50	<10	<50	<10
Limonta GeoPlus (mg/kg)	<50	<10	<5	<50	<50	<2	<10	<50	<10	<50	<10	<50	<10	<50	<10	<50	<10
Requirements	*≤70000*	*≤560*	*≤47*	*≤18750*	*≤15000*	*≤17*	*	*≤46000*	*≤130*	*≤7700*	*≤160*	*≤15000*	*≤94*	**	*≤460*	*≤56000*	*≤930*

	SBR A		SBR B		EPDM	TPE A	TPE B
	#1	#2	#1	#2			
Polychlorinated biphenyls PCB (mg/kg)							
PCB 28	*<0.02*	*<0.02*	<0.02	<0.02	*<0.02*	*<0.02*	*<0.02*
PCB 52	*<0.02*	*<0.02*	<0.02	<0.02	*<0.02*	*<0.02*	*<0.02*
PCB 101	*<0.02*	*<0.02*	<0.02	<0.02	*<0.02*	*<0.02*	*<0.02*
PCB 101	*<0.02*	*<0.02*	<0.02	<0.02	*<0.02*	*<0.02*	*<0.02*
PCB 118	*<0.02*	*<0.02*	<0.02	<0.02	*<0.02*	*<0.02*	*<0.02*

PCB 138	*0.028*±0.011	*<0.02*	<0.02	<0.02	*<0.02*	*<0.02*	*<0.02*
PCB 153	*0.022*±0.009	*<0.02*	<0.02	<0.02	*<0.02*	*<0.02*	*<0.02*
PCB 180	*<0.02*	*<0.02*	<0.02	<0.02	*<0.02*	*<0.02*	*<0.02*
SUM PCB-7	0.05	<0.14	<0.14	<0.14	<0.14	<0.14	<0.14
Polycyclic aromatic hydrocarbons PAH (mg/kg)							
Naphthalene	0.72 ± 0.22	0.69 ± 0.21	0.49 ± 0.15	0.40 ± 0.12	0.15±0.05	<0.050	<0.050
Acenaphthylene	0.19 ± 0.06	0.16 ± 0.05	0.10 ± 0.03	0.24 ± 0.07	*0.09*±0.03	<0.050	<0.050
Acenaphthen	1.3 ± 0.4	1.3 ± 0.4	0.24 ± 0.07	0.19 ± 0.06	<0.050	<0.050	<0.050
Fluorene	1.2± 0.4	1.2 ± 0.4	0.82 ± 0.25	0.63 ± 0.19	<0.050	<0.050	<0.050
Fhenanthrene	6.8 ± 2.1	6.8 ± 2.0	7.4 ± 2.2	5.9 ± 1.8	0.77±0.23	<0.050	<0.050
Anthracene	0.68 ± 0.20	0.75 ± 0.23	1.9 ± 0.6	1.7 ± 0.5	<0.050	<0.050	<0.050
Fluoranthene	9.9 ± 3.0	8.5 ± 2.5	8.7 ± 2.6	9.2 ± 2.8	*1.5*±0.5	<0.050	<0.050
Pyrene	27 ± 8	23 ± 7	32 ± 10	30 ± 9	8.8±2.7	<0.050	<0.050
Benzo (a) anthracene	0.58 ± 0.18	1.3 ± 0.4	0.68 ± 0.20	1.6 ± 0.5	<0.050	<0.050	<0.050
Chrysen	0.54 ± 0.16	1.4 ± 0.4	0.78 ± 0.23	1.7 ± 0.5	<0.050	<0.050	<0.050
Benzo (b) fluoranthene	1.2 ± 0.4	1.3 ± 0.4	1.4 ± 0.4	2.5 ± 0.8	<0.050	<0.050	<0.050
Benzo (k)fluoranthene	0.41 ± 0.12	0.34 ± 0.10	0.30 ± 0.09	0.66 ± 0.20	<0.050	<0.050	<0.050
Benzo (a) pyrene	1.2 ± 0.4	1.4 ± 0.4	1.4 ± 0.4	1.9 ± 0.6	*<0.050*	<0.050	<0.050
Dibenzo (ah) anthracene	0.13 ± 0.04	0.18 ± 0.06	0.16 ± 0.05	0.38 ± 0.11	<0.050	<0.050	<0.050
Benzo (ghi) perylene	3.6 ± 1.1	3.4 ± 1.0	4.6 ± 1.4	5.2 ± 1.6	<0.050	<0.050	<0.050
Indeno (123cd) pyrene	0.57 ± 0.17	0.41 ± 0.12	0.61 ± 0.18	0.80 ± 0.24	*<0.050*	*<0.050*	*<0.050*
SUM PAH-16	56	52	62	63	11	<0.8	<0.8
Sum PAH – carcinogenic	3.9	6.0	4.6	8.4	*<0.25*	*<0.25*	*<2.5*
Phthalates (mg/kg)							
Dimethylphthalate (DMP)	*<0.80*	*<0.80*	*<0.80*	*<0.80*	*<0.80*	*<2.0*	*<2.0*

Diethyl phthalate (DEP)	*<0.80*	*<0.80*	*<0.80*	*<0.80*	*<0.80*	*<2.0*	*<2.0*
Di-n-propyl phthalate (DPrP)	*<0.80*	*<0.80*	*<0.80*	*<0.80*	*<0.80*	<2.0	<2.0
Di-n-butyl phthalate (DBP)	0.97 ± 0.34	0.86 ± 0.3	*1.2*±0.4	*1.4*±0.5	17±6	*<2.0*	*<2.0*
D-iso-butyl phthalate (DIBP)	2.6 ± 0,9	2.3 ± 0.8	2.8±1.0	3.0±1.0	*<0.80*	*<2.0*	*<2.0*
Di-pentyl phthalate (DPP)	*<0.80*	*<0.80*	<0.80	<0.80	*<0.80*	<2.0	<2.0
Di-n-octyl phthalate (DNOP)	*<0.80*	*<0.80*	<0.80	<0.80	*<0.80*	*<2.0*	*<2.0*
Di- (2-ethylhexyl) phthalate (DEHP)	6.4 ± 2.2	6.8 ± 2.4	*14*±5	*11*±4	*<0.80*	*34*±12	*149*±52
Butyl Benzyl Phthalate (BBP)	<0.80	<0.80	<0.80	<0.80	*<0.80*	<2.0	*<2.0*
Dicyclohexyl Phthalate (DCHP)	<0.80	<0.80	<0.80	<0.80	*<0.80*	<2.0	*<2.0*
Phenols (mg/kg)							
4-n-Nonylphenol	*<0.001*	*<0.001*	*<0.001*	*<0.001*	-	-	-
4-iso-Nonylphenol	5.3 ± 0.8	4.8 ± 0.7	5.3 ± 0.8	5.5 ± 0.8	-	-	-
4-t-octylphenol	16 ± 2	12 ± 2	12 ± 2	19 ± 3	-	-	-
Sum Octylphenol	-	-	-	-	*<5.0*	*<5.0*	*<5.0*
Sum Nonylphenol	-	-	-	-	*5.0*±1.0	*<5.0*	*<5.0*
Single elements							
Arsen (As)	0.27	0.22	0.33	0.19	*<0.8*	*<0.7*	*>0.6*
Cadmium (Cd)	*1.7*	*1.6*	0.93	1	0.07 ± 0.05	*0.31*±0.08	*0.13*±0.05
Cobalt (Co)	*212*	*178*	101	128	0.06 ± 0.21	*0.25*±0.21	*0.27*±0.18
Chrome (Cr)	*0.97*	*1.0*	1.3	1.0	0.43 ± 0.11	*0.97*±0.20	*427*±80
Copper (Cu)	*105*	*97*	49	45	11 ± 2	<0.9	*15*±3

Mercury (Hg)	<0.04	0.042	<0.04	<0.04	<0.1	*<0.09*	*<0.08*
Nickel (Ni)	2,9	2,5	*2.3*	*2.7*	<0.4	*4.0*±1.2	*3.7*±1.1
Lead (Pb)	23	24	*21*	*18*	<0.4	*7.6*±1.5	*<0.3*
Vanadium (V)	*0.70*	*0.67*	*0.90*	*0.93*	0.26	*5.8*	*1.5*
Zinc (Zn)	*20220*	*19100*	*17500*	*16500*	3.5 ± 1.6	*7640*±200	*2.2*±1.2