

The facts about SBR

**Tire Crumb Rubber Used in
Artificial Turf Fields**

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Section 1:

Introduction

INTRODUCTION

The success of artificial turf fields has had an impact on the suppliers of natural grass fields. As growth of artificial turf increases dramatically on a global scale it now represents a considerable threat to this established industry.

Artificial turf has also had an impact on the local communities where such fields are installed. The installation of any new artificial turf field means kids can now play on it day and night - without fear of destroying the grass or creating mud baths in bad weather. As a result, many installations are often followed by lights, increased usage during the day and night and the subsequent crowds that such activity brings.

Concessions, traffic and other inconveniences have affected the homeowners nearby. The local community usually feels threatened by new construction as, unfortunately, most local residents have limited input in such decisions. Unless the homeowners have children who use the facilities, their reaction is usually based on protecting the peace and quiet of their lives and the value of their property, which they fear will be affected.

In past they have been unable to stop progress. But now the natural grass industry and those who have issue with artificial grass (or anything artificial) are using the local residents to put forward their own agenda to try to stop the installation of new artificial turf fields. There is nothing like an environmental or health scare to put the brakes on any new construction. And we believe it is the natural grass industry lobby that have been feeding local communities, their town halls and the local media with these scare tactics. And in some regions it's working.

So much study has already been done on this subject. Hundreds of reports and tests have created thousands of documents of very detailed medical reports. Making sense of this complex literature and making it available and understandable to the general public is a far more difficult task.

Everyone understands the truth, but hysteria and wild claims of imminent danger are a lot easier to make headlines with - and so such tactics continue to be effective. In the lobby against artificial turf in particular, there have been many such claims.

First it was **Silicosis**, with threats that playing on artificial turf with sand in the infill meant inhaling silica, which cause silicosis. This proved to be a ridiculous assumption, since the size of our smallest particle of silica sand is many times larger than the particle size the lung is able to ingest. In any case, it required locating many of the countless studies published to prove that it was in fact an empty threat.

Then it was **Heat**. This threat purported dangers of kids dying on hot artificial grass fields, fuelled by a few tragic incidents where young athletes dies of heat exhaustion and related conditions. These horrible events actually took place on natural grass, not on artificial turf.

Next was the **Staph** scare, where artificial turf was blamed for serious infections that were making headlines. As it turned out, this was completely false when it turned out that such infections were caused by bad hygiene, the transfer of germs from open wounds and germs on surfaces inside the sports facility training and locker rooms.

Then it was **Global Warming**, blaming artificial turf for increasing temperatures on earth through the destruction of green space. A scientific review of global warming contributions from shopping center parking spaces alone, made such claims microscopic in comparison.

And now the latest scare is the dangers of **cancer-causing** materials found in the SBR crumb rubber from used tires. This has caused a lot of noise and controversy - but has been proven to be as overstated as the rest of these scares. The scare starts with PAHs or Polynuclear Aromatic Hydrocarbons. In the making of salt, two dangerous particles Sodium and Chlorine are combined to create salt, a harmless substance consumed daily by every human. The manufacture of rubber tires also combines some dangerous particles during the vulcanization process. While such substances are being phased out of production worldwide, these dangerous substances cannot be extracted from the tire product, unless extreme solvents and processes are utilized. If a child was to eat a handful of crumb rubber, the particles, which may contain dangerous materials, will pass right through the body untouched. The human digestive system is unable to break down these compounds. In the same way, the rubber cannot be absorbed by the lungs or the skin and therefore, like salt, potentially dangerous substances have no effect on human safety.

The following pages are copies of existing, documents, medical reports, tests and studies that debunk this particular myth.

CONSIDER THE MATH

To date 46,000,000,000 (46 billion) tires have been worn out on our roads. During this same period 160,000,000 (160 million) tires have been ground up and put into 4,000 playing fields.

If we are to believe the scare tactics that tire rubber particles represent a health hazard, consider this: The large rubber granules in playing fields represent less than .03% of the rubber particles vehicle wear has ground into fine airborne particles, currently part of our global atmosphere.

To calculate the potential danger posed to children playing on an infilled field, each field would represent 1/4000 of a total field hazard of .03% which is equal to .0000075.

Section 2:

FIFA

**An Open Letter Concerning
the Potential Cancer Risk
from Certain Granulate Infills
from Artificial Turf**



cc: J. Champagne, Dr. J. Ekstrand, M. Harvey, Dr. C. Fuller, M. Timmer,
Dr. E.G Harrison, L. Bretscher, N. Fletcher

Zurich, 12 July 2006

An Open Letter concerning the potential cancer risk from certain granulate infills from artificial turf

As you will be aware both FIFA and UEFA have invested substantial resources in recent years in the development of artificial turf to ensure more people, more often have more opportunities to participate in Football at all levels of the game in a safe environment.

Both organisations have both been aware of recent reports that have suggested a potential cancer risk from certain granulate infills from artificial turf.

FIFA and UEFA have investigated this issue and analysed the risk involved. In particular we have reviewed the results of numerous studies into this issue and our findings to date are listed below:

- The list of publications which FIFA and UEFA have scrutinised is given below.
- The studies to date have concluded that PAHs [Polynuclear Aromatic Hydrocarbons] are not released or at most negligibly released from tyre abradate (The University of Dortmund Institute for Environmental Research 1997). Epidemiological studies conducted by the Health Effects Institute, The World Health Organisation and other investigators do not implicate tyre wear particles in ambient air as contributing to human health effects (respiratory and cardiovascular diseases)
- In general tyre abradate is a much finer particulate than the granules used as infill materials in Football Turf. The research demonstrates that the finer the particles the greater the surface area and higher potential for chemicals to leach out of the rubber.
- The majority of the studies have been on higher surface area particles and have concluded they are currently acceptable. Therefore the larger granules used in artificial turf will have even less potential for emissions. For example a study undertaken by the Danish Ministry of the Environment



concluded that the health risk on children's playgrounds that contained both worn tyres and granulate rubber was insignificant.

The available body of research does not substantiate the assumption that cancer resulting from exposure to SBR granulate infills in artificial turf could potentially occur. For further information of the issue and the risk, please consult the references below.

A handwritten signature in black ink, appearing to read 'Jiri Dvorak', is located to the left of the typed name.

Prof. Dr. Jiri Dvorak
FIFA



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Section 3:

SAPCA

**The Use of Recycled
Rubber in Sports Surfaces**



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The Use of Recycled Rubber in Sports Surfaces

In conjunction with the British Standards Institute (BSI), the Sports and Play Construction Association (SAPCA) is helping to prepare new European (CEN) Standards for artificial sports surfaces. Through this work SAPCA has become aware of concerns being voiced in some European countries over the use of recycled rubber from vehicle tyres in sports surfaces. In response SAPCA has convened a working group of UK experts to investigate the situation. So far, SAPCA has carried out a substantial review of previous national and international studies undertaken by scientists on the risks from rubber aggregates in sporting contexts.

Waste rubber aggregate materials, derived primarily from vehicle tyres, are currently widely used in roads, railways, building construction, agriculture, packaging, bulk products, mining, automobiles and trucks, marine structures, landscaping and sports and play surfaces. The issue originates from some of the materials used in the manufacture of rubber. There are a number of organic and inorganic substances used in rubber manufacture that are potentially hazardous inviting caution. It has been suggested that there may be risks from leaching and therefore chemical pollution of soils and waters; there may also be possibilities of inhalation of volatile constituents, skin contact, ingestion, and abrasion of surfaces with particulate release.

SAPCA's opinion is that, because tyre rubber is designed to be strong, durable and substantially impermeable, it is unlikely that any losses could occur to air or water in concentrations that would pose serious human or environmental risk. This opinion is supported by the reports and academic studies reviewed, which have shown insignificant environmental effects of such chemicals or release of volatiles and particulates into the atmosphere. SAPCA is continuing with its investigations but subject to that our view is that there are negligible additional risks to humans based on theoretical extrapolation - indeed we have not identified from our initial investigation any evidence of reported symptoms or adverse health effects.

As with any health, safety or environmental concern, SAPCA will continue to maintain a watching brief on the situation. SAPCA has therefore initiated a dialogue with independent researchers and experts in this field. Where any avenues of further research are identified the Association will actively support necessary programmes to ensure that these materials continue to be used safely and meet the required standards for all concerned.

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THE USE OF RECYCLED RUBBER IN SPORTS SURFACES

In conjunction with the British Standards Institute (BSI), the Sports and Play Construction Association (SAPCA) is helping to prepare new European (CEN) Standards for artificial sports surfaces. Through this work SAPCA has become aware of concerns being voiced in some European countries over the use of recycled rubber from vehicle tyres in sports surfaces. In response SAPCA has convened a working group of UK experts to investigate the situation. So far, SAPCA has carried out a substantial review of previous national and international studies undertaken by scientists on the risks from rubber aggregates in sporting contexts.

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From SAPCA's perspective, it is reasonable to suppose that, because tyre rubber is designed to be strong, durable and substantially impermeable, it is unlikely that any losses could occur to air or water in concentrations that would pose serious human or environmental risk. This opinion is supported by the reports and academic studies reviewed, which have shown insignificant environmental effects of such chemicals or release of volatiles and particulates into the atmosphere. SAPCA is continuing with its investigations but subject to that our view is that there are negligible additional risks to humans based on theoretical extrapolation - indeed we have not identified from our initial investigation any evidence of reported symptoms or adverse health effects.

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Section 4:

**Laboratory of Research &
Control for Rubber & Plastics**

**Environmental Impact End
of Life Tire Crumb Rubber**



FIELDTURF TARKETT SAS

2 rue de l'Égalité
92749 NANTERRE Cedex

Att. Mrs Boucher

Documentary report D

N°D321394/EN

15/05/2006

**Use of end-of-life tyre rubber crumb in sports floors:
environmental consequences. 2006 update**

*Centre Français du Caoutchouc
et des Polymères industriels*

<http://www.lrccp.com/>

60, RUE ALBER – 94400 VITRY-SUR-SEINE CEDEX – TEL : 01 49 60 57 57 – FAX : 01 49 60 70 66
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FIELDTURF TARKETT SAS

Report D321394/EN

15/05/2006

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Documentary report D
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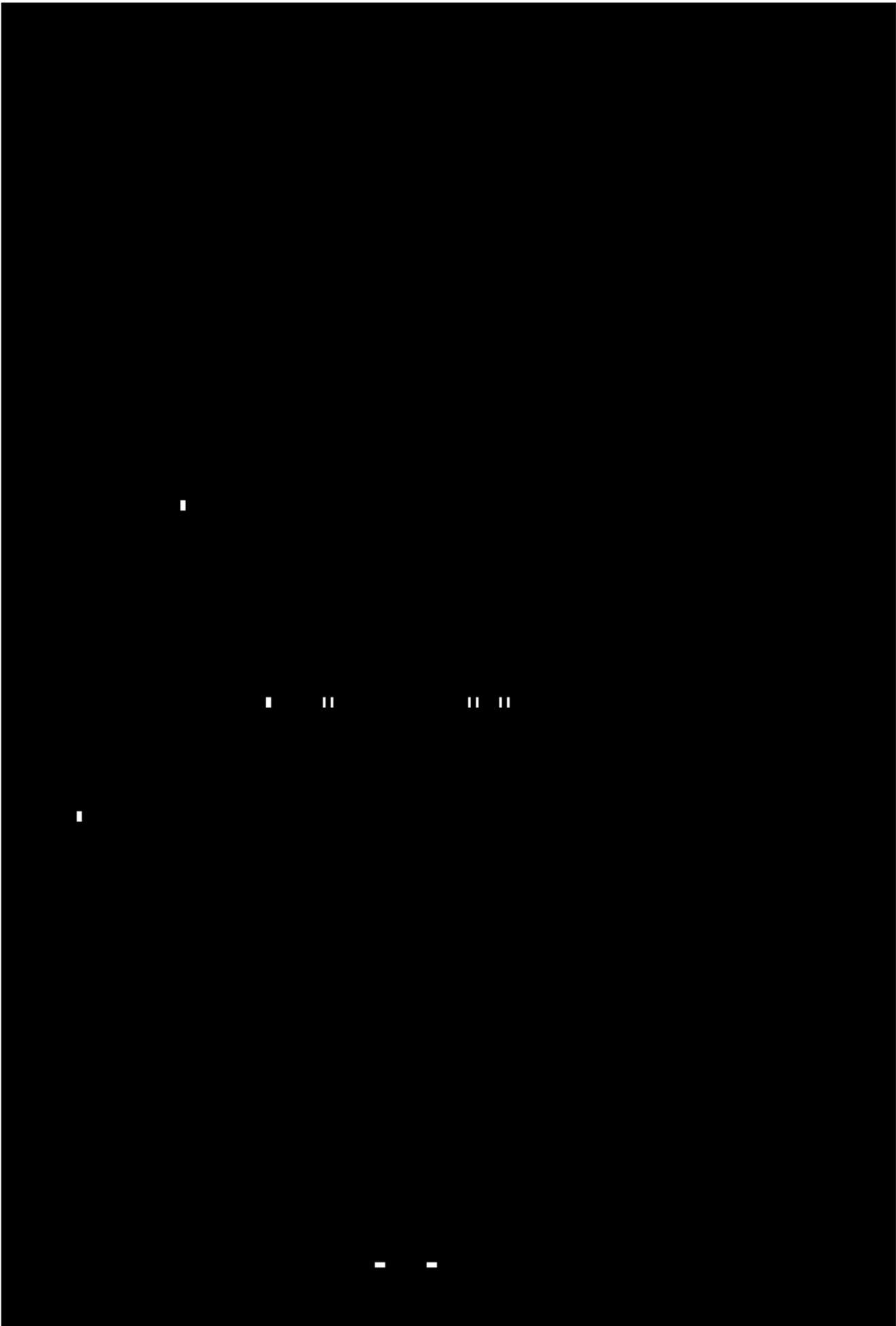
**Use of end-of-life tyre rubber crumb in sports floors:
environmental consequences. 2006 update**

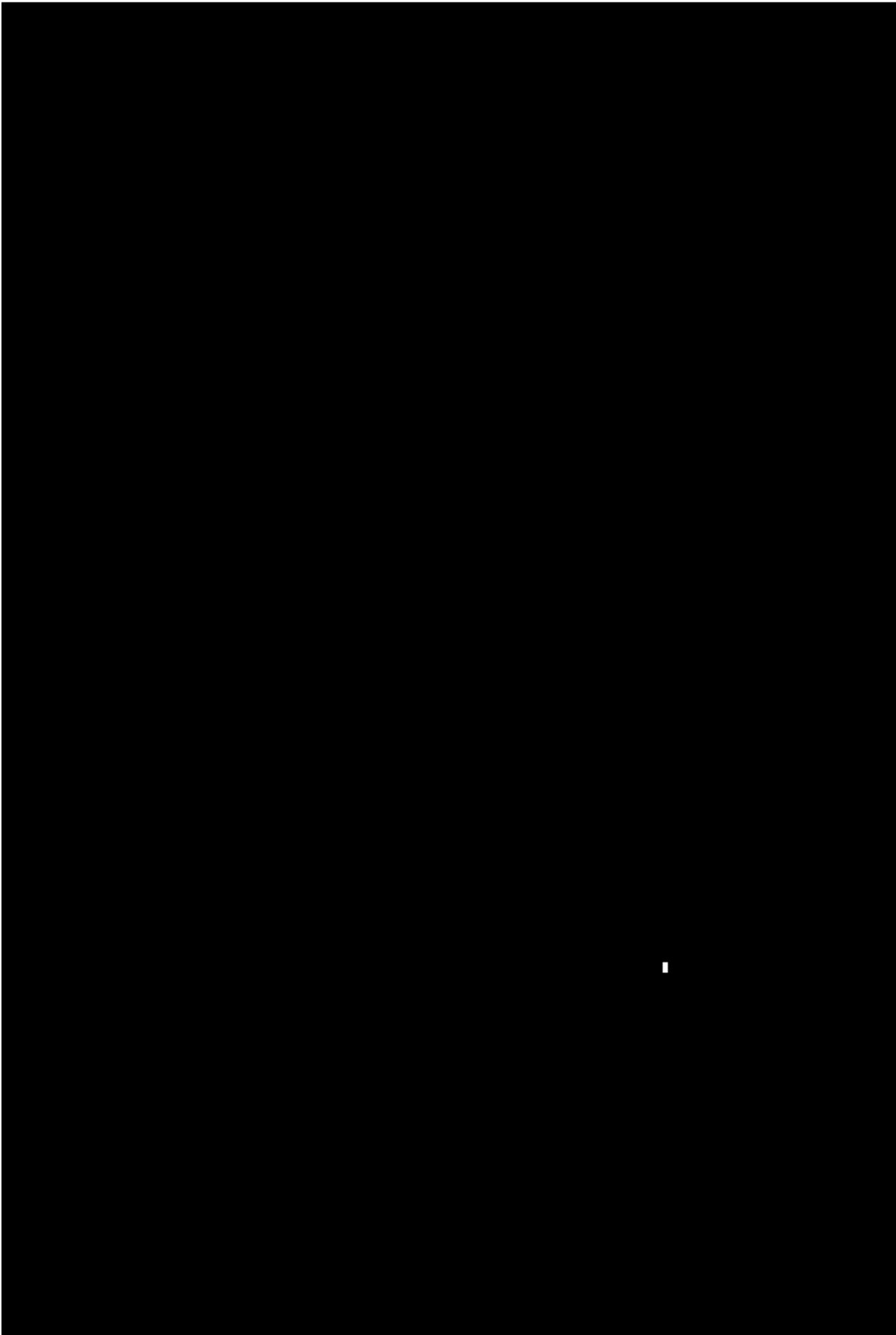
Author: Catherine RIGAUD

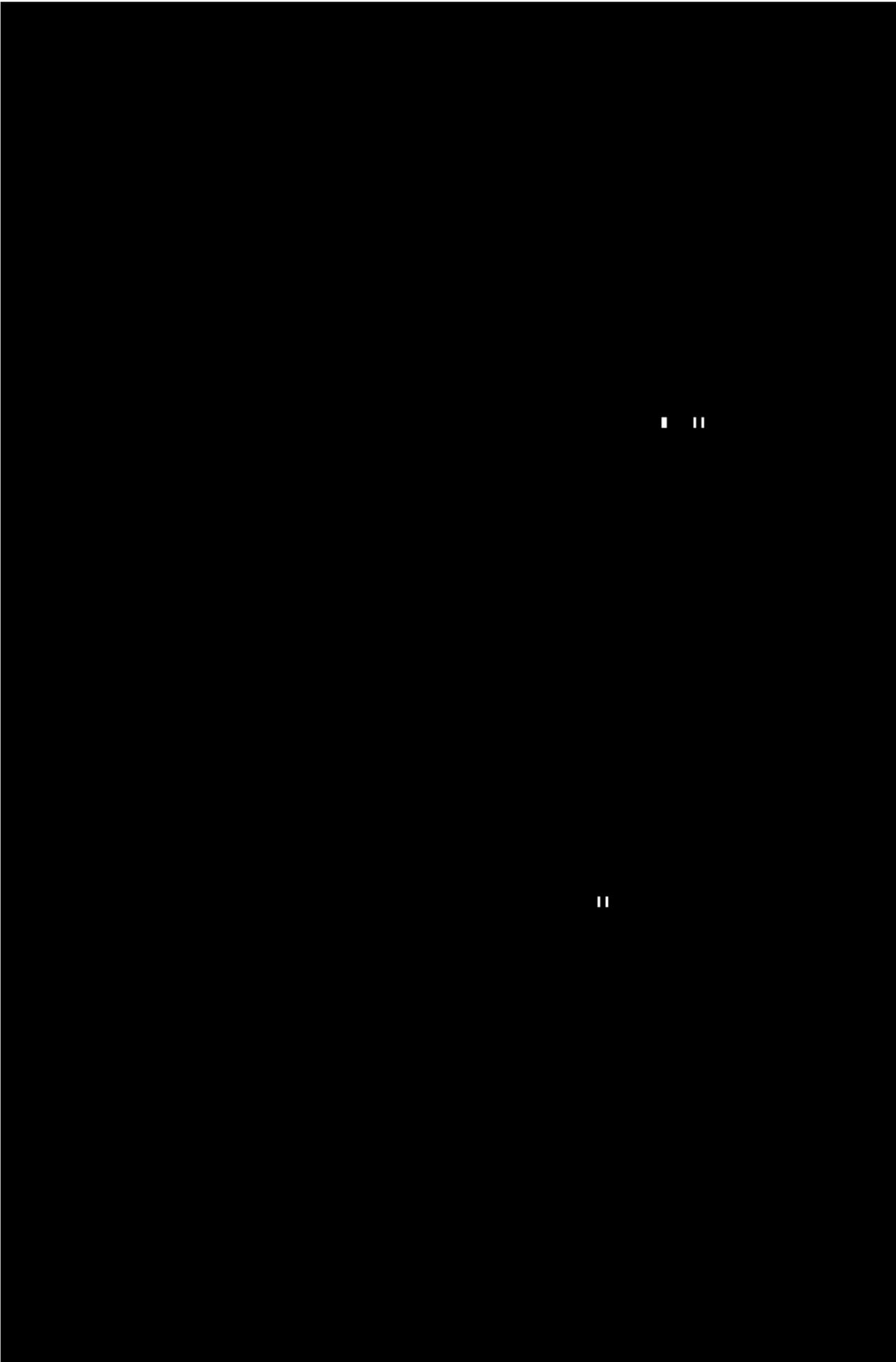
References:

LRCCP estimate no 394.06/CR dated 05/04/2006
Acceptance according to estimate dated 13/04/2006
LRCCP report D320971

This report may only be copied in its entirety.
It consists of **9 pages and 9 appendices.**

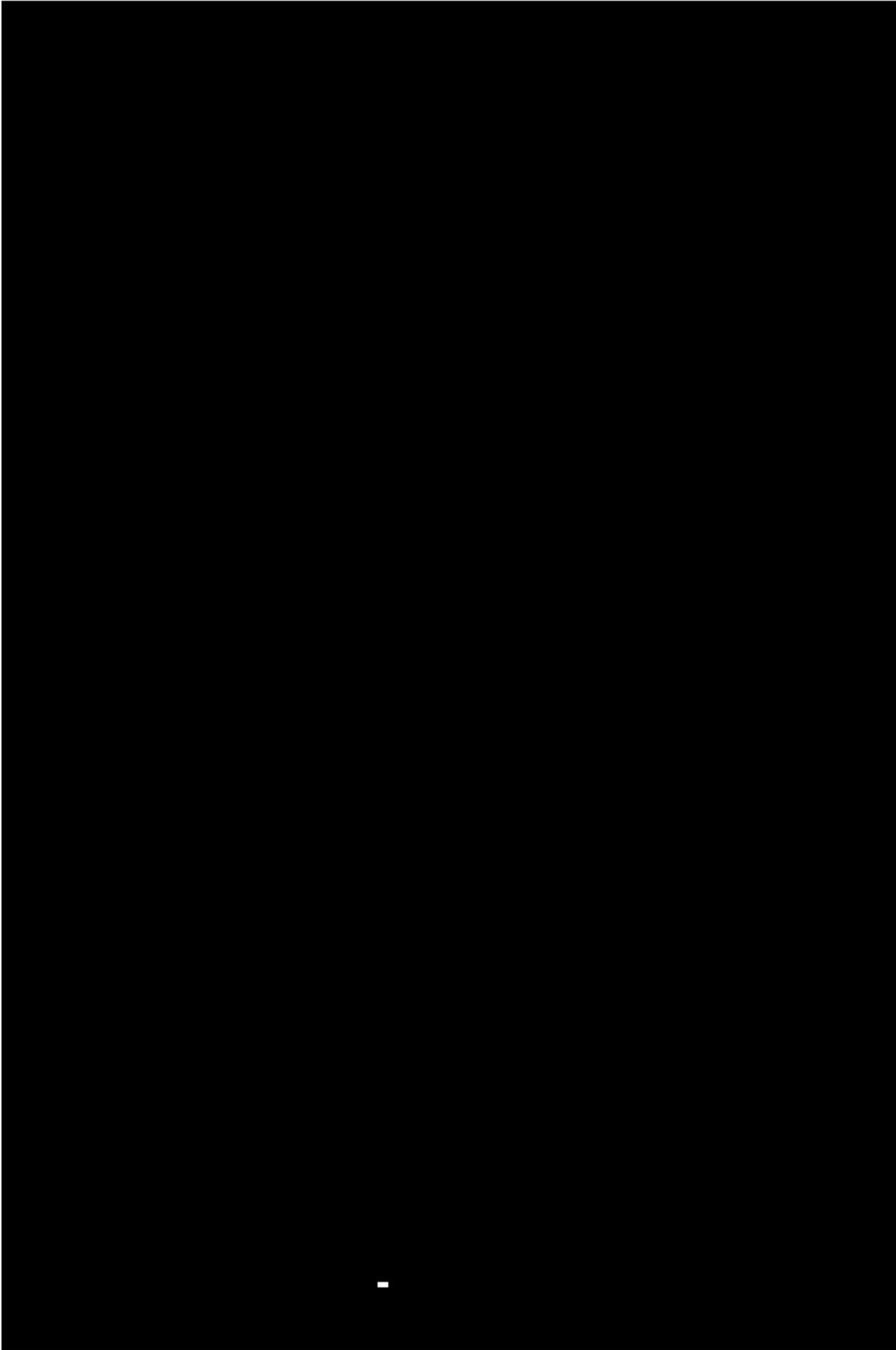


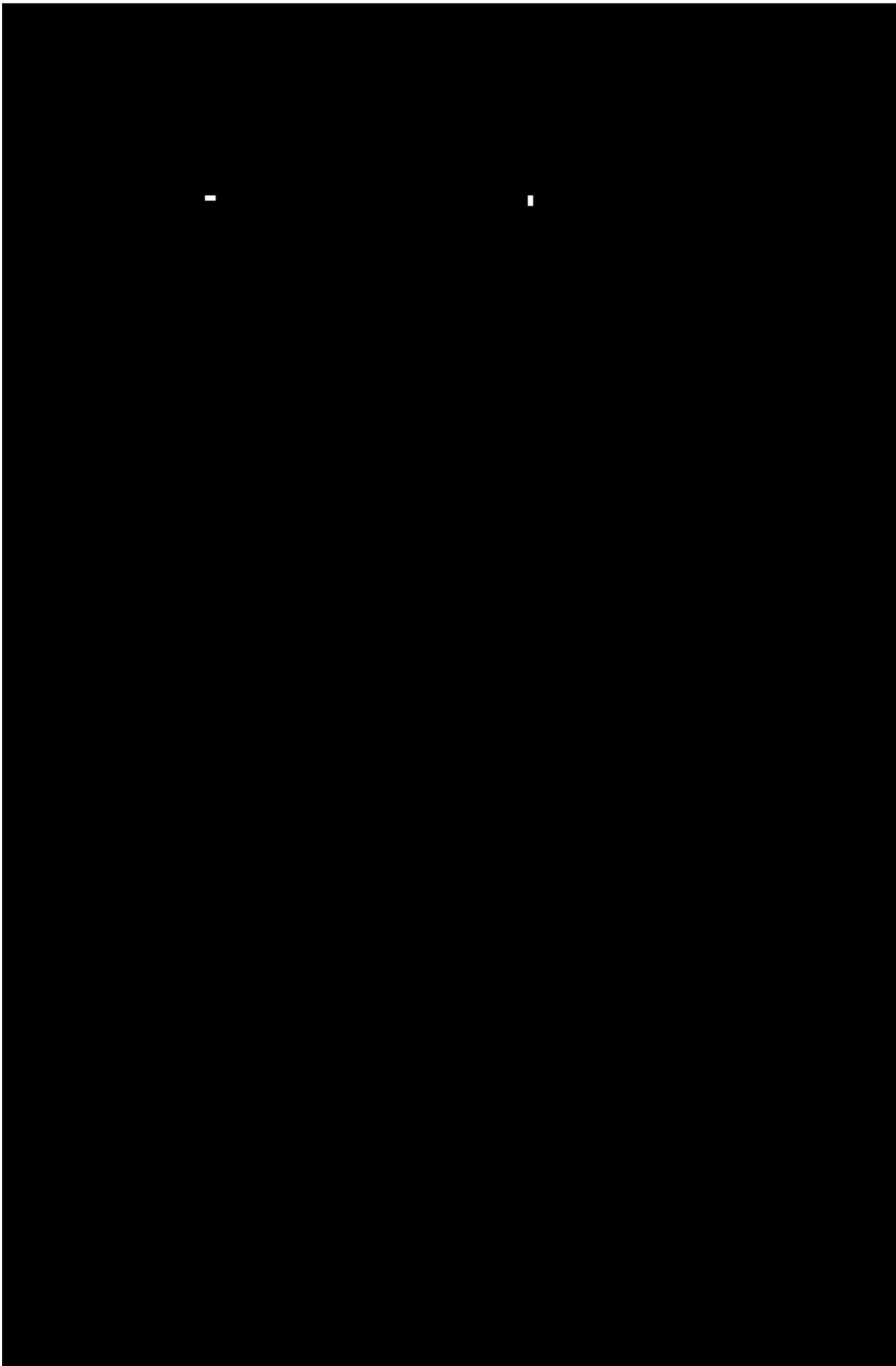


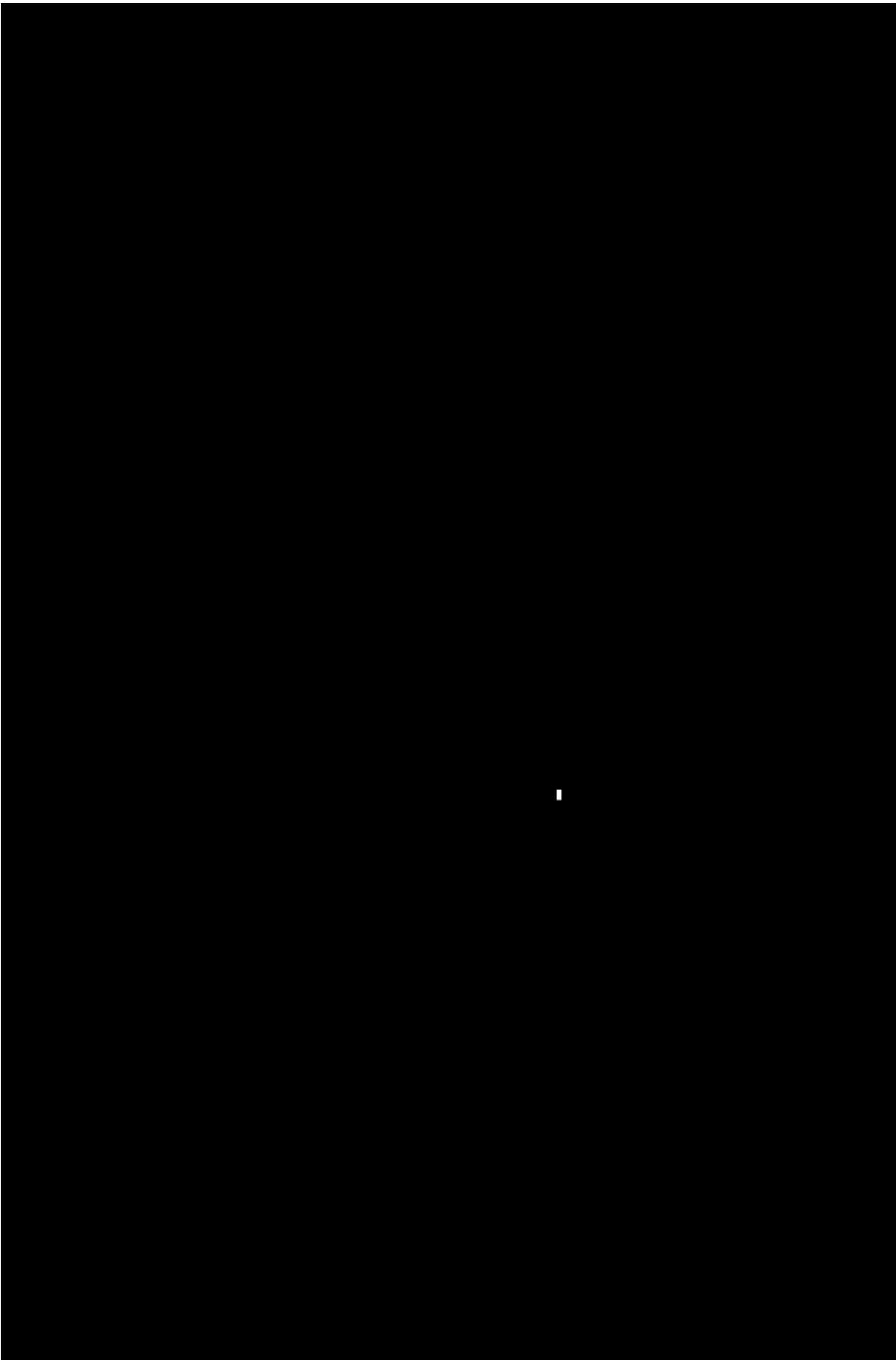


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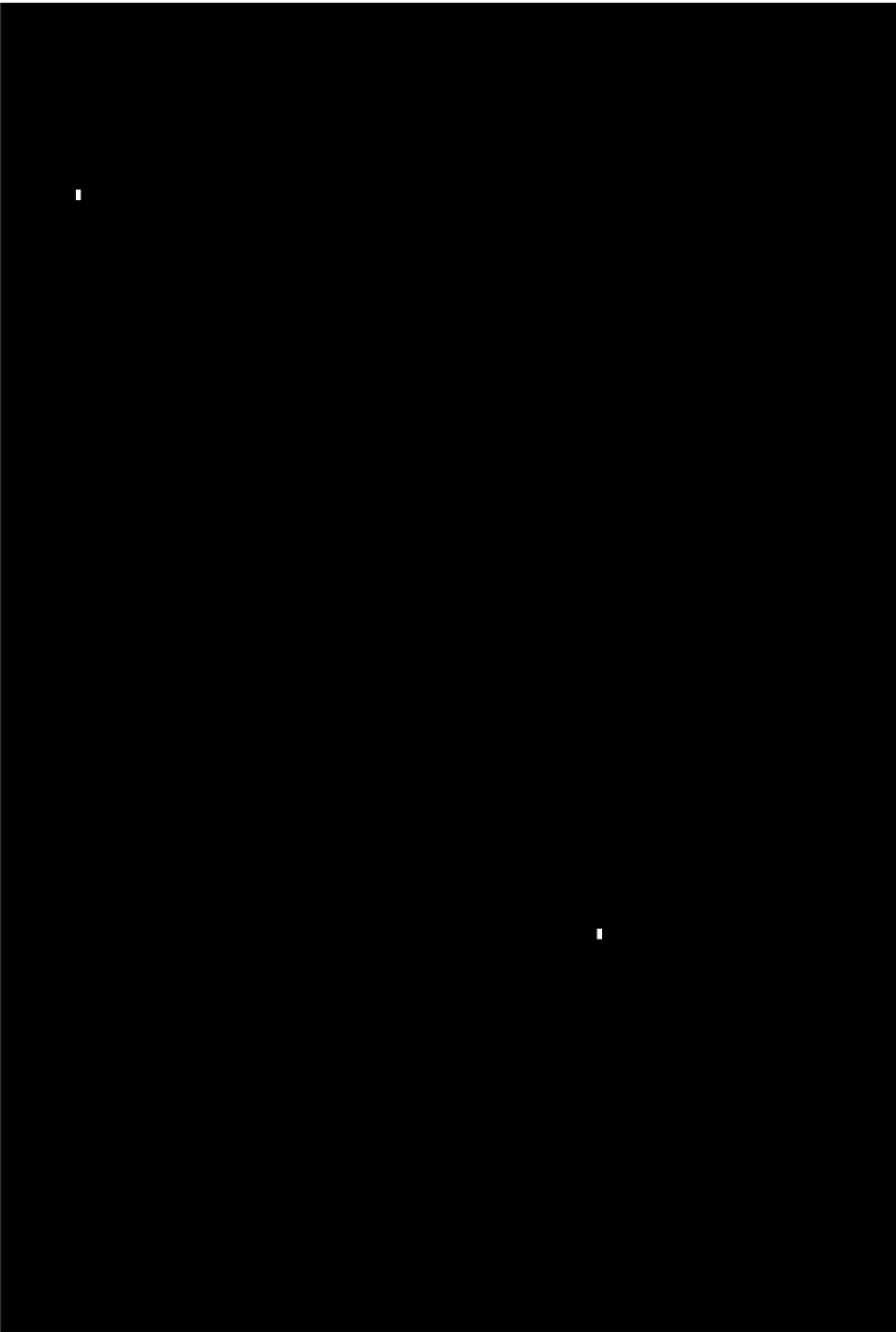


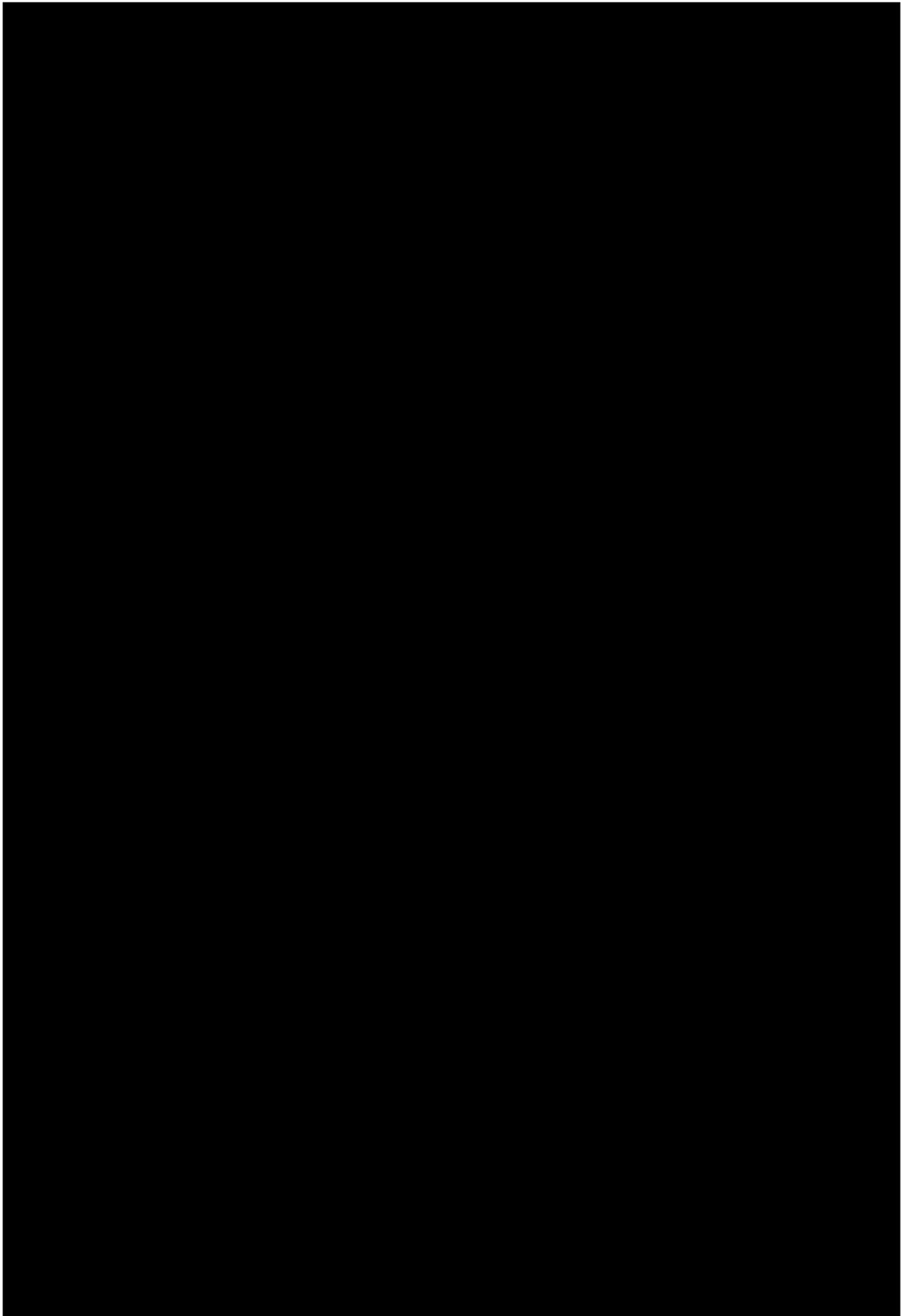


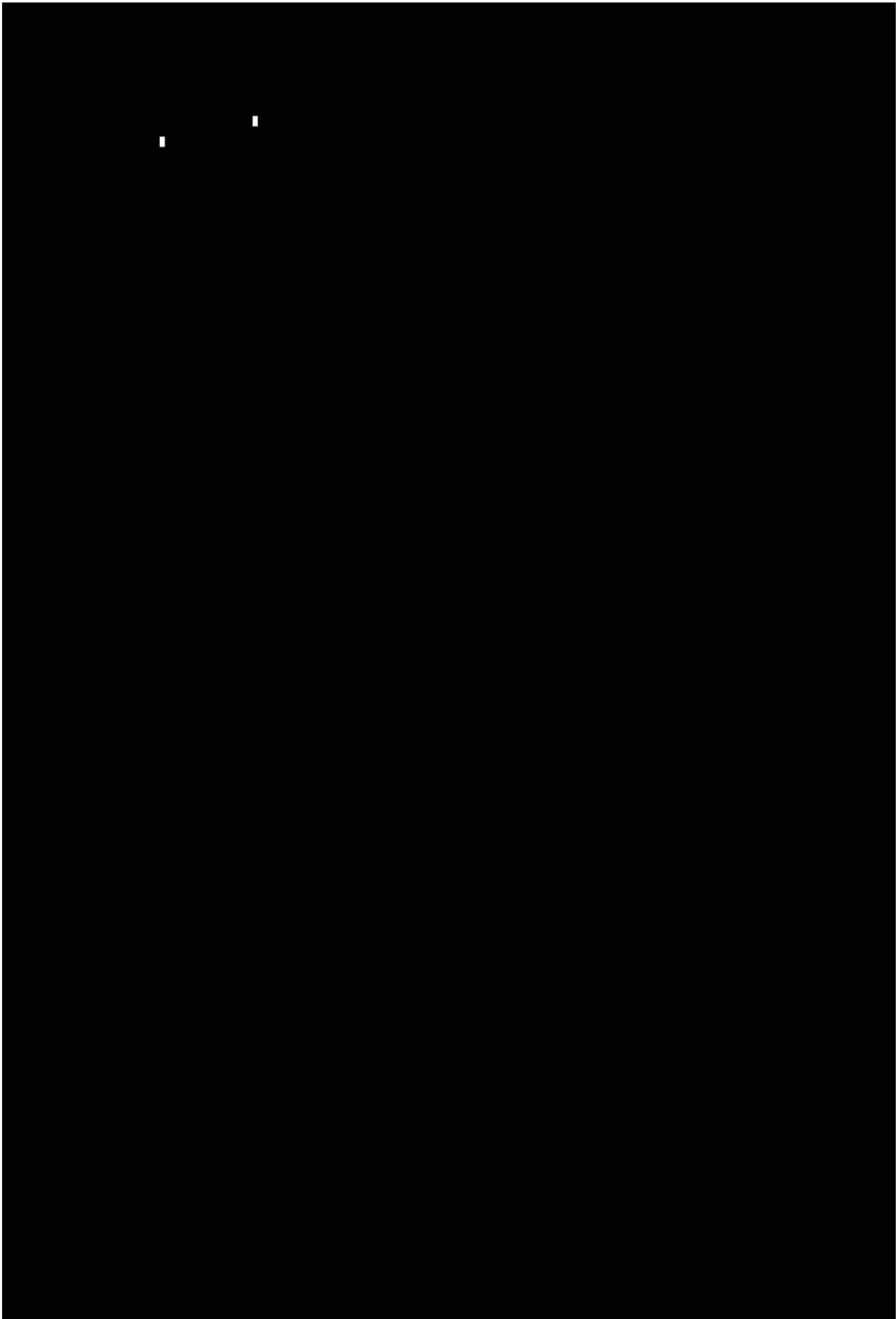


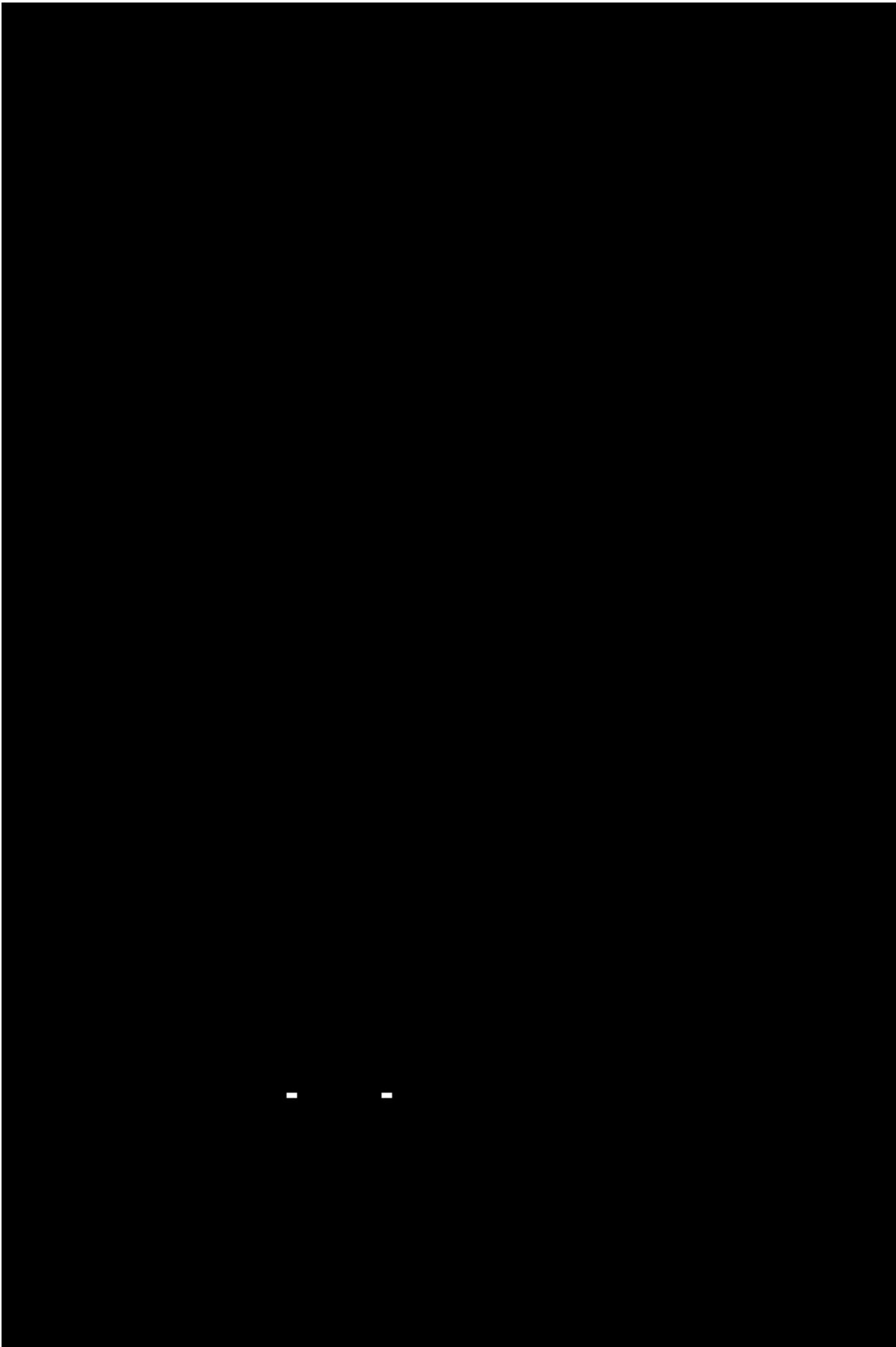
Section 5:

**Air & Waste Management
Toxicological Evaluation
for the Hazardous Assessment
of Tire Crumb for Use in
Public Playgrounds**

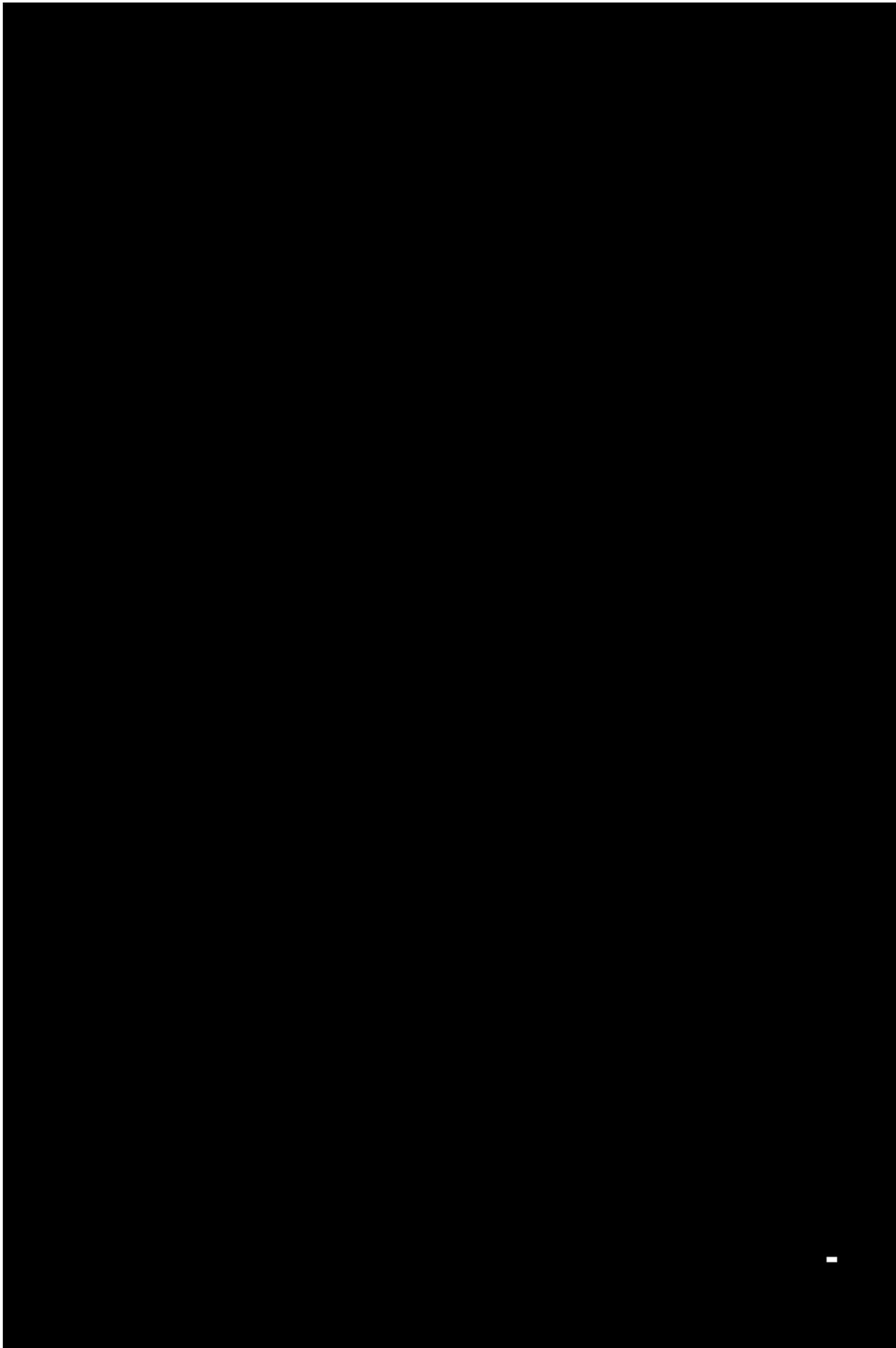








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Section 6:

**Dutch National Institute for Public Health &
the Environment**

**Answers to Questions on Harmful Substances
in Artificial Turf Fields**

**Public Health, Social
Welfare & Sport**

Ministry of Social Housing, Regional Planning and Environmental Administration (VROM)
Department DGM/SAS
For the attention of Martijn Beekman
P.O. Box 30945
2500 GX THE HAGUE

Re
Rubber granules as infill material in artificial turf fields

Dear Mr Beekman,

On 22 May 2006, you asked the RIVM to react to comments made on Undersecretary van Geel's answer to questions in the Lower House (2050603510) on harmful substances in artificial turf fields. The comments raised the issue of the assessment of the health risks posed by rubber granules.

In connection with this request, the RIVM assessed the health risks of rubber granules (Appendix 1), and studied the answers to the questions in the Lower House. In supplement thereto, the environmental risks of rubber granules on sport fields were also broached (Appendix 2). Herein please find the conclusions and recommendations of the study.

Health risks of rubber granules

The RIVM has reached the conclusion that PAHs can in fact be released, to a small degree, from rubber granule particles in artificial turf fields, but on the basis of the available data, this does not seem to entail any health risk. Nor is there any risk from oral exposure to DEHP as a representative of the accelerator group. There are no data available for the other chemical substances that can occur in rubber granules so as to enable us to assess the health risk. Since there is no risk for PAHs, as the most harmful component in PAHs, it seems unlikely that this would be the case for other substances.

Answer to questions raised in the Lower House

Question 4

Second question: Can a conclusion be drawn on the basis of the TUV report, that skin contact with ground car tyre particles on artificial turf fields are hazardous for human health?

Answer 4

Second question: No, I think that the chance of harmful health effects from PAHs in rubber granules in artificial turf fields is negligibly small, for the following reasons:

1. the PAHs are absorbed in the matrix of the rubber granules, and do not leach;
2. carcinogenic PAHs occur in very small quantities, namely in parts per billion in rubber granules (0.03 ppb), according to a study commissioned by the European association of tyre manufacturers;
3. The staying time for people is relatively short, and consequently the time that one is in contact with the rubber granules is only small; and
4. The TUV report speaks about a safe skin contact of more than 30 seconds at a content of less than 10 mg/kg.

The concentration of 0.03 ppb means a level of about one million times below the limit recommended in the TUV report. I consider such a margin safe enough.

The Undersecretary's conclusions about the health risks of rubber granules in artificial turf fields correspond with those of the RIVM. The assessment of the health risk was however conducted on other grounds; the following marginal comments can be made to the Undersecretary's arguments:

- Various studies have shown that PAHs leach to a very small degree in contact with water (see tables in Appendix 2). The leachability of PAH in water is not a good yardstick for determining health risks;
- The concentration to which the Undersecretary refers (0.03 ppb) concerns the total of the carcinogenic PAHs in a leaching test. The total content of PAHs in rubber granules made from car tyres is in the order of 14 to 112 mg/kg or ppm (see tables, Appendix 2); the share of the carcinogenic PAHs, concerns about 40-80%.
- In his answer to the questions raised in the Lower House, the Undersecretary refers to a TUV report which

contains a recommendation for maximum admissible values for PAHs in devices and toys. This recommendation does not include the use of rubber granules in sporting fields. A correspondence between TUV and Kempeneers (2006) shows that the values are based on best practices for PAH containing electrical appliances; they are not based on toxicological tests of migration at indicated concentrations and contact times. This is a recommendation, not a TUV standard, which must be seen as an initial attempt to derive a standard.

· The Undersecretary compares the results from a leaching test with the indicated contents in the TUV report. For a correct comparison, this should have been the total PAH content in the rubber granulate (14-112 mg/kg, see above). In case of skin contact longer than 30 seconds (which is plausible when doing sports on a field), at such concentrations this recommendation can be exceeded.

Environmental risks of rubber granules

The RIVM came to the conclusion that the MAR value for surface water was exceeded for three substances, because these substances leached from the rubber granules to the surrounding surface water; for 4-t-octylfenol by a factor 6, and for copper and zinc by 14 and 25 respectively. The MAR is also exceeded for all PAHs by a factor of 2. Adverse effects on aquatic organisms cannot be excluded at such levels. The conclusions from the RIVM research correspond to the results of a comparable study from Norway (NIVA, 2005). The standard for zinc is exceeded also in accordance with the Building Materials Decree (Hofstra, 2006).

Recommendations

With these presents we want to express our concern about the use of rubber granules from shredded car tyres on artificial turf fields. Rubber granules contain a large number of chemical substances which can leach into the surrounding surface water. In view of the provisional results of this study, drainage water must not be discharged directly (untreated) into the surface water.

The assessment of the health and environmental risks is based on a limited set of "exposure data."

· Additional information on the availability of chemicals from rubber granules upon dermal and oral exposure can provide further support for the provisional conclusion that there is no health risk from using rubber granules in artificial turf fields.

· Additional information for the assessment of the current concentration of compounds in the aquatic environment, will reduce considerably the uncertainties in the analysis of the environmental risks.

Kind regards,

Dr. J.M. Roels
Head of Substances Expertise Centre

Health risks

1. Introduction

At the request of the Ministry of Regional Planning, Housing and Construction and the Environment (known by the Dutch acronym VROM), the following questions are answered:

- In which concentrations do PAHs occur in rubber granules? In ppb order or much higher?
- Are PAHs released from rubber granules upon contact with the skin during sporting activities? In reply to questions in the lower house, the undersecretary stated that PAHs do not leach.
- How do you assess the exposure time?
- Is there any real health risk from exposure to rubber granule particles?

2. In which concentrations do PAHs occur in rubber granules? In ppb order or much higher?

The total content of PAHs in rubber granules made of used car tyres is in the order of 14 to 112 mg/kg or ppm (see Appendix 2); the share of the carcinogenic PAHs is ca. 40-80%. It can be concluded that the PAH content in rubber granules is actually much higher (a factor of 100,000 for carcinogenic PAHs and a factor of 1,000,000 for total PAHs) than the 0.03 ppb which is mentioned in the reply to questions put in the lower house. The concentration to which the undersecretary refers (0.03 ppb) concerns the sum of the leached carcinogenic PAHs in a leaching test on water (BLIC, 2005).

3. Are PAHs released from rubber granules upon contact with the skin during sporting activities? In reply to questions in the lower house, the undersecretary stated that PAHs do not leach.

No information is available on the release of PAHs from rubber granules upon skin contact. There is a study available in which the migration of PAHs from car tyres is measured with the help of artificial perspiration (perspiration stimulant) (Danisch EPA, 2004). This study indicates that a demonstrable migration can be shown only for fluoranthene and pyrene. Migration is not however shown for benzo[a]pyrene, the most harmful (carcinogenic) PAH.

4. Exposure assessment

Exposure to chemicals present in rubber granules can occur through the skin (dermal adsorption), through the mouth (oral) and through breathing (inhalatory). No reliable information on rubber granules is available for any of these routes.

Background concentrations of benzo[a]pyrene in urban areas in Europe amount to about 1-10 ng/m³ (WHO, 2000). Additional inhalatory exposure to PAHs through evaporation of these materials from rubber granules does not appear likely in the atmosphere during sporting, given the low vapour pressure of PAHs. As rubber granules are coarse (size ca. 0.5 to 2 mm), the inhalation thereof is excluded. Inhalatory exposure is therefore not a source of an additional risk.

For exposure to the ground when playing, the National Institute of Public Health and the Environment assumes, for children aged 1 to 7, an average ingestion from hand-mouth contact of 100 mg per day (RIVM, 2002). For young children (18 months), an intake of 300 mg per day is assumed. In the Danish research study (Danisch EPA, 2004) cited in replying to the following question, an intake by children of 10 grams of polluted sand per day is assumed during half a year. This is a very conservative exposure scenario. In the present case, we are not dealing with ground or sand, but with rubber granule particles with a size of ca. 0.5 to 2 mm. The oral ingestion thereof does not seem very likely, but a value of 100 mg/day can be used here as a default for the oral ingestion of rubber granules.

No reliable scenarios are available for skin contact with rubber granules through sitting, lying, falling (sliding) on an artificial turf field. The Danish study (Danisch EPA, 2004) assumes 1 hour per day and exposed skin surface of 200 cm² for skin contact of children with rubber toys (old car tyres). This seems a considerable overestimation for the situation with rubber granules, since rubber granules are used as infill materials and direct contact with the skin tends to take place with the plastic fibres of the artificial grass than with the rubber granules.

5. Is there any real health risk from exposure to rubber granule particles?

As already indicated above, there is no information available to be able to assess the possible health risks upon contact with rubber granules. We therefore rely in part on data mentioned in the report of the Danisch EPA (2004). This report describes the possible risks of rubber toys in sandpits. It examines dermal exposure through direct contact with car tyres as well as oral exposure through the ingestion of polluted sand. The latter situation is not directly comparable with rubber granules, but it is illustrative for the assessment of a possible health risk.

5.1 Risk from dermal exposure

No migration could be shown in a test with a perspiration stimulant for benzo[a]pyrene, the most toxic PAH. It can consequently be concluded that there is no risk from dermal exposure on that basis. It would be more realistic, however, to assume a detection limit for the migration of PAHs of about 0.001 ng/cm² for the migration of BaP, as reported by the Danisch EPA (2004). By comparison with data from the Danish study, a systematic BaP burden of about 1-2 ng/kg of body weight through dermal exposure can be estimated. A benchmark dose (BMD10) for carcinogenic effects of 100 µg/kg of body weight per day is derived by WHO (2005) for BaP as a marker for the total carcinogenic PAHs in a mixture. This BMD10 corresponds to a dose that shows a 10% incidence on tumours in the exposed laboratory animal population. The exposure estimated above of about 1 ng/kg of body weight then corresponds to an additional lifelong cancer risk of 1 in a million. In other words, the risk from dermal exposure to PAHs is negligible.

Data are not available for the other substances present in rubber granules to enable any statement on the dermal risk. However, as there is no health risk for BaP as a marker for all PAHs and as the most toxic component in rubber granules, it appears unlikely that this would be the case for the other substances.

5.2 Risk from oral exposure

As indicated above, in the absence of real data, we assume an ingestion of 100 mg of rubber granules/day. Combined with a concentration of BaP in rubber granules of about 3 mg/kg, this corresponds to an intake of 0.3 µg BaP/person per day. When we assume (worst case estimate) that 10% of the BaP present in rubber granules can become available, the result, for a person weighing 60 kg is an oral exposure of 0.5 ng/kg of body weight per day. On the basis of the aforementioned WHO (2005) estimate of the cancer risk, an exposure of 0.5 ng/kg of body weight per day corresponds to an additional risk of 0.5 in a million. So the risk is negligible.

The Danisch EPA (2004) estimates the oral exposure to BaP from rubber toys to about 0.1 ng/kg of body weight per day. On the basis of the cancer risk estimate by WHO (2005), this corresponds to an additional lifelong cancer risk of 1 in 10 million. This supports the conclusion that there is no risk for PAHs from oral exposure.

In addition to PAHs, other chemicals occur in rubber granules, such as phthalates (softening agents). For one of the most harmful phthalates, diethylhexyl phthalate (DEHL), the risk from oral exposure to rubber granules can be estimated by analogy to the method used above. The rubber granule concentration for DEHP is about 20 mg/kg. At an intake of 100 mg and availability of 10%, this corresponds to an oral exposure of about 0.003 µg/kg of body weight per day. This is about a factor of 15,000 lower than the TDI derived by the EFSA (2005). In short, there is no health risk from oral exposure to rubber granules for DEHP (and the other phthalates) either.

General

Furthermore, it can be pointed out that the assumption of an oral availability of 10% of the chemicals present in rubber granules is very likely considerably overestimated. Results from leaching tests point to an availability in the order of 0.01%. In addition, a long-term daily exposure is assumed for the risk assessment (both dermal and oral). This too is very likely an overestimate of the situation in case of exposure to rubber granulate.

6. Conclusion

PAHs can in fact be released to a limited extent from rubber granule particles, but based on the available data, this does not lead to a health risk. There is no health risk for DEHP from oral exposure either.

Data for the other chemicals in rubber granules are lacking to enable a realistic assessment of the health risk. But as there is no health risk for PAHs as the most toxic component in rubber granules, it seems unlikely that this would be the case for other substances.

7. Recommendation

Additional information on the availability of chemicals from rubber granules upon dermal and oral exposure can provide further support for the provisional conclusion that there is no health risk from using rubber granules in artificial turf fields.

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Appendix 2

Environmental risks from the use of rubber granules on artificial grass football pitches

1. Introduction

Infill is the filling that lies on the top layer of the artificial turf field. Artificial turf football pitches often have an infill of sand and rubber. The infill's function is to stabilise the field and give the artificial turf specific properties, e.g. for sliding. Shredded car tyres or new EPDM ("aromatic free") rubber can be used for the rubber granules.

2. Formulation, chemical composition and results of leaching tests

Shredded car tyres are usually used. The composition of the infill rubber granules is then identical to that of the car tyres. The rubber of the car tyres contains a multitude of chemical compounds that provide the specific properties of the material. The composition of the rubber can vary widely depending on the specific properties that one wants to give to the rubber. The table below (Table 1) gives a picture of the difference in the composition (formulation) of rubber. The rubber industry works with formulations that indicate the used quantities of a certain product (additives) to produce a specific type of rubber. These are not only simple chemical compounds, but also a composition thereof, such as wax and process oils.

Table 1. Global composition (formulation) of the type of rubber for car tyres¹⁾.

Ingredient	Formulation A	Formulation B	Formulation C	Formulation D
polymer	18.3	88.9	46.8	55.9
carbon black	11.0		45.6	30.7
ZnO	0.5	2.7	1.4	2.8
Sulphur	0.4	2.2	1.2	0.1
Stearic acid	0.4	1.8	0.9	1.4
Anti-oxidant	0.2	2.7	1.4	0.8
Wax	0.2	0.4	0.2	1.1
Accelerators	0.1	1.3	0.8	0.3
Aromatic process oil	69.0		1.7	4.5

¹⁾ CIWMB (1996)

In addition, there are data relative to the chemical composition of car tyre rubber. To this end, the content of organic chemical compounds and metals in the rubber is determined by means of a chemical analysis. Table 2 provides a summary of the results of some chemical analyses of rubber granules for a number of organic compounds.

Table 2 Concentrations of organic compounds (in mg/kg) in rubber granules for car tyres.

Substance	Sample I ¹⁾	Sample II ²⁾	Sample III ²⁾	Sample IV ²⁾	Sample V ²⁾
Naphthalene	0.55	0.4	0.32	0.72	0.19
Acenaphthylene	5.6	0.6	0.79	1	<0.08
Acenaphthene	0.3	<0.2	<0.2	0.32	<0.08
Fluorene	<0.15	0.4	0.55	0.68	<0.08
Phenanthrene	4.3	4.8	5.9	5.8	0.43
Anthracene	0.83	0.6	0.55	0.76	<0.08
Fluoranthene	4.3	7.8	11	11	0.12
Pyrene	17	23	37	34	0.16
Benzo[a]anthracene	8.5	1.4	1.9	1.8	<0.08
Chrysene	6	2.2	2.2	4.2	<0.08
Benzo[b]fluoranthene	3.3	2.2	3.5	3.9	<0.08
Benzo[k]fluoranthene	2.5	0.4	0.55	1.5	<0.08
Benzo[a]pyrene	3	2.4	3.1	3	0.12
Dibenzo[a,h]anthracene	<0.47	<0.4	<0.2	0.44	<0.08
Benzo[ghi]perylene	6	3.4	5.8	5.1	<0.08
Indeno[1,2,3-cd]pyrene	0.21	0.8	0.95	1.4	<0.08
Total PAH (16)	62	51	74	76	1
Dimethyl phthalate		<1.0	<1.0	<1.0	3.4
Diethyl phthalate		<1.0	<1.0	<1.0	1.5
Dibutyl phthalate		3.4	2.6	3.9	1.6
Benzylbutyl phthalate		1.3	2.8	1.9	<1.0
Diethylhexyl phthalate		21	21	29	3.9
Di-n-oktyl phthalate		<1.0	<1.0	<1.0	3.2
Di-isononyl phthalate		57	78	-	-
Di-isodecyl phthalate		<1.0	<1.0	-	-
4-t-octylphenol		33.7	27.8	19.6	0.05
4-n-octylphenol		<0.005	<0.005	<0.005	<0.005
iso-nonylphenol		21.2	21.6	9.12	1.12

¹⁾ LUT (2004)

²⁾ NBI (2004)

Table 3 provides a summary of the measured PAH contents, both the benzo[a]pyrene content and the total PAH content, in rubber and EPDM, from different studies.

Table 3: Summary of measured PAH contents (in mg/kg) in rubber granules and EPDM (Noordermeer, 2006; Hofstra 2006).

Type of sample	Reference	Benzo[a]-pyrene content	Total PAH content	Reference content
Tyre powder	Norges Byggeforskningsinstitut	2.4	51	1
Tyre powder	Norges Byggeforskningsinstitut	3.1	74	1
Tyre powder	Norges Byggeforskningsinstitut	3	76	1
Tyre powder	TÜV Rheinland Group	<0.1	46	1
Treated tyre powder	TÜV Rheinland Group	<0.1	47	1
Tyre powder				
Passenger car	TNO	4.9	112	1
Tyre powder				
Lorry	TNO	3.0	90	1
Lorry	Intron Sittard	0.3	14	1
Passenger car	Intron Sittard	0.68	33	1
EPDM powder	Norges Byggeforskningsinstitut	0.12	1	1
EPDM	TÜV Rheinland Group	<0.1	1.2	1
EPDM	TÜV Rheinland Group	<0.1	0.45	1
EPDM	TÜV Rheinland Group	<0.1	0.14	1
EPDM	TNO	<0.05	<1	1
EPDM	Intron Sittard	<0.1	3.8	1
Field sample	INTRON	0.35	58	2
Field sample	INTRON	0.32	47.5	2
Field sample	INTRON	0.29	61.6	2
Field sample	INTRON	0.41	71	2
Field sample	INTRON	0.26	46.1	2

¹⁾ Noordermeer (2006)

²⁾ Hofstra (2006)

In addition to organic chemical compounds, there are also metals in rubber (see Table 4), essentially zinc. Zinc comes from the zinc oxide added to the rubber, which is added as vulcanisation accelerator to the rubber during the production thereof.

Table 4. Concentration of metals (in mg/kg) in rubber granules of car tyres.

Substance	Sample I ¹⁾	Sample II ²⁾	Sample III ²⁾	Sample IV ²⁾	Sample V ²⁾
Arsenic	<9.95	<3	<3	<2	<2
Cadmium	<1.99	1	1	2	<0.5
Cobalt	<1.99				
Chromium	<1.99	<2	<2	<2	5200
Copper	32.1	35	20	70	<3
Iron	452				
Manganese	3.51				
Nickel	<1.99	<2	<1	<5	<5
Lead	<9.95	20	15	17	8
Zinc	174	7500	7300	17000	9500
Mercury		0.04	0.04	<0.03	<0.03

¹⁾ LUT (2004)

²⁾ NBI (2004)

In addition to the determination of the content of organic compounds and metals in rubber granules, leaching tests are carried out (with rubber granules) to measure the degree of leaching (leaking) of substances from the granules to water. The leaching tests are conducted according to a NEN ISO 1457 standard protocol. Rubber granules are thereby brought into contact with deionised water at a ratio of 10 litres of water per kg of rubber granules. Leaching then takes place for a period of 24 and 48 hours under stirring for metals and organic compounds respectively (LUT, 2004 and NBI, 2004). After this period, samples are taken from the water and analysed for the different compounds.

The analysis of results from the leaching tests are given in Tables 5 and 6.

Table 5. Measured concentrations (in µg/l) or organic compounds in water of leaching test with rubber granules from

car tyres

Substance	Sample Ia ¹⁾	Sample Ib ¹⁾	Sample II ²⁾	Sample III ²⁾	Sample IV ¹⁾
Naphthalene	11	<0.29	0.15	<0.01	
Acenaphthylene	<0.14	0.46	0.27	<0.01	
Acenaphthene	<0.5	<0.5	0.03	0.02	
Fluorene	<0.2	2.8	0.04	0.04	
Phenanthrene	0.1	<0.05	0.16	0.17	
Anthracene	<0.01	<0.01	0.03	0.03	
Fluoranthene	<0.01	0.09	0.06	0.06	
Pyrene	<0.05	<0.06	0.13	0.12	
Benzo[a]anthracene	0.03	<0.01	<0.01	<0.01	
Chrysene	<0.01	<0.01	<0.01	<0.01	
Benzo[b]fluoranthene	<0.01	<0.04	<0.01	<0.01	
Benzo[k]fluoranthene	<0.01	<0.01	<0.01	<0.01	
Benzo[a]pyrene	<0.01	<0.02	<0.01	<0.01	
Dibenzo[a,h]anthracene	<0.01	<0.01	<0.01	<0.01	
Benzo[ghi]perylene	<0.05	<0.06	<0.01	<0.01	
Indeno[1,2,3-cd]pyrene	<0.01	<0.01	<0.01	<0.01	
Total PAHs	<12.15	<4.43	<0.95	<0.54	
Dimethyl phthalate			0.6	1.6	
Diethyl phthalate			6.6	8.3	
Dibutyl phthalate			3.3	2.1	
Benzylbutyl phthalate			<0.1	0.3	
Diethylhexyl phthalate			5.1	5.6	
Di-n-oktyl phthalate			2.9	4.4	
Di-isononyl phthalate			2.7	2.2	
Di-isodecyl phthalate			<1.0	1.0	
4-t-octylphenol			3.6	2.95	50 – 0.2
4-n-octylphenol			0.043	<0.02	0.3 - 0.001
iso-nonylphenol			1.12	0.568	0.5 – 0.7

¹⁾ LUT, 2004

²⁾ NBI, 2004

The total contents for PAHs (EPA-16) vary from 0.54 µg/litre to 12.15 µg/l (parts per billion, ppb). For benzo[a]pyrene, the contents measured in water are less than 0.02 µg/l. A recent research study (Hofstra, 2006) on the leaching of chemicals from rubber granules of Dutch artificial turf football pitches shows that the measured contents for PAHs (16-EPA) are in the range of <0.34; <0.40; <0.64; <0.11 and 0.45 for a water-granule ratio of 1:1 (LS=10). The total contents for PAHs (16-EPA) for production samples are between <0.44 and <0.94 µg/l (Hofstra, 2006). The measured contents correspond with the results of the Norwegian study (NBI, 2004) and the values reported by BLIC (2005). The higher deviating contents from LUT (2004) are caused in particular by high concentrations of certain compounds (naphthalene and fluorine). Table 6. Measured concentrations (in µg/l) of metals and arsenic in water from the leaching test with rubber granules from car tyres.

Substance/	Sample Ia ¹⁾	Sample Ib ¹⁾	Sample II ²⁾	Sample III ²⁾	Sample IV ²⁾	Sample ^{v2)}
Arsenic	2.27	1.69				
Cadmium	0.078	0.12				
Cobalt	5.33	5.81				
Chromium	2.95	5.96				<2
Copper	5.77	383				
Iron	0.284	0.462				
Manganese	56.4	5.57				
Nickel	4.31	1.37				
Lead	8.44	48.8				
Zinc	1310	7050	2290	1220	590	80
Mercury	<0.02	0.0386				

¹⁾ LUT, 2004

²⁾ NBI, 2004

The study carried out by INTRON (Hofstra, 2006) reports zinc contents in eluent of 7500 – 6000 µg/l where the study was carried out according to DIN V 18305-7. This test is comparable with that used in (NBI, 2004). The tests carried out by INTRON are different. Here, what are known as column tests (NEN7383) are used (Hofstra, 2006), in accordance with the Building Materials Decree. This makes it possible to compare the results between the different leaching tests. Here, the ratio between the quantity of eluent (water) and rubber, the L/S ratio is important. In an L/S ratio of 10, the zinc contents vary from 400 to 1200 µg/l for production samples and from 1200 and 5300 µg/l for field samples. These values are comparable with the zinc concentrations reported by LUT (2004) and NBI (2004).

For samples Ia and Ib, the leaching tests are carried out at different pH values. In addition, the results of leaching tests with shredded car tyres are given for a number of substances (Sample IV). A comparison of the results of the leaching tests with rubber granules and shredded car tyres shows a higher extent of leaching for rubber granules. This is to be compared with the fact that the granule has a far greater specific surface (smaller particles), whereby the available surface for leaching is greater. Rubber granules concern particles of 1 mm to 10 mm in size. Cut and shredded car tyres concern pieces of 10-50 mm and 50-300 mm in size respectively, according to the European nomenclature, CWA 14243 (LUT, 2004).

3. Assessment of environmental risks

To get an idea of the possible effects on the environment, the concentrations measured in the leaching tests are compared with the surface water standards in force in the Netherlands, where the maximum admissible risk (MAR) and the target value (TW) are used (VROM, 2006). The MAR values are taken from the Substances and Risks website (RIVM, 2006). The maximum value of the measured concentration for each site is compared with the MAR. For substances with the same toxic action mechanism, the separate ratios between the concentration and the MAR can be added, for what is known as the "toxic unit" approach. This toxic unit is followed for the PAHs. The total (sum) for the PAHs is also given in the results (table 7.) The ratio between the concentrations and the MAR gives an impression of the possible effects for the environment (ratio > 1 is a potential risk).

In this case, "environment" refers to the receiving surface water. A situation is assumed whereby the drainage water from an outdoor artificial turf football pitch is discharged in a ditch situated nearby. It is assumed that the drainage water has the same concentration as the maximum measured concentrations of the leaching tests. In addition, it is customary, when assessing the risk of substances, to assume that water discharged in the surface water is diluted with a factor of 10. For a local risk assessment, it is further assumed that no biological or chemical degradation takes place. The results of the comparison between the estimated concentrations in the surface water and the surface water standards in force in the Netherlands are given in Table 7.

The standards are expressed as total concentration in water. This comprises both the dissolved part as the part bound to

the floating matter.

Table 7. Maximum concentration in the eluate, maximum estimated concentration in the surface water and ratio to MAR, for organic compounds.

Substance	Maximum concen (µg/l)	Concentration in water (µg/l)	MAR (µg/l)	Conc./MAR ratio
Naphthalene	11	1.1	1.20	0.92
Acenaphthylene	0.46	0.046		
Acenaphthene	<0.5	<0.05		
Fluorene	2.8	0.28		
Phenanthrene	0.17	0.017	0.3	0.06
Anthracene	0.03	0.003	0.080	0.04
Fluoranthene	0.09	0.009	0.500	0.02
Pyrene	0.13	0.013		
Benzo[a]anthracene	0.03	0.003	0.030	0.10
Chrysene	<0.01	<0.001	0.900	<0.001
Benzo[b]fluoranthene	<0.04	<0.004	0.025	<0.16
Benzo[k]fluoranthene	<0.01	<0.001	0.200	<0.01
Benzo[a]pyrene	<0.02	<0.002	0.200	<0.01
Indeno[1,2,3,cd]pyrene	<0.01	<0.001	0.400	<0.003
Dibenzo[a,h]anthracene	<0.01	<0.001	0.001	<1.00
Benzo[g,h,i]perylene	<0.06	<0.006	0.500	<0.01
Total PAHs⁴⁾				≥.12- <2.31-
Dimethyl phthalate	1.6	0.16		
Diethyl phthalate	8.3	0.83		
Dibutyl phthalate	3.3	0.33	10 3)	0.03
Benzylbutyl phthalate	0.3	0.03	7.5 3)	0.004
Diethylhexyl phthalate	5.6	0.56	1.3 1)	0.43
Di-n-octyl phthalate	4.4	0.44		
Diisononyl phthalate	2.7	0.27	-	
Diisodecyl phthalate	1	0.1	-	
4-t-octylfenol	3.6	0.36	0.06 2)	6.00
4-n-nonylfenol	0.043	0.0043	0.33 3)	0.01
iso-nonylfenol	1.12	0.112	0.33 3)	0.34

MAR* this is the added MAR according to the formula below

1) Standard from the Water Framework Directive

2) Standard from the Water Framework Directive

3) Derived MAR based on the predicted no effect concentration (PNEC) from EU risk assessment reports (this is not an official national standard. This standard is comparable with MAR) 4). For the PAHs, the sum of the ratios between the

concentration and the MAR is calculated by including and excluding the values that belong to concentrations below the detection limit (<- sign). It should moreover be pointed out that standards are not (yet) available for all PAHs.

Metals and arsenic come to the environment from nature. The naturally present contents of these compounds are included in the MARs. The concentrations measured in the leaching tests are taken as the point of departure, and these concentrations are added to the natural background concentrations. For this reason, the MARs must be corrected with the natural background concentrations (BC), according to the following calculation

$$\text{MAR}_{\text{total}} = \text{MAR}_{\text{added}} + \text{BC}$$

$$\text{MAR}_{\text{added}} = \text{MAR}_{\text{total}} - \text{BC}$$

The results of the comparison between the estimated concentrations in the surface water and in the surface water standards in force in the Netherlands are given for metals and arsenic in Table 8.

Table 8. Maximum concentration in the eluate, maximum estimated concentration in the surface water, and ratio to MAR for metals and arsenic.

Substance	Maximum conc. (µg/l)	Concentration in water (µg/l)	MAR (µg/l)	BC (µg/l)	Conc./MAR* ratio
4	2.3	0.227	32	1	0.01
Barium	11	1.06	230	76	0.01
Cadmium	0.12	0.012	2	0.4	0.01
Cobalt	5.8	0.581	3.1	0.2	0.20
Chromium	6.0	0.596	84	1.6	0.01
Copper	383	38.3	3.8	1.1	14
Mercury	0.039	0.00386	1.2	0.06	0.00
Nickel	4.3	0.431	6.3	4.1	0.20
Lead	49	4.88	220	3.1	0.02
Zinc	7050	705	40	12	25

MAR*: this is the added MAR according to the foregoing formula.

The comparison between the expected maximum concentrations in the surface water and the standards shows that the standard in the surface water was exceeded for three substances. For 4-t-octylphenol, this is by a factor of 6, and for copper and zinc by a factor of 14 and 25 respectively. For the total PAHs, the sum of the individual ratios is greater than one (Σ.1-<2.3) and thus the standard is likewise exceeded.

When the standard is exceeded for several substances, adverse effects on aquatic organisms cannot be excluded.

4. Comparison with other research

The conclusions from this research study correspond with a comparable study from Norway, NIVA (2005). In the latter study, zinc and 4-t-octylphenol came to the fore as possibly toxic for the aquatic environment owing to the use of rubber granules as infill, in particular for football pitches. The conclusion of this research on zinc corresponds to the results of the INTRON study (Hofstra, 2006), although it is worth pointing out that the conclusions from the latter study are based on standards from the Building Materials Decree.

5. Uncertainties in the risk assessment

The results from the leaching tests apparently reflect an extreme situation compared with the reality. The contact time of rainwater with the rubber granules is actually far shorter. The contact time during the leaching tests is 24-48 hours, whereas in reality, this will be far lower, and can thus provide a different picture of the quantity of leached substances. No judgement can be passed on the time-dependency of the leaching on the basis of the leaching tests, however. In

addition to the time aspect, there is also the fact that the ratio between the quantity of granules and water is actually much higher.

Furthermore, exposure in the surface water takes place only during short period (during rain showers). On the other hand, a dilution factor for ditches during rain showers may be smaller than the factor of 10 used. However, the factor 10 is based on long-term effects (and not soon after rain showers per se), which again supports the application of the factor 10, because the standards are likewise based on long-term effects.

It is assumed that 100% of the substance in the surface water is 'bioavailable.' In the case of metals, only a part of the substance will actually be bioavailable (and thus toxic) for organisms. This has to do with the bonding etc. of the metal ion with other particles in the water. There is always more knowledge available for metals to apply a concrete correction for bioavailability. This correction depends on a number of abiotic parameters in the water, for instance pH, hardness and the quantity of dissolved organic carbon (DOC). The bioavailability correction has still not been "officially" introduced in the Netherlands, however, and is not applied in this study.

6. Recommendations

The following recommendations are made:

- In addition to the afore-named substances, there are also other compounds that occur in rubber, such as anti-oxidants and accelerators. A good foundation of the exposure data found in the literature (BLIC, 2005) is still lacking for these substances. An initial, provisional analysis has shown that, for a number of chemical compounds (e.g. aniline), the measured concentrations in (ground)water are higher than the PNEC (= MAR). The PNECs used here come from the risk evaluation reports (RARs) drawn up by the EU. It is therefore advisable to examine thoroughly other substances that occur in rubber. These substances could contribute to the overall risk of rubber granule application in the aquatic environment.
- To get a better picture of the kinetics (time-dependency) of the extent of leaching, specific leaching tests must be carried out. These must rely on a more realistic situation for rubber granule application in artificial turf fields.
- To get a good picture of the actual exposure of the aquatic environment, the occurrence of rubber chemicals in the drainage water from artificial turf fields should be measured (monitoring campaign).
- Given the (provisional) results of this study, drainage water should not be discharged directly (untreated) in the surface water.

Section 7:

FQC

Infill Health Statement

Recent reports have suggested a potential cancer risk from certain granulate in fills. In response to this a study has been made of the available publications relating to this issue. The list of publications that have been scrutinised is given below. The particular cause for concern is the presence of Polynuclear Aromatic Hydrocarbons (PAHs) in some rubber infill formulations. It is known that certain PAHs are potential human carcinogens. It is accepted that the vast majority of PAHs in the environment derive from the incomplete combustion of fossil fuels in particular diesel exhausts from truck and car emissions. The studies to date have concluded that "PAHs are not released or at most negligibly released from tyre abradate", The University of Dortmund Institute for Environmental Research 1997. "Epidemiological studies conducted by the Health Effects Institute, The World Health Organisation and other investigators do not implicate tyre wear particles in ambient air as contributing to human health effects (respiratory and cardiovascular diseases). "Tyre debris is found in diffuse roadside soils, but the published studies present no evidence for ecotoxic effects in or from roadside soil". In general tyre abradate is a much finer particulate than are the granules used as infill materials in Football Turf. The finer the particulates the greater the surface area and higher potential for chemicals to leach out of the rubber. The majority of the studies have been on these higher surface area particles and have concluded they are currently acceptable. The larger granules used in Football Turf will therefore have even less potential for emissions. A study undertaken by the Danish Ministry of the Environment concluded that the health risk on children's playgrounds that contained both worn tyres and granulate rubber was insignificant.

European Commission Opinion of the Scientific Committee on Toxicity, Ecotoxicity and the Environment (CSTEE) ON Brussels, C7/GF/csteop/PAHs/12-131103 D(03)

European Union Commission Report IP/04/208 Brussels 16th February 2004

European Union Commission 27th amendment to the Council Directive 76/769/EEC

TÜV Produkt und Umwelt Information 08/2005

Department of the Environment Investigation Denmark 2004

Goodyear Tyres 2003 Environmental Health and Safety Report

Chelsea Center for recycling and Economic Development University of Massachusetts Technical Report 2 Environmental Impacts of Recycled Rubber in Light Fill Applications August 1998

BIOLOGI Rapport, provtagningsären 96/97, 97/98, 98/99 Environmental monitoring in Stockholm Municipality Laboratory for Aquatic Ecotoxicology and Institute of applied Environmental research Stockholm University 2002

Perspect 110 Suppl 3 451-489 2002 Cancer risk assessment, indicators, and guidelines for polycyclic aromatic hydrocarbons

Gas and Particle Emissions from automobile Tires in Laboratory and Field Studies Rubber Chemistry and Technology, 52, 146-158 1978

Rubber Dust from the normal wear of tires Rubber Chem. Technol. 47, 1011-1037, 1974

The Determination of Rubber in Atmospheric Dusts Rubber Chem. Technol. 232-241 1974

EEA CORINAIR Summary Report Final Version. Report to the European Environmental Agency from the European Topic Center on Air Emissions 1997

Particulate air pollution with emphasis on traffic generated aerosols Rfiso R-1053(EN), Riso National Laboratory, Roskilde, Denmark, 1999

IARC Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans. Polynuclear Aromatic Compounds Part 1, Chemical, Environmental and Experimental Data, Vol. 32, Lyon, France P.39. 1983

IPCS Environmental Health Criteria 202, World Health Organisation Geneva 1998

The effects of motorway runoff on freshwater ecosystems: 1 Field Study. Env Toxicol Chem 14, 1079-1092 1995a

The effects of motorway runoff on freshwater ecosystems: 2 Identifying major toxicants *Env Toxicol Chem* 14, 1101-1092, 1995b

Tire wear as a source of PAH, Umweltbundesamt, Berlin CSTEE/2003/18/4

Source of fine organic aerosol 3. Road dust, tyre debris, and organometallic brake lining dust: Roads as sources and sinks. *Environ Sci Technol* 27, 1892-1904, 1993

Biomarker responses and chemical analyses in fish indicate leakage of polycyclic aromatic hydrocarbons and other compounds from car tire rubber. *Environ Toxicol Chem* 22, 2926-2931 2003

Fate and effect of Zinc from Tire Debris in Soil *Environ. Sci. Technol.* 2002, 36, 3706-3710

Section 8:

Incorrect Reporting

**De Telegraaf on Research Report on Infill
Used in Artificial Grass**

Incorrect Reporting in De Telegraaf on Research Report on Infill Used in Artificial Grass

Wednesday May 31, 11:55 am ET

ALMELO, The Netherlands, May 31 /PRNewswire-FirstCall/ -- In its 31 May 2006 edition, the Dutch daily newspaper, De Telegraaf, once again reported a number of factual inaccuracies on the use of SBR rubber in artificial grass fields. The information in the report does not substantiate any of the statements reported in the intended article.

Principals and purpose

- The research was commissioned by leading companies in the artificial grass industry, the rubber processing industry, the ISA Sport test institute, the NOC/NSF and the KNVB.
- The purpose of the research was to obtain more detailed insight into the leaching of (mainly) metals in practice, and to initiate research into the purported harmful effects it may have on the public health. This stands in stark contrast to the statements carried in the report in De Telegraaf to the effect that the research targeted the "hazards posed by artificial grass". The balanced composition of the policy groups responsible for the research indicates that the industry is assuming full responsibility for its social position in this regard. The research is being conducted as a multi-phase project, whereby the first phase is dedicated to the generation of factual information.

Erroneous interpretation of conclusions concerning health and environmental aspects

- De Telegraaf claims that artificial grass definitely poses hazards with respect to health and environmental aspects. This is however not the conclusion drawn in the report in question.
- De Telegraaf further claims that, according to the report, zinc leaching is assuming 'disturbing forms'. The latter conclusion is by no means borne out by the report.
- The same applies to the statement, by De Telegraaf, to the effect that the levels by which leaching exceeds the limiting values (zinc) are 'alarming'.
- The potentially harmful substances mainly include zinc, volatile chemicals and polycyclic aromatic hydrocarbons. Artificial grass fields that use SBR rubber and are laid in accordance with industry standards fully comply with the limiting values for zinc leaching, as well as for polycyclic aromatic hydrocarbons levels. As no specific limiting values have as yet been determined for sports fields, the most relevant standards applicable in this case are the conditions of the Building Materials Decree (Bouwstoffenbesluit). The decree however stipulates that a minimum of 20 cm infill must be used, while, in practice, only 2-3 cm rubber infill is being used. In accordance with the standards prescribed by the Building Materials Decree (which are unrealistic for artificial sports fields) the only limiting values that are exceeded are those applicable to zinc leaching. In other words, these limiting values are not exceeded in the case of sports fields. It does however specify the need for more detailed attention to the issue of the correct use of rubber infill and good "housekeeping", whereby the infill must remain in place on the field.
- Although research has been conducted in several countries into the possible harmful effects of rubber infill, with comparable results, only the Italian football federation has so far actually issued a ban on the use of untreated rubber granulates. To date, no other country has as yet considered this necessary.
- There is also no specific legislation available with respect to public health. The most relevant standards in that regard are the European standards applicable to the toy manufacturing industry and the recent recommendation issued by TÄV with respect to the directives for the evaluation of polycyclic aromatic hydrocarbons levels in fixed products.

The following are the conclusions drawn by the report with respect to health risks:

- All heavy metal levels are in compliance with the standards applicable to toy manufacturing and the risk of harmful effects on sportsmen and women is therefore negligible.

- The levels of polycyclic aromatic hydrocarbons fail to comply with the TAV directives in the case of skin contact exceeding 30 seconds. The question as to whether extended skin contact is actually harmful has not been answered satisfactorily by any research projects conducted to date. Short periods of skin contact (whether realistic in the case of, e.g. a slide) are therefore deemed risk free.

- Indoor and outdoor use of rubber infill poses absolutely no risk to sportsmen/sportswomen or other parties concerned through inhalation.

Further research needs to be done on a number of aspects, including long-term skin contact with rubber infill. The conclusion, on the grounds of this research, to the effect that artificial grass fields with rubber infill are harmful to the public health, is therefore premature and incorrect. There is no direct reason to forthwith stop the use of rubber infill in artificial grass sports fields.

Role played by TenCate

TenCate (Euronext: KTC) is a participant in this research project because, as a market leader in the field of artificial grass fibres, it wishes to plead for the use of the safest possible system that will, at the same time, retain its play-technical properties for the longest possible period of time. By conducting this research, TenCate wishes to demonstrate its commitment to its social responsibility in the industry. The industry research contributes to the determination of enhanced quality criteria for artificial grass sports fields through the collection of the necessary factual information.

TenCate has been producing an alternative for rubber infill since 2004: This is partially done with a view to ensuring the full recyclability of these types of sports fields in the longer term. The new type of infill also retains its play-technical qualities in the long term. The system has been used for, among other applications, the training fields at KNVB, AZ and AFC Ajax and the main playing field at Heracles Almelo.

For more detailed information, please refer to the Ten Cate Thiolon website

www.thiolon.com

Conclusion

TenCate maintains the view that the use of rubber infill is fully responsible, both with respect to public health and the environment. TenCate will continue to strive for further optimisation and innovation with respect to continuing developments in the advancement of artificial grass systems. In the long term, TenCate expects alternative infill materials to be more easily available to the volume market.

www.tencate.com

Section 9:

**PAHs & Other Organics in Tires
Origins & Potential for Release**

BRYAN G WILLOUGHBY
BSc PhD CChem FRSC FIMMM MFOH(S)
Consultant in Polymer Chemistry
- processing, service, emissions

TECHNICAL NOTE: BGW/60623

Date: 23rd June 2006

PAHs AND OTHER ORGANICS IN TYRES – ORIGINS AND POTENTIAL FOR RELEASE

Background Material for the Standards for Artificial Turf Working Group

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Page 1 of 6 of BGW/60623

1. PROLOGUE

These notes have been prepared to provide a background to discussions of the Standards for Artificial Turf Working Group. In particular they seek to show that the risk scenarios linked to rubber and its products are far from simple, and questions of what is safe should be qualified by considerations of the context intended – i.e. safe with respect to what?

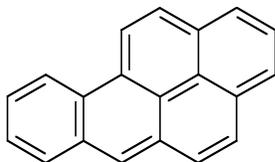
This does mean that care must be taken to avoid dealing with one problem only to provoke another. As is always the case, a balanced approach is necessary in risk assessment. The challenge is striking the right balance.

2. POTENTIAL HAZARDS FROM RUBBER

2.1 Polycyclic Aromatic Hydrocarbons

Polycyclic aromatic hydrocarbons (PAHs) are widespread in the environment and are formed as formed as the result of the action of heat on organic materials, and especially alongside combustion.

Concerns over PAHs arise from the fact that some examples are potent carcinogens. An example of such is benzo[a]pyrene shown below.



benzo[a]pyrene
a polycyclic aromatic hydrocarbon

The carcinogenic PAHs are encountered amongst the less volatile examples of this class (e.g. typical Bps in excess of 450°C).

A wide range of PAHs – including the carcinogenic ones – are found in the air – especially in urban air. They originate from various combustion sources (e.g. power generation, vehicular traffic, space heating or social activities such as cigarette smoking) and adsorb on smoke particles to become airborne (i.e. the carcinogenic PAHs are found on particulates not as vapours).

DEFRA routinely monitors PAHs levels in air. The results below are for mean levels for three carcinogenic PAHs at a site in Manchester.

Annual mean ambient concentrations (ng/m³) of three PAHs in urban (Manchester) air (NETCEN, 1998)

	1991	1992	1993	1994	1995	1996	1997
benz[a]anthracene	2.5	1.1	0.6	0.8	0.3	0.8	1.1
benzo[b]fluoranthene	1.5	1.4	1.0	1.2	0.6	0.8	1.3
benzo[a]pyrene	1.8	1.6	0.7	0.8	0.4	0.5	0.8

Note these are average levels and the concentrations may vary widely from day to day (depending on the weather – i.e. dispersal factors). On one occasion in the outside air in rural Shropshire, I found 17 ng/m³ of benzo[a]pyrene.

Possibly the highest levels of airborne PAH in the UK are routinely found in rural Scotland. These are near the aluminium smelter at Kinlochleven.

Given their widespread availability, human exposure to PAHs (and the carcinogenic ones) cannot be avoided. Some exposure scenarios are:

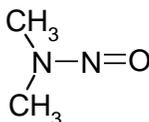
- inhalation of smoke particles
- ingestion of smoked, charred or char-grilled foodstuffs
- skin contact with soot.

Exposure does not stop at the risks from smokes and chars - as any particulate pollutant, once released into the air, can be transferred to other media. Hence the PAHs carried on smoke can settle on the ground (or vegetation) or be washed by rain into ground waters.

This means that, if you go hunting for PAHs (yes, even the carcinogenic ones), you will find them.

2.2 N-Nitrosamines

N-Nitrosamines are the N-nitroso-derivatives of amines, and a number are carcinogenic (e.g. N-nitrosodimethylamine).



N-nitrosodimethylamine (dimethylnitrosamine)

N-Nitrosamines figure prominently in concerns over cancer risks from rubber, although they have the potential to be formed whenever protein-containing material is roasted in a current of air. Beer, whisky and bacon contain carcinogenic N-nitrosamines.

Unlike the carcinogenic PAHs, N-nitrosamines are volatile. They can be formed during vulcanisation and released from the rubber (12 different ones are regulated for the German rubber industry). Over the last twenty years, the tyre industry has responded to worldwide concerns and effected large reductions in N-nitrosamine levels. Quite possibly they are now completely undetectable.

That may be the case for tyres – but is it so for EPDM? N-Nitrosamines can be particularly difficult to eradicate from EPDM.

2.3 Sensitisers

Most people can survive contact with rubber, but a few can show sensitive reactions. Potential sources of sensitisation are:

- the proteins in natural rubber
- the organosulphur and organonitrogen compounds from vulcanisation.

For those sensitised, the former gives rise to immediate (Type 1 allergy) hypersensitivity, whilst the latter gives rise to irritation and delayed (Type IV allergy) hypersensitivity. Together, irritation and Type IV hypersensitivity are known as contact dermatitis. Contact dermatitis results in skin rashes, blistering, etc. Contact dermatitis is not normally associated with tyres or industrial rubber goods, but may be encountered where more prolonged skin contact is possible (e.g. elasticated garments, rubber gloves, condoms, etc.).

Type 1 allergy is only associated with natural rubber – it affects only a very few people, and the exposure scenarios are unusual (e.g. by inhalation of dusts which have been in intimate contact with the rubber). Nevertheless, since the individual may go into anaphylactic shock, the condition is potentially fatal. This has brought natural rubber into an uncomfortable focus. The UK market for natural rubber latex gloves has fallen considerably as a result.

3. EXPOSURE RISKS

3.1 Inhalation

The inhalation risk scenarios for PAHs from rubber were amongst the earliest to be studied (e.g. from the early 1970s) and provide some valuable lessons for any monitoring strategies.

The major source of the PAHs in tyre rubbers lie in the aromatic process oils used for plasticisation. These are oils have a boiling range 250-680°C, and are waste products of refinery processes.

Plasticisation of tyre rubber enhances aspects of processing and product performance. Processing benefits include reduced energy consumption, and performance gains include higher hysteresis (and wet grip, etc.). It is always important to match the oil to the rubber and aromatic process oils are reserved for aromatic rubbers – i.e. the styrene-butadiene rubber (SBR) used extensively in passenger tyres.

The aliphatic EPDM (ethylene-propylene diene monomer) rubbers are plasticised with different oils – not aromatic types. Apart from perhaps decorative trim (whitewalls?), EPDM rubbers are not used in tyres.

The presence of carcinogenic PAHs in aromatic process oils makes the oils themselves carcinogenic. These oils carry the R45 (“may cause cancer”) labelling. Great care must be exercised in handling these oils in the rubber factory – skin contact must be avoided. The industry would like to stop using them but there are both cost and performance issues here.

Note it is the oil which is labelled R45 – but not the product tyre. After the oil is incorporated, the rubber is vulcanised. In simple terms, the effect of vulcanisation turns about two-thirds of the tyre into a single molecule. The oil itself is unchanged, but it is now trapped in this huge (infinite at the atomic level) molecular network.

One of the earliest studies of airborne PAH in tyre factories (started in 1973) quickly found that the results made little sense without comparative measurements on the outside air. Studies, over the remainder of that decade, in both the UK and USA, found that:

- no carcinogenic PAH was present in excess over ambient air levels

Additionally, laboratory studies have found,

- no PAH less volatile than pyrene (Bp 404°C) in hot rubber fume.

These studies were conducted over a period of some ten years and resulted in a number of publications. They reveal that the process of volatile release from rubber can be viewed as a fractional distillation where only the most volatile oil components are released. Indeed, despite the fact that some three-quarters of the oil is aromatic, it is the smaller aliphatic content that dominates the volatile release from these oils.

By comparison, the aliphatic oils used in EPDM and other rubbers are a more prolific source of volatiles from hot rubber.

Odour issues are more problematic in that the specific source of the odour has not been clearly defined. One named candidate is 2-mercaptobenzothiazole (MBT), which is both an ingredient and a reaction product of rubber vulcanisation. Why this has been named is not clear – as MBT smells nothing like any rubber!

The vapours released vary widely with the type of rubber and its temperature. One publication lists some 150 different species in the volatiles from rubber. Organonitrogen and organosulphur compounds are more likely to be released from hot rather than cold rubber.

At ambient temperature the volatiles released from the tread area of an SBR tyre are likely to be rich in alkenes (e.g. dodecenes) and ketones (e.g. methyl isobutyl ketone). Amines (e.g. dimethylamine, dibutylamine) are likely to be encountered in the volatiles from the inner (butyl liner) region of the tyre. The volatile released from natural rubber are likely to include natural alkenes (e.g. terpenes).

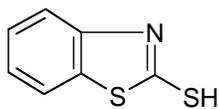
Volatile releases from rubber have been studied for over thirty years and much is already in the public domain. Nevertheless, the analyses are not unduly difficult to perform, and grade-related variations could form a part of any research strategy.

Of course, these considerations relate to volatile risks from rubber at temperatures up to those in manufacturing (e.g. up to around 200°C). If the rubber is exposed to much higher temperatures, the volatilisation of higher boiling PAHs will become an issue. Certainly the fumes from burning tyres would be carcinogenic. But so are the fumes from vehicle exhausts, barbeques, etc., etc.

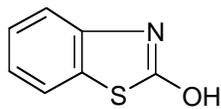
3.2 From Leachates.

The number of potential by-products from rubber vulcanisation increases significantly when involatile low molecular weight (i.e. potentially migratable) species are also included. One recent report to the Food Standards Agency on potential releases from food contact rubbers ran to over three hundred pages.

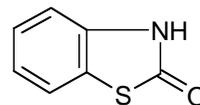
Additionally there is the potential for change after leaving the rubber, e.g. as in the hydrolysis of MBT to hydroxybenzothiazole and benzthiazolone.



mercaptobenzothiazole



hydroxybenzothiazole



benzthiazolone

Waste waters in tyre manufacturing plants have been the subject of study, where evidence for the presence of some of the lower molecular weight (non carcinogenic) PAHs can be found. Particular examples include naphthalene and various alkyl naphthalenes.

Issues regarding the migration of the higher molecular weight PAHs (carcinogenic) from tyres, tyre dust or tyre crumb have initiated much research (e.g. see Eric's synopsis), but studies in the field are inevitably confounded by the presence of such PAHs from other sources (i.e. washed out of the atmosphere). Laboratory extractions will yield more definitive data in terms of source-related effects – but balancing any contribution from rubber against that from other sources will be necessary. The overall findings to date seem to indicate that the contribution from the rubber is of no real concern.

Submerged scrap tyres are also used in the marine environment. No toxic risks have come to light, although there are increasing concerns over engineering issues and the stability of such structures in storms.

3.3 Skin Contact.

Section 2.3 above mentioned that contact dermatitis is not normally a problem associated with tyres. In any event, a Type (IV) allergic reaction usually subsides if there is no repeated contact.

Type 1 allergy is a different issue as emotions can run high. There is no evidence that fine tyre dust from natural rubber tyres can cause a Type 1 reaction – but the question has certainly been raised.

Section 10:

Recycled Rubber Nitrosamines Analysis

Tun Abdul Razak Research Centre
Brickendonbury, Hertford SG13 8NL.

Tel: 44 (0)1992 584966 Fax: 44 (0)1992 504248

Test Report

Sample(s) description: Recycled rubber powder

GR No. 06/035

Date received: 19 Jan 2006

MCG Test Report No.R9955

Date of report: 25 Jan 2006

Recipient: James B. Gray
Company name and address: Lehigh Technologies
5308 River Ridge Drive, Suite 101
Brighton, MI 48116
USA

The various tests carried out, with their log identifying numbers, dates of testing and the initials of the person who carried out the tests, are tabulated below. UKAS-accredited tests are identified by their test reference numbers. Test references marked '*' denote tests which are not UKAS accredited and are not included in the UKAS Accreditation Schedule for our laboratory. Opinions and interpretations expressed herein are outside the scope of UKAS Accreditation

UKAS Test ref. no.	Test type by initials and test identifying run nos.	Date of testing	Operator
051 (FDA)	GC-NB-0564	24-25 Jan 06	PES / PCG

This report has been approved for release by

Sue Stephens; Head, Materials Characterisation
Ext 2005, E-mail sstephens@tarrc.co.uk

Report No. R9955 (RC16719)

The sample of recycled rubber powder was analysed as received for volatile N-nitrosamines according to our method reference 051 (FDA) in line with AOAC 1990, 987.05.

The following were the only N-nitrosamines observed in comparison with the set of reference standards which includes NDMA, NDEA, NDnPA, NDBA, N-PIP, N-PYR, and N-MOR and the results are reported as parts per billion (ppb) or micrograms per kilogram ($\mu\text{g}/\text{kg}$). The limit of detection is 1.5 ppb.

Material	Reference	Nitrosamines ($\mu\text{g}/\text{kg}$)
Recycled rubber powder	Lehigh PolyDyne 80/140 mesh	NDMA 2 N-MOR 2

Checked by:

P C Gugan

Approved by:

I S Stephens

Interpretation and Opinion

Using the most severe extraction methodology, the nitrosamines found were only slightly above the detection level. These low levels of NDMA and N-MOR represent a worst-case scenario with regard to the product. The dichloromethane extraction removes all volatile nitrosamines from the rubber, and so the results represent the maximum amount that could become airborne.

Section 11:

**The Effects of Motorway Runoff
on Freshwater Ecosystems**

The effects of motorway runoff on freshwater ecosystems:

1. Field study

L. Maltby, D.M. Forrow, A.B.A. Boxall, P. Calow & C.I. Betton

Abstract

The effects of motorway runoff on the water quality, sediment quality, and biota of small streams were investigated over a 12-month period. Downstream of motorway runoff discharges there was an increase in the sediment concentrations of total hydrocarbons, aromatic hydrocarbons, and heavy metals and an increase in the water concentrations of heavy metals and selected anions. Hydrocarbon contamination of sediments was positively correlated with potential contaminant loading (i.e., length of road drained/stream size). The greatest effect was observed at Pigeon Bridge Brook, a small stream receiving drainage from a 1,500-m stretch of the M1 motorway. The dominant PAHs in contaminated sediment at this site were phenanthrene, pyrene, and fluoranthene, whereas the dominant metals were zinc, cadmium, chromium, and lead. Differences between the station upstream and downstream of discharges in the diversity and composition of the macroinvertebrate assemblages were detected in four out of the seven streams surveyed. However, there was no evidence of an effect on either the diversity or abundance of epilithic algae. The diversity of the aquatic hyphomycete assemblage was only affected at the most impacted site. Reductions in the macroinvertebrate diversity were associated with reductions in the processing of leaf litter and a change from an assemblage based on benthic algae and coarse particulate organic matter to one dependent upon fine particulate organic matter.

Reference

Maltby, L., Forrow, D.M., Boxall, A.B.A., Calow, P. & Betton, C.I. (1995). The effects of motorway runoff on freshwater ecosystems: 1. Field study. *Environmental Toxicology and Chemistry*, 14: 1079-1092.

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Web: www.cranfield.ac.uk/ecochemistry

Section 12:

**Environmental
Health & Safety Report**

2003 ENVIRONMENTAL HEALTH & SAFETY REPORT

HOT TOPICS

Goodyear keeps a pulse on global issues relating to the environment, health and safety of customers, associates and communities in which the company operates. Many times, the company takes sides on particular issues that are in the news or that face government scrutiny. For 2003, these Hot Topics include low-rolling-resistance tires, aromatic oils and tire wear particles.

To access these topics, either click on the following or scroll to find the articles:

- Low-rolling-resistance Tires
- Aromatic Oils
- Tire wear Particles

Low-rolling-resistance Tires

Low-rolling-resistance tires normally are used as original equipment on many vehicles to help auto manufacturers meet federal corporate average fuel efficiency (CAFE) standards. These U.S. mileage standards were adopted to reduce the use of fossil fuels and to improve the environment.

Some people have suggested that low-rolling-resistance tires should be adopted as the standard for all tires. However, low-rolling-resistance tires have a shorter life and are more expensive to manufacture than current replacement tires. We believe a full understanding of tire design trade-offs, life cycle impacts and higher cost is necessary.

Tire design

Tire design is based on balancing competing and conflicting objectives for each tire. The major objectives include wet and dry traction, ice and snow, ride, treadwear, rolling resistance and cost. Different tires are designed for different customers based on the characteristics they value most. Tradeoffs must be made to maximize any single characteristic.

Customers are familiar with these issues as they frequently hear advertising and base purchasing decisions on tire performance characteristics (snow and ice tires, wet weather tires, tires with premium ride and tires with long wear). Low-rolling-resistance tires can have reduced treadwear, less traction and higher costs than conventional replacement tires.

Life cycle impacts

Goodyear believes its products should be evaluated according to environmental impacts relating to materials used in their manufacture, the manufacturing process, their use and their disposal.

Because low-rolling-resistance tires have a shorter life, more new tires and more raw materials will be required to provide tires for the same vehicle miles. Low-rolling-resistance tires also produce more emissions during manufacture. And a shorter tire life ensures that more scrap tires will be produced. Opinions on low-rolling-resistance tires have focused on their fuel economy benefits without consideration for other phases in life cycle.

Economic Impacts

Economic analyses have focused on fuel cost savings, yet no detailed analysis has factored in higher manufacturing costs and shorter tire life. In addition, no definitive analysis has been conducted of other alternatives. For example, proper tire inflation maintenance is a low-cost alternative for improved rolling resistance and tire life.

The Rubber Manufacturers' Association's "Be Tire Smart, Play your PART" program is designed to raise consumer awareness and improve tire performance.

Conclusions

There are currently inadequate environmental or economic data to support legislative requirements that all tires be low rolling resistance. In fact, legislating low-rolling-resistance tires is expected to have a detrimental effect on tire life cycle due to tradeoffs required to achieve low rolling resistance. Consumers would be expected to pay more for tires that provide less performance in other areas they consider important long life and traction.

Goodyear supports programs to research and test alternatives to determine the best life cycle and best economic

solution. Until comprehensive studies addressing the entire life cycle of a tire have been considered and that data demonstrate the advantages of making all tires low rolling resistance, Goodyear will continue to provide a wide range of options for its customers.

Highly Aromatic Oils in Tires

Current scientific data does not support legislation or regulations to restrict the manufacture or marketing of tires with highly aromatic oils containing polynuclear aromatic hydrocarbons (PAHs). In addition, aromatic oils when incorporated into rubber or into tires do not pose health risks to humans, and their release into the environment is negligible.

It is recognized and supported that the emission of carcinogenic substances into the environment should be as low as possible to control any risks to human health and the environment. Existing research data indicate that during tire manufacture, exposure to aromatic oils is minimal to zero. Chemical analysis has been unable to detect any PAH release into the environment from tire debris.

Several reports pertaining to aromatic oils, including from the International Agency for Research on Cancer, point to other environmental sources of PAH, such as asphalt run-off, auto emissions, polluted air, cooking, wood smoke, and tobacco smoke among other sources. The Swedish National Chemicals Inspectorate report (June 1994) alludes to an environmental contribution, but is based solely on inaccurate theoretical assumptions and calculations.

Human risk?

The risk for high levels of PAHs in highly aromatic oils is the potential for skin cancer to develop in workers exposed to oils, with prolonged and repeated skin contact, where good hygiene is not practiced. In the rubber industry where aromatic oils are used as process and extender oils, the incidence of skin cancer has not been increased by the handling of oils during the manufacturing processes. The rubber manufacturing industry has taken measures to eliminate exposure risk during handling by the installation of enclosed systems.

Ratpan and Hayes (1989) performed animal skin-painting studies (1989) with polymers containing highly aromatic oils. No skin cancer developed during the 18 months of study. Also, there is no reported incidence of human skin cancer from exposure to these types of oil-containing polymers. Using laboratory tests (Ames in-vitro assays) similar to those tests used to help determine the carcinogenic potential of highly aromatic oils, organic extracts of tire wear debris did not show any mutagenic activity (Hannigan, 1994).

Environmental risk?

Current scientific knowledge indicates that zero to negligible PAHs are emitted into the environment from tire wear particulates as a consequence of tire tread abrasion. There is no reliable environmental scientific justification for prohibiting the use of highly aromatic oils in tires.

The "University of Dortmund, Baumann/Ismeier, Institute for Environmental Research" research project paper (1997) indicates that PAHs are not released or at the most negligibly released from tire abradate (debris). This study was performed under contract from the German Federal Office of the Environment.

L'Institut Pasteur conducted inhibition, mobility and mortality tests in 1996 following European Union protocols. The tests, using rubber powder buffed from passenger tire treads, indicated extremely low levels of aquatic toxicity for water leachate. Thus, the leachate material is not considered toxic to aquatic organisms.

Safety considerations

Tires are a key component in automotive safety. Tires enable the driver to safely accelerate, maneuver, and stop under a wide range of speeds, surface conditions and weather, while providing ride comfort and long wear. Highly aromatic oils contribute directly to tire performance, integrity and traction. These oils, therefore, play a critical part in tire quality and the safety of all users and passengers in motor vehicles.

Because tire integrity and the safety of the end user are paramount, it is essential that any mass change in oil or any critical component not be undertaken until a full and thorough evaluation is complete, and that safety has been fully demonstrated.

Tire technology issues

Numerous materials are blended with natural and synthetic rubber to make rubber tire components. The various components are used to form and construct a tire. The tire is then cured under high temperature to produce the final composite thermoset finished tires.

Goodyear is committed to producing new types of tire lines. Hundreds of Goodyear engineers and scientists constantly evaluate new materials and new combinations of old materials. Goodyear continually works to develop new tires that meet constantly increasing customer requirements and expectations, while decreasing the impact on the environment.

Goodyear continues to explore the use of low-aromatic oils and other substitute materials. When product performance criteria are satisfactorily achieved, all safety considerations are addressed, product quality is assured and life cycle issues finalized. Use of replacement oils then can commence.

Conclusions

It can be concluded that rubber tires contain PAHs originating from certain oils used in tire manufacturing, but there is clear scientific evidence that any release into the environment is negligible relative to other PAH sources. The European Commission's Scientific Committee on Toxicity, Ecotoxicity and the Environment (CSTEE) supports this conclusion.

The CSTEE states that, "a reduction of the concentration of PAHs in tyres will insignificantly reduce the overall concentration of PAHs in the environment." [Brussels, C7/GF/csteep/PAHs/12-121103 D(03)]. The CSTEE adopted the risk assessment for PAHs in extender oils and tires in its plenary meeting of 12-13 November 2003.

It also has been demonstrated that the risk of rubber workers developing skin cancer from exposure to highly aromatic oils contained in rubber is non-existent. Therefore, there is no scientifically based need to restrict the use of highly aromatic extender oils to produce tires.

Furthermore, it is Goodyear's Environmental Health & Safety policy to ensure our products are safe by using materials that will not cause harm to our workers or the environment. It is also our policy to comply with our global environmental, health, and safety standards and the laws of each country where Goodyear does business.

Tire wear particles

Goodyear has analyzed the published literature on the concerns to health and the environment produced by tire particulate emissions. Based on the published data and evaluations, Goodyear concludes that wear and abrade (coarse particles greater than 93 percent, fine particles less than 7 percent). The rate of treadwear is influenced by many variables, including the type of tire produced, roadway characteristics and driving styles.

Studies conducted by Blok, l'Institut Pasteur and other investigators indicate that tire debris and fine airborne tire dust resulting from tire wear pose no significant environmental issues. Tire wear is a minor source of particulate matter, compared with tailpipe and road dust, and contributes 1.1 percent or less of the PM10 and PM2.5 from all sources in the European Union-15 countries (CEPMEIP, 2001).

Epidemiological studies conducted by the Health Effects Institute, the World Health Organization and other investigators do not implicate tire wear particles in ambient air as contributing to human health effects (respiratory and cardiovascular diseases).

Organic pollutants, including polycyclic aromatic hydrocarbons (PAHs) found in road dust and in airborne particulate matter, are derived primarily from vehicle exhaust and stationary combustion sources. Scientific data do not indicate that PAHs are released into the environment from tire debris.

Tire debris is found in diffuse roadside soils, but the published studies present no evidence for ecotoxic effects in or from roadside soil. Also, tire wear debris in roadside soils is degraded by bacteria and fungi and/or decomposed by oxygen and sunlight.

There are no definitive data to associate road runoff leachate with adverse effects on aquatic ecosystems.

The hypothesis that extractable dry natural rubber protein causes allergic reactions or contributes to asthmatic conditions has been refuted with scientific data.

Conclusion

Based on all available scientific data, Goodyear concludes that tire wear particles pose no environmental concerns.

Section 13:

**Cancer Risk Assessment,
Indicators & Guidelines for
Polycyclic Aromatic Hydrocarbons in the
Ambient Air**

Cancer risk assessment, indicators, and guidelines for polycyclic aromatic hydrocarbons in the ambient air.

Bostrom CE, Gerde P, Hanberg A, Jernstrom B, Johansson C, Kyrklund T, Rannug A, Tornqvist M, Victorin K, Westerholm R.

Swedish Environmental Protection Agency, Stockholm, Sweden.

Polycyclic aromatic hydrocarbons (PAHs) are formed during incomplete combustion. Domestic wood burning and road traffic are the major sources of PAHs in Sweden. In Stockholm, the sum of 14 different PAHs is 100-200 ng/m³ at the street-level site, the most abundant being phenanthrene. Benzo[a]pyrene (B[a]P) varies between 1 and 2 ng/m³. Exposure to PAH-containing substances increases the risk of cancer in humans. The carcinogenicity of PAHs is associated with the complexity of the molecule, i.e., increasing number of benzenoid rings, and with metabolic activation to reactive diol epoxide intermediates and their subsequent covalent binding to critical targets in DNA. B[a]P is the main indicator of carcinogenic PAHs. Fluoranthene is an important volatile PAH because it occurs at high concentrations in ambient air and because it is an experimental carcinogen in certain test systems. Thus, fluoranthene is suggested as a complementary indicator to B[a]P. The most carcinogenic PAH identified, dibenzo[a,l]pyrene, is also suggested as an indicator, although it occurs at very low concentrations. Quantitative cancer risk estimates of PAHs as air pollutants are very uncertain because of the lack of useful, good-quality data. According to the World Health Organization Air Quality Guidelines for Europe, the unit risk is 9×10^{-5} per ng/m³ of B[a]P as indicator of the total PAH content, namely, lifetime exposure to 0.1 ng/m³ would theoretically lead to one extra cancer case in 100,000 exposed individuals. This concentration of 0.1 ng/m³ of B[a]P is suggested as a health-based guideline. Because the carcinogenic potency of fluoranthene has been estimated to be approximately 20 times less than that of B[a]P, a tentative guideline value of 2 ng/m³ is suggested for fluoranthene. Other significant PAHs are phenanthrene, methylated phenanthrenes/anthracenes and pyrene (high air concentrations), and large-molecule PAHs such as dibenz[a,h]anthracene, benzo[b]fluoranthene, benzo[k]fluoranthene, and indeno[1,2,3-cd]pyrene (high carcinogenicity). Additional source-specific indicators are benzo[ghi]perylene for gasoline vehicles, retene for wood combustion, and dibenzothiophene and benzonaphthothiophene for sulfur-containing fuels.

Publication Types:

- Review
- PMID: 12060843 [PubMed - indexed for MEDLINE]

Section 14:

ETRMA



For the kind attention of:
Mr Lennart Johansson
President of UEFA
Route de Genève 46
Case postale
CH-1260 Nyon 2
Switzerland

Brussels, June 19 2006

Dear Mr Johansson,

RE: Your projected publication concerning the comparison of infill materials in synthetic pitches (attached).

First of all please allow me to introduce our association and its members on behalf of who I am writing to you. The European Tyre & Rubber Manufacturers associations (ETRMA) represents 4,100 European companies among which all the tyre manufacturers producing in Europe (Bridgestone Europe, Continental, Cooper-Tire, Goodyear-Dunlop, Marangoni, Michelin, Nokian, Pirelli, and Vredestein), employing 360,000 people with a turnover of the industry exceeding € 42 b.

In 1989, a dedicated Used Tyres group was set up to promote the environmentally and economically sound management (elimination) and use of end of life tyres in a wide array of applications. The European tyre industry is committed to assist in promoting environmentally and economically sound end of life management of its products. The industry continues to promote the development of appropriate markets of end of life tyres, provides technical and policy information and advocated a legislative and regulatory framework that contributes to the achievement of its goals.

In this respect, the news concerning the use of rubber granulates as infill material in synthetic sports surfaces attracted our attention. In addition, members have recently become aware of your draft publication (attached) describing the advantages and drawbacks of the different filling materials such as recycled black granulates..

Conscious of the importance of improving our technical and scientific knowledge and possible environmental effects of such application, compared to the traditional techniques, the major tyre I manufacturers through our French end of life tyre management company, Aliapur (in charge of the recovery of 85% of tyres sold in the French market, being 31,500,000 tyres corresponding to 283,000 tonnes) have initiated early 2005 a scientific study programme. This programme evaluates and compares the environmental impacts of synthetic fibres and the different infill materials such as recycled black granulate, EPDM (Ethyle-Propylene-Diene Rubber) granulates and TPE (thermoplastic elastomers) – all cited in your projected publication.

This programme also includes as a partner a leader in synthetic sport surfaces (FIELDTURFTARKETT) and the French Environmental Agency (ADEME) to guarantee complete objectivity. It evaluates pitches in typical usage conditions with experiments on an outdoor training pitch and mini-soccer fields. They are set up to allow the collection and analysis of water which passes through them and to evaluate the gas emissions released by the materials according to the criteria used for the construction materials.

These studies led by independent laboratories, began 9 months ago and are producing the first results (the programme finishes in 3 months). Jointly with its partners, industry will present all the results of the scientific analysis on the environmental impacts of EPDM and TPE granulates and of recycled black granulates from tyre recovery.

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previously BLIC

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Your projected publication prohibits in certain applications without any demonstrated scientific ground the use of recycled black granulates particularly for their non-environmental friendliness. However, with regard to the current knowledge about these products and the work in progress, such assertions are without apparent scientific basis and are difficult to accept.

Our Association and its corporate tyre members are concerned with scientifically unfounded marketing comments appearing regularly in the European media or in such reports, as the one we have been referring to in this letter (and which is attached). We propose therefore that UEFA stops any communication until the completion of the current field test programme carried out in France. We shall be pleased to share with you and your experts the findings before the end of this year.

In the meantime, should you have any further question, we shall be pleased to assist.

As a matter of information about the industry European activities on end of life tyre management, I am sending you by mail the Association's latest report on this matter.

Yours sincerely,

A handwritten signature in black ink, appearing to read 'F Cinaralp', is written on a light-colored rectangular background. A vertical line is positioned to the right of the signature.

Mrs F. Cinaralp
Secretary General

Section 15:

VACO

**Use of rubber granulate in playgrounds
forms no relevant risk to children or the
environment;
Prolonged daily skin contact with rubber tyres
does not pose any relevant health risk.**



PRESS RELEASE, 20 June 2006

RUBBER GRANULATE FROM RECYCLED CAR TYRES IS SAFE FOR PEOPLE AND THE ENVIRONMENT

Recent reports in the media have created uncertainty about the risks to health and the environment associated with the use of rubber granulate (tiles) on sports fields and playgrounds. However, new and existing studies conducted by various independent institutes show that rubber granulate used as infill material does meet the statutory requirements for health and the environment. This should dispel any doubts sportspeople and parents may have about health risks.

For years, tyres used all over the world have been recycled into rubber granulate and used in all kinds of products such as rubber playground tiles, in athletics tracks and as infill material for artificial turf fields and lawns. These applications help prevent unnecessary injuries.

In recent months, INTRON Certificatie B.V has carried out research into the risks to health and the environment associated with the use of rubber granulate in artificial turf sports fields. The research was commissioned by the builders of sports fields and DSM and set up under the supervision of a committee on which the VACO Association also had a seat. The research programme comprised both experimental studies of the chemical composition and leaching of rubber granulate, and literature studies of existing reports and articles on risks to health and the environment. The experimental research included an assessment of the leaching out of substances over a period of 100 years, in accordance with the guidelines of the Building Materials Decree.

The main conclusions of INTRON's research are:

- € The rubber granulate meets the Building Materials Decree requirements regarding chemical composition and the leaching out of substances. This assumes the layer thickness of 2 to 3 cm applied in practice. It should be noted, however, that the Building Materials Decree does not cover rubber granulate but only stony building materials.
- € The rubber granulate meets the standards set for heavy metals and the Toys Decree.
- € On the basis of the available literature, it can be concluded that no health risks are posed by breathing in or brief skin contact.

Although the VACO Association is satisfied with these conclusions, it believes that the INTRON research does not provide sufficient information on the possible risks of young children eating rubber, prolonged skin contact with rubber and the possible toxicological effects of substances leaching into the environment. As a result, the VACO Association commissioned additional literature research of scientifically substantiated toxicological studies on the subject. No studies showing that rubber granulate poses a risk to health and the environment were unearthed. However, two studies were found that concluded the following:

- € [the use of rubber granulate in playgrounds forms no relevant risk to children or the environment.](#) This study also looked at the dangers of eating rubber granulate, University of Alberta, 2003.
- € [prolonged daily skin contact with rubber tyres does not pose any relevant health risk,](#) Danish Technology Institute 2005, commissioned by the Danish Ministry of the Environment.
NB! It may take some time to download this file (8.09 MB)

On the basis of INTRON's research and the recent research information produced by the independent scientific studies conducted in Canada and Denmark, the VACO Association is convinced that the products made of recycled car tyres by its members in the Netherlands are safe for people and the environment.



The VACO Association would like to emphasise that the use of rubber granulate in sports fields and the use of rubber tiles on playgrounds make a significant contribution to the prevention of unnecessary injuries among sportspeople and children.

The Dutch government is also extremely positive about the recycling of tyres and the use of rubber granulate as infill for artificial turf. The Ministry of Housing, Spatial Planning and the Environment (VROM) would like to see at least 20 per cent of the car tyres that are collected recycled into high-quality granulate. Since last year, VROM has classified rubber granulate for artificial turf fields that meet the ISA-M37.a standard as a non-waste product. Use of rubber granulate in artificial turf sports fields and rubber tiles on playgrounds are high-quality applications that make a positive contribution to Dutch environmental policy.

Jointly responsible for the environment-friendly collection and recycling of used car tyres, the VACO Association, the Dutch industrial branch association for the tyre and wheel industry (www.vaco.nl) and the Tyre & the Environment Association, the association of manufacturers and importers of car tyres (www.bandenmilieu.nl), are delighted with these conclusions. To sum up, the use of rubber granulates and rubber tiles poses no threat to people or the environment and make a positive contribution to safety on sports fields and playgrounds. Both organisations believe that this new research really opens up the way for the use of rubber granulates as infill material on artificial turf fields. Recycling tyres and using them as a raw material spares the environment and ensures the responsible use of scarce raw materials. The use of rubber granulates is safe for the surroundings, sportspeople and spectators.

Note for the editors - not for publication

1. For more information, please contact Jeroen Jongeling, Sector Manager of the VACO Association, telephone +31 (0)71 568 69 70, email: vaco@kcleiden.nl.
2. The text of this press release is also available as a Word file. For a copy, please send an email to subp@kcleiden.nl.

Section 16 :

**Recycled Rubber Use
for Sports Surfaces
Problems & Research
to Delineate Risk**

Recycled Rubber Use for Sport Surfaces Problems and Research to Delineate Risk

**Prepared by Professor Nick Christofi,
Pollution Research Unit
Napier University, Merchiston Campus,
Edinburgh EH10 5DT**

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The Problems

The health hazards, to humans and the environment, associated with the use of rubber crumb materials in artificial surfaces for playgrounds and sporting arenas have been identified to include:

- Leaching and chemical pollution of soils and groundwaters
- Inhalation of volatile constituents
- Skin contact and ingestion
- Abrasion of surfaces and particulate release

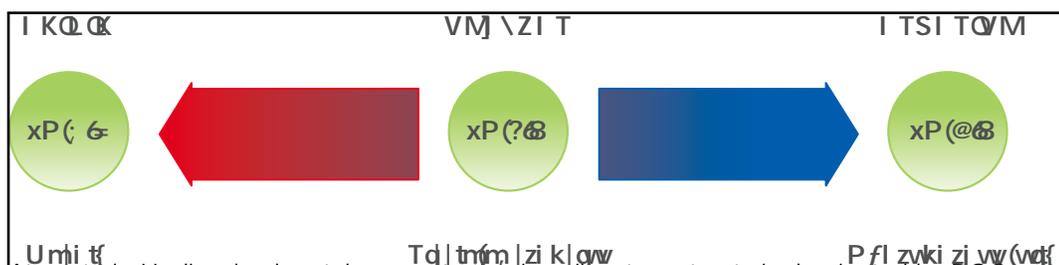
Leachate Problems?

Rainwater percolating through the porous artificial rubber turf can lead to leaching of additives and other rubber constituents. Currently little information on techniques used and extent of leaching in real Playground and Sport artificial surfaces is available. It has been determined that rubber tyres disposed to landfill can add chemicals to leachate arising from the tyres constituents. Tyres are used in various environments including harbours where they act as bumpers. Hartwell et al (1998) explained that toxic substances appear to be leached from tyre surfaces and not from within the tyre matrix, and, that the use of tyres in higher salinity environments appears to pose little direct toxicological risk to native organisms. Unknown toxic substances were found to be present in leachates for waters of different salinities but no assessment was made regarding persistence, fate, transport, or possible bioaccumulative effects.

Approved soil leachate/extraction tests in accordance with standard procedures need to be carried out. Such tests are given in international standard ISO 15175:2004¹. A number of leaching tests are available and include column leaching tests, lysimeter leaching tests, extraction or batch type tests and tank leaching tests for compacted granular materials. Important consideration for testing surfaces must be the examination of leaching from compacted turf and subsequent migration in the receiving soil environment. Soil physical chemical characteristics such as pH and ion exchange capacity can control speciation and binding and affect mobility of any released organic and inorganic chemicals. Biological activity can lead to the degradation of organic leachate reducing mobility that is ultimately controlled by water infiltration. The rate and extent of groundwater contamination will depend on the depth of the water table. The derived soil leachate test concentration would need to conform to water standards for the substance.

The leaching characteristics of tyre shred have been examined using a wide range of pH conditions. At neutral pH, iron and manganese levels increase as these metals are extracted from any exposed tyre reinforcing wire. These metals are generally present in soils, and the increases are generally not considered to be harmful to people or the environment. The rate of dissolution of wire increases under acidic conditions (pH<7), and zinc present within surface rubber can also be leached, but levels generally remain within acceptable parameters. Under alkaline conditions where pH>7 is encountered, organic compounds can be leached in trace quantities (Hammer & Gray, 2004). Fig. 1 shows the effect of pH on pollutant release.

Figure 1. Effect of pH on metal and organic release from rubber crumb.



At neutral pH, dissolved metal concentration in soil water extracts is dominated by DOC- metal complexes. At low pH, dissolved metal concentration in soil water extracts is dominated by free ionic forms (e.g. Cu²⁺, Zn²⁺, Pb²⁺) followed by

¹ ISO 15175:2004. Soil Quality- Characterization of soil related to groundwater pollution. British Standards Institution.

ion pairs (e.g. CuSO₄, ZnSO₄, PbSO₄). Results suggest that as soil pH decreases, the availability and mobility of metal ions increases due to chemical form of metal ions in soil solutions (Reddy et al, 1995). Clay soils tend to be well buffered with little leaching of metals. Any released organics may migrate but there would be biodegradation processes (see e.g. Kanaly & Harayama, 2000) that would limit the transport of the low concentrations likely to be released from sport surfaces.

A recent testing of heavy metal presence and leaching from grass yarns carried out by an independent German Institute for BONAGRASS Yarns has shown low leaching with a conclusion that the artificial material may be used anywhere without restriction including sensitive areas. There is also a suggestion that the yarns can be recycled, burned and dumped as normal waste (www.bonayarns.com).

A recent briefing² to FIFA by Dr Eric Harrison examines the potential cancer risk of PAHs (polycyclic aromatic hydrocarbons) in certain granulate infills. The Danish Environmental Protection Agency carried out tests to examine PAH and aromatic amine concentrations in playground tyres as well as leaching of these constituents to sand and artificial sweat in contact with tyre materials (Nilsson et al., 2005). Their summary was that there was an insignificant risk in the use of waste tyres in playgrounds. Softeners and extenders are used to increase the workability of the rubber prior to vulcanisation. These are mainly petroleum oils and coal tar substances that will contain polycyclic aromatic hydrocarbons (PAHs) of environmental concern as they are implicated in induction of cancers. Plasticisers including thiophenols, other thiol compounds, and disulphides can be used to reduce the viscosity of the rubber during preliminary processing. These compounds are generally recovered by solvent extraction but can be found in proprietary rubber compositions. Tyres contain carbon black (that has traces of organics including PAHs associated with it) as a pigment and a filler to improve the tensile strength and abrasion resistance of rubber tyres. Titanium dioxide and silicon are also used. Carbon black represents by far the largest additive mass in a rubber tyre.

In an 11-month study, tyres bathed in rainwater at pH 4.0 and water at pH 7.0 leached a number of organic compounds shown in Table 1. Reddy & Quinn (1997) also showed the release of various organic constituents from rubber crumb including benzothiazole, 2-hydroxybenzothiazole and 2-(4-morpholino) benzothiazole.

Table 1. Laboratory tests to examine the long-term leaching products of tyres in distilled and acid rain water (Baumann and Ismeier 1998).

Substance	Concentration [mg/L]
2-Mercaptobenzothiazol	< 0.5
Benzothiazole	15 – 1972
2-Methylbenzothiazol	< 2
2-Methylthiobenzothiazol	< 2
Aniline	5.9 – 294
Dicyclohexylamine	< 35 – 218
Cyclohexylamine	< 1 – 423

A number of chemicals are used on artificial surfaces to improve the quality of the playing surface including salts to lower freezing point of water, fabric softeners to avoid pitch stickiness and chemical antiseptic cleaners. These will leach into soils but additionally may affect those using the surfaces following contact.

Inhalation of Volatile Constituents?

Numerous chemicals are used in the manufacture of rubber and rubber products. A comprehensive list with role is given in Appendix 6. Many of these chemicals are toxic or poisonous and have been shown to pose health hazards for rubber workers. These hazards can result in either acute short-term effects or can become chronic long-term diseases. Acute effects are caused by single or short-term exposures to chemical hazards. Chronic effects on the other hand result from continuous exposure to chemicals at concentrations lower than those shown to elicit acute effects.

All products made with SBR rubber, including automotive tyres have a distinct odour. This odour eventually dissipates leaving no detectable smell. The odour is caused by the various volatile organic carbon compounds used in the manufacture of the rubber (see Table 1). There is a paucity of data for air and soil emissions of rubber additives. A reason proposed as to why tyres give off odours is the photo degradation of rubber. Electromagnetic radiation, particularly light

2 Harrison, E. (2006). FIFA Statement on the potential cancer risk of certain granulate in fills. Unpublished Note (personal communication).

in the UV region, reaching the rubber can cause polymer degradation and release of smaller volatile compounds. In the absence of light and when surface coatings protect the rubber, this does not happen. Photodegradation by light is unlikely to play a major role in chemical release (OECD, 2004). It is generally accepted that rubber surfaces become dissipated of volatiles and that abrasion may expose surfaces with concomitant release of small concentration of tyre organics that would be insignificant. In addition, the chemicals in rubber do not have a high vapour pressure and inhalation would be negligible. It has been considered that low level exposure to pollutants, including PAHs, can lead to cancers and that this is a concern for artificial surfaces (see Appendix 1). Studies do not bear this out (see e.g. Birkholz et al., 2003).

Artificial surfaces may become colonised by algae (some of which produce toxins) and fungi producing aerial fruiting structures with numerous spores that can be released and inhaled. Is there any evidence that these can cause problems to humans? Regular cleaning should control biofilm formation.

Skin Contact and Ingestion?

Contact with a number of rubber industry chemicals can lead to dermatitis. Skin is usually difficult to penetrate with chemicals other than solvents that can penetrate the protective fat layer of the skin and enter the blood. Water is not an effective extraction medium for rubber and the concentration of chemicals likely to be extracted and presented to skin would be low. Skin exposure and entry would represent a low hazard.

The routes by which chemicals enter the human body are inhalation, swallowing and skin absorption. Ingestion of crumb would also represent a low hazard as eating of loose crumb would be improbable as would release of sufficient chemicals from crumb within the human body.

A recent report by Anderson et al (2006) indicated that there is no specific published information concerning exposure to rubber constituents from the use of rubber crumb products in playgrounds. Generally, studies have not been carried out to evaluate the use of rubber products in actual sporting and playground environments.

Abrasion of Surfaces and Particulate Release?

Rubber abrasion will lead to the release of particles, dust and expose more surfaces that may increase leaching of rubber additives. Most studies have looked at abrasion of car tyres on roads and transport to various environments including soils. A number of additives have been shown to be released from tyre materials. Fauser et al (2002) monitored aerial concentrations of tyre and bitumen particles near and at distance from roads. Concentrations decreased with increasing distances from roads and human and soil uptake can pose a danger. This danger is expected to be far greater than any danger posed by release from artificial surfaces.

Abrasion has been shown to significantly add to the release of persistent breakdown products of rubber additives, e.g. benzothiazole and methylated benzothiazole. In other studies, mass flow calculations have shown that runoff zinc, cadmium, copper and lead (constituents of rubber) from roofs and streets account for 50-80% of the total mass flow in domestic sewage (Boller, 1997).

Williams et al. (1995) studied aerial particulate pollutants and showed that black respirable rubber fragments may contribute to lung diseases. It requires to be demonstrated whether respirable particles are produced during normal use of artificial sporting surfaces, considering the high abrasion energy needed to generate fine particles.

Research Needs

The perceived problems are shown in Fig 2.

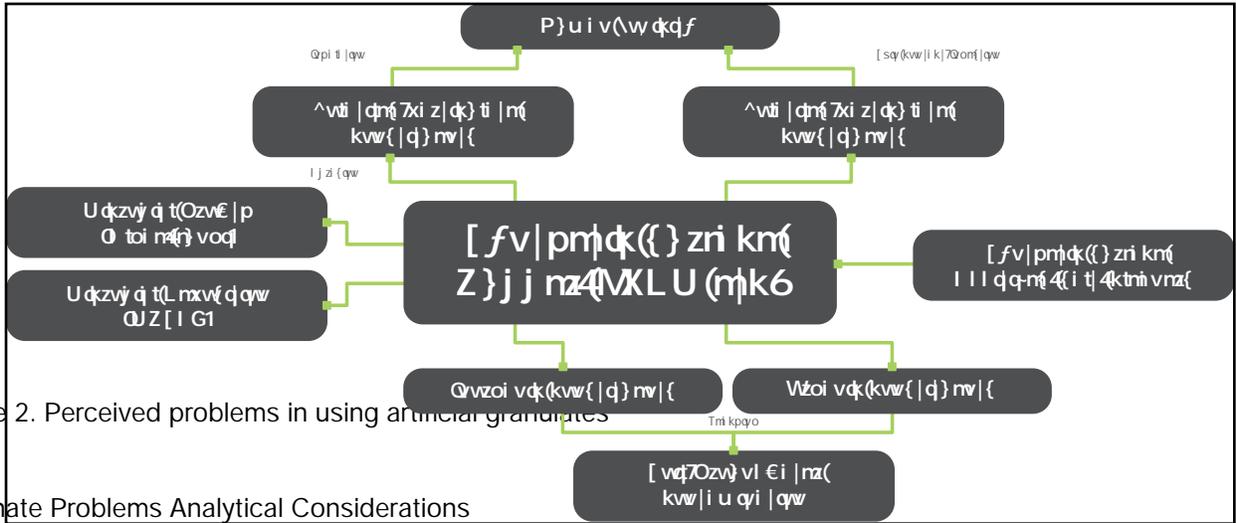


Figure 2. Perceived problems in using artificial granulates

Leachate Problems Analytical Considerations

• Leachate Tests:

Laboratory leaching tests can be carried out using predetermined sizes of crumbed tyres submerged into different solutions for periods of time after which leachate is analysed. This type of test can be used to indicate the types of contaminants released by crumbed tyre material. Information gleaned from laboratory leaching tests can then be used to design comprehensive field studies to evaluate environmental effects. Field studies using tyre material of various sizes embedded in soil with subsequent sampling of soils can be done. A recommendation would be to examine soils underneath playgrounds and sport fields where synthetic turf has been present for a number of years to examine for pollutants such as PAHs and heavy metals. Groundwaters in the vicinity can also be sampled downstream from fields and differences in chemical content compared with upstream levels. In addition, a survey should be carried out of cleaning agents used, frequency and analyses (chemical and toxicological) of major constituents in soils and groundwater samples.

Examine soils and groundwater at existing synthetic turf site/control sites

- Organic and Inorganic Analyses
 - Heavy metals including Zinc, Cadmium
 - PAHs

Leaching experiments using various granulates

- Organic and Inorganic Analyses
 - Heavy metals including Zinc, Cadmium
 - PAHs

Leaching experiments can be carried out by Professor Andrew Wheatley, School of Water & Environmental Engineering, Loughborough University.

Chemical analyses can be done by Professor Wheatley or by a NAMAS/UKAS Accredited Laboratory. With respect to the latter, ALcontrol Laboratories and the Eclipse Scientific Group are suggested.

Toxicity Tests:

Aqueous samples from crumb/tile leachate experiments and extracts from soil and groundwater can be used to carry out toxicity tests utilising a range of bioassays covering different trophic levels including microbial, algal, invertebrate and mammalian toxicity testing. The toxicity data together with actual concentrations monitored in real sites will delineate risk.

Toxicology experiments can be carried out by the Pollution Research Unit, Napier University under the direction of Professor Nick Christofi and Dr Teresa Fernandes.

Inhalation of Volatile Constituents Analytical Considerations

It is very difficult to carry out tests on the effects of any volatiles released as these tend to be chronic effects given that small concentrations are likely to be released from abrasion and UV or other chemical processes. It is not recommended that this be considered for this study. Also it is more likely that any effects would have been recorded as a result of tyre use on roads. As far as we are aware there are no such toxicity documented.

Skin Contact and Ingestion Analytical Considerations

Leachate analyses in concert with leachate toxicology will enable an assessment to be made of the effects of chemical constituents to human health. One aspect that is a potential problem is the perceived increases in MRSA (Methycillin-Resistant Staphylococcus aureus) infections with increased use of artificial turfs. It is recommended that a study be made of existing surfaces to determine the presence of human skin inhabitants including S. aureus. Random swab sampling can be done and the use of differential media to detect for specific organisms. A survey can also be made to determine biofilms of algae and fungi on surfaces.

Microbiological Testing can be carried out at the Pollution Research Unit, Napier University by Professor Nick Christofi.

Abrasion of Surfaces and Particulate Release Analytical Considerations

There is a need to test the quality of air above an artificial playing surface to determine any risk from inhalation of particulates arising from abrasion. It is recommended that cumulative air sampling be carried out during a sporting event and that toxicity tests be used to assess the risk. Worst-case scenarios can be done in controlled environment chambers where abrasion is carried out over periods of time with concomitant air sampling. This can be done at Napier University where the chamber is situated in collaboration with Sport Labs and their abrasion equipment. Aerial pollutants generated by the abrasion tests and trapped on filters can be used for mutagenicity and general toxicity using microbial biosensors, mammalian cell lines and macrophage assays.

Chemical Analyses:

Trapped constituents of the filters can be tested for organic and inorganic substances trapped. This will determine types and quantities released and can be linked to toxicology data.

Chemical analyses can be done by ALcontrol Laboratories and/or the Eclipse Scientific Group.

Toxicity Tests:

Trapped constituents of the filters can be extracted and used in toxicity tests where one carries out whole constituent testing that determined any additive, antagonistic and synergistic effects.

Mutagenesis (genotoxicity) and general toxicity testing can be carried out at Napier University under the direction of Professors Nick Christofi and Vicki Stone, and Dr Geraint Florida-James; Abrasion testing will be done in collaboration with Sport Labs, Livingston.

Frequently Asked Questions (FAQs) and Perceived Problems

Q. 1. Is cryogenically produced rubber crumb 'safer' than ambient SBR?

A. Cryogenically produced rubber contains particles with a smooth surface exhibiting different physical and chemical properties from mechanically ground rubber tyres. The smoother surfaces may reduce leaching of crumb chemicals but this needs to be determined.

Q. 2. Is EPDM 'safer' than SBR?

A. EPDM (ethylene propylene diene rubber) and SBR (Styrene Butadiene Rubber, a copolymer of polystyrene and polybutadiene) are thermosetting elastomers (See Appendix 2). The constituents used to produce these vulcanisates would have equal environmental concerns.

Q. 3. Is coated SBR safer than uncoated SBR?

A. This would depend on the stability (abrasion resistance) of the coating used and its formulation. Coating SBR would reduce rubber abrasion and photodegradation reducing the rubber odours.

Q. 4. What are the key components of tyres and are any of them hazardous / harmful?

A. The key components of rubber are shown in Tables 1 & 2 and a full listing with potential toxicity in Appendix 6. Many are hazardous but only in high concentrations. Rubber vulcanisates are specifically formulated to be stable and to resist wear, so it is unlikely that organic and inorganic constituents will migrate in large concentrations. Studies have shown insignificant environmental effects of leachates. A particular group of toxicants identified are the PAHs. Carbon black contains traces of PAHs some of which are known carcinogens. Some studies indicate that PAHs are strongly bound to carbon black presenting no hazard. Other studies, however, indicate that under certain conditions PAHs may be released and may present risk to humans.

Q. 5. Is EPDM technically 'better' than SBR?

Q. 6. What causes the smell of rubber surfaces and will it disappear?

A. Volatile organic compounds (VOC) used in rubber compounding formulations cause the smells. These would normally dissipate but abrasion may continue to release small concentrations into the air that continue to impart odour. Volatile degradation products of rubber may also contribute to the smell. The odours are characteristic of amines and sulphur-containing organic compounds (mercaptans) that have a very low odour threshold.

Q. 7. What is the difference between car and truck SBR and which is better / safer?

A. Car tyres are predominantly made using synthetic rubber (~47%) such a SBR whereas truck tyres consist mainly of natural rubber (~45% & ~11% SBR). Both tyres have similar organic and inorganic additives that may be considered hazardous (see Table 5).

Table 5. An example of a passenger car tyre composition. Truck tyres contain more natural rubber.

Compound constituent [phr] [wt-%]	Recipe Recipe	
Synthetic rubber butadiene (SBR)	80.28	43.63
Butadiene rubber (BR)	19.72	10.72
Fatty acid	1.97	1.07
Plasticiser	11.97	6.50
Waxes	1.69	0.92
Zinc oxide	3.10	1.68

Carbon black	60.56	32.91
Anti ageing agent	1.69	0.92
Accelerator	1.20	0.65
Sulphur	1.83	0.99
Total	184.01	99.99

[Phr]- parts per hundred

Q. 8. Since it is a recycled material, how can you guarantee that only truck tyres have been used and how can you guarantee the consistency between manufacturers tyres? (Usually asked in response following EPDM presentation where the 16-9 consistency / components can be guaranteed statement has been made).

Crumb with a guaranteed production from used truck tyres should be sourced from accredited suppliers. There may need to be accreditation of crumb manufacturers with certification by SAPCA. A tyre guarantee mark can be incorporated on sidewalls of tyres.

Q. 9. Is all EPDM the same, or is there a 16-9 best EPDM?

Q. 10. Are there any personal safety issues playing on rubber filled fields?

A. The European Seed Association has highlighted problems associated with the use of artificial turf made from recycled rubber in promoting the benefits of using natural grass. These, in addition to direct injury from physically participating in a sport played on artificial turf, include general health and safety concerns. These have been identified (ESA, 2006) as:

Increased incidence of MRSA (Methicillin-Resistant Staphylococcus aureus) bacterial infections. These may arise from turf burns and subsequent communal bathing. It could conceivably arise from MRSA and other bacteria deposited on synthetic surfaces from human sweat, blood, urine, sputum and vomit can be subsequently translocated.

Foot blisters due to higher turf temperatures of artificial pitches.

Toxicity problems from ingesting or licking rubber materials.

Odorous compounds generated from the playing surface.

Particulates (fines and ultrafines) released from surfaces following abrasion.

Fire hazard.

Q. 11. Are there any differences in the behaviour of EPDM and SBR when exposed to high temperature e.g. flares?

Q. 12. In life cycle 'costs' which is more environmentally friendly, SBR or EPDM?

Both are synthetic rubbers with a range of chemical additives that could be a health problem if released.

Q. 13. Where else are recycled tyres used?

A. Appendix 4 provides a comprehensive list of uses of waste tyre materials.

Q. 14. How can the infill, SBR or EPDM, be 'recycled' when the pitch reaches the end of its useful life?

Q. 15. How long have these fields been around and have any long-term studies on leaching been carried out? If so what are the findings?

Q. 16. Are there any toxicity problems associated from ingesting or licking rubber turf materials?

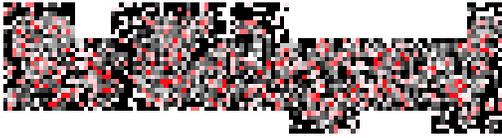
Work carried out by the Danish Environmental Protection Agency suggests that there is an insignificant risk from licking or ingesting rubber granulates, as the release of substances such as PAHs to body surfaces outside or inside the body is very small and unlikely to cause toxic effects.

Q17. Is there any likelihood of contracting staphylococcal infections from playgrounds and sport surfaces made from recycled tyres?

Staphylococcus aureus can be found on the skin, hair and mucous membranes and very high concentrations are often found in wounds, sores or septic spots. These bacteria can be deposited onto surfaces and these can be transferred to people. This situation is not different to direct contact between people and transfer that is more likely. Survival of bacteria associated with humans on the turf surfaces is not known but SAPCA is testing this possibility.

Section 17:

Dutch Media Reversal



Serious blunder with artificial turf

“Scattered rubber granules safe for sports after all”

by Jouke Schaafsma

ARNHEM, Friday – Poisonous nitrosamine vapours floating above artificial turf pitches have probably never existed. According to the State Institute for Public Health (RIVM), artificial turf pitches sprinkled with rubber granules are in fact not damaging for health, as had been previously assumed.

Since RPS Advies came across carcinogenic nitrosamines in the air above artificial turf pitches in its assignment for the Hulpverlening Gelderland-Midden community health organisation, dozens of local authorities have banned use of the granules. Some of them have even gone so far as to spend tens of thousands of euro ordering replacement products.

Working on behalf of Arnhem council, the RIVM has conducted a larger-scale follow-up investigation. In the report published yesterday, it states that the initial examination of the problem was unreliable. The follow-up investigation, conducted by a different laboratory, indicates that there are no nitrosamines in the air.

The RIVM has also had the RPS Advies research bureau, which conducted the first tests, check the air once again. But the RIVM also filled a test vial that was clean and contained no nitrosamines at all. However, RPS Advies did come across nitrosamines in the air.

“There was an error in the analysis,” states a spokesman from the Gelderland-Midden health department. “The method of examination used in the first instance has now been shown to be wrong. There is no problem at all with playing sport on artificial turf pitches.” After the first examination, the department had stated that there was a risk.

RPS Advies is very unhappy with the RIVM's no-holds-barred conclusions and believes that it is unjustifiably being made to carry the can. “The foreign laboratory that we use still stands behind its conclusions,” says spokesman Jan Willem Peters.

A further investigation is currently underway into the presence of heavy metals in rubber granules.

Nitrosamines in artificial football pitches pose no risk to health

30th November 2006

This is a joint press release from the State Institute for Public Health (RIVM) and the Hulpverlening Gelderland Midden community health organisation (HGM).

No nitrosamines have been found in various samples of air taken above artificial turf pitches that have been sprinkled with rubber grains. As a result, playing football on these pitches involves no health risk from exposure to nitrosamines. These are the findings of additional tests that Hulpverlening Gelderland Midden (HGM) has had carried out by the RIVM. As background to the issue, these substances were detected earlier this year in Arnhem above an artificial turf pitch. Both the RIVM and HGM doubt these earlier findings.

In this additional investigation, various artificial turf pitches in Arnhem were tested. To obtain as accurate a result as possible, the fresh analyses were not conducted by the RIVM alone. In this case, two laboratories analysed air samples independent to the Institute itself: the lab brought in this summer by HGM and a German laboratory with a great deal of experience in analysing nitrosamines. Neither the RIVM nor the German lab found any nitrosamines in the air samples. The other laboratory did, however, but that lab also found nitrosamines in clean control samples that contained no nitrosamines. It is for these reasons that both the RIVM and HGM have doubts about these and the earlier analysis results from this particular laboratory.

According to the RIVM, there is no health risk caused by exposure to nitrosamines while playing sport on artificial turf pitches that have been sprinkled with rubber granules. The reason for the follow-up investigation was the laboratory report of tests conducted in August 2006 by HGM on behalf of Arnhem council.

The RIVM had already concluded that based on published studies, exposure to carcinogenic plasticisers and PAKs did not constitute a danger for health. It seems that the quantity of PAKs, volatile aromatic hydrocarbons and heavy metals (including zinc) pose no health risk for people playing sport. However, the same research indicated that nitrosamines occurred in raised concentrations in the air above the pitch. Because the testing for nitrosamines had been only limited and Arnhem wanted to exclude any risk, HGM advised the city council to conduct additional research. HGM requested the RIVM to carry out these additional tests.

The research

Working in conjunction with HGM, the RIVM took readings in the air of four artificial turf pitches in Arnhem, including the sports field at Sportpark Rijkerswoerd. This is where the earlier research had been conducted. Readings were also taken at three other artificial turf football pitches, including the Johan Cruyff pitch, which has not been sprinkled with granules made from car tyres, but instead is treated with Thiolon® Infill Pro. These granules are manufactured specifically as rubber to be sprinkled on artificial turf pitches, rather than being produced from ground up tyres. The other pitches have rubber granules produced from tyres of varying ages.

A number of different readings were taken for each artificial pitch at various heights above the ground. The air samples were then tested not only by the RIVM laboratory, but also by the lab used by HGM for the initial testing, as well as by the German laboratory mentioned earlier. Each lab also analysed samples in which there were no nitrosamines present, the so-called 'clean' control samples.

These tests were solely about the health risks runs by exposure to nitrosamines and did not extend to the health risks of other substances or any environmental problems that the granules might pose. Based on additional information about the product, provided by the manufacturers and suppliers of the granules, a more complete picture of the possible risks was produced.

Section 18:

Netherlands Changes Position

For internal use

Key outcomes from the meeting with the Governing commission of the Intron project on environmental-and health aspects from the use of rubber granulate as in-fill material for artificial grass fields at Intron dd. 9 of March 2007.

The attendees were informed on the content of the discussions at the expert meeting on 7 of March. These were related to SBR as well as EPDM, TPE and TPV and the meeting will get a follow-up meeting at the request of VROM. VROM will take a decision in due time on what will/ will not be acceptable, what are the limit values/ norms to be applied); on the basis of this meeting, the dialogue with the sectors and their internal reflections. The members of the coordination/ governing committee will be kept informed on the progress made within the expert meeting.

Three departments of VROM are dealing with the SBR-problem:

- Soil and Water
- Substances and standards
- Waste

Martijn Beekman (VROM) stated that it is important that the sector is taking its own responsibility given the withdrawing government. This is valid for SBR as well as EPDM, TPE and TPV. This is amongst other the reason why VROM will therefore for the time being not take a position in respect to SBR. On basis for the following reasons:

- The amount of leaching and the risks of pollutions is too vague (soil, groundwater and surface water).
- On the international level virtually no countries an negative advice on the use or ban has been imposed from the government.
- The involved organization may also take measures to reduce the risks on pollution (e.g. the separate collection of drainage water, in order to avoid that this is automatically released to the surface water).

VROM suggest that every one should take their own decisions on basis of the report. The competent authority (represented by Mr Beekman) has the freedom and also the responsibility to make a correct assessment. Remarking some form of reservation in respect to the recent installation of the minister (Mrs Kramer), who didn't have the opportunity to look at the content of the report and therefore might respond differently at later stage. He will make a note for the minister. VROM is positive towards the proposal of the tyre industry to perform additional research to assess the real risks from the leaching of Zinc. This project will be performed in close dialogue with RIVM and VROM. VROM would like to see the results from this project in the coming months. Hereby he is thinking about measurements from draining water (FC Volendam has performed similar measurements with positive results) VROM wants to create more certainty on short term. The tyre industry has indicated that good research on the long-term leaching behavior of SBR in practical circumstances will require more time. In this project the positive results from projects in Switzerland and France will be taken into consideration. The research should address the complete build-up of the artificial grass fields and not only the SBR top-layer. Taking this into consideration this would require more uniformity in the build up of artificial grass fields. Ulbert Hofstra (Intron) will make an overview of the issues that can be achieved on short term and what would require more time.

Martijn and Rein Eikelboom (VROM) would also like to see further information on the environmental and health aspects of EPDM, TPE and TPV. The tyre sector has the opinion that the information on these materials should be comparable to the Intron report on SBR. Alberto Dozeman (DSM) informed that he can make available this information on a confidential basis (composition is confidential). Composition and leaching are known.

The "waterschappen" impose different demands to surfacewater. At this moment there is hardly an limitation on the use of zinc gutters. The leaching from these and the consequences for the surface water are compared to the leaching of zinc from SBR. VROM will in the near future think on the setting of leaching limits for zinc from Rubber granulates, because the current limits are not applicable and subsequently the Legislation and regulations are hardly applicable.

VROM has the opinion that every one who has the intention to install an artificial grass field has to apply for a permit at the "waterschappen" given the potential consequences on the leaching of Zinc. The "waterschap" will determine if a permit is granted (in theory these would already be required for houses with zinc gutters, However for administrative purposes this is not applied). VROM is taking into consideration that the "waterschappen" might require permits for the construction of artificial grass fields to a greater extent due to the content of the Intron report.

Alberto Dozeman (DSM) proposed to establish a shadow group (commission) similar composition to the current group (commission) for establishing a standards for in-fill materials to be applied on artificial grass fields. According to observation such activities have already been started at the European Level in (CEN/TC 217). Alberto stated that the composition of this commissions (many companies, no governments) leads to a wrong standard.

The tyre industry pleads that the research should be performed on the European level, given the fact that there also is a need for further information in other countries, while a lot of information from work performed in other countries is already available. Additionally, the tyre industry would like to compare the setting of standards in the Netherlands with those from other countries. In follow-up Rein Eikelboom (VROM) indicated that these are most likely not determined per Country, but often fall under the responsibility of the regional authorities (Local permits), As it is the case in the Netherlands where the local "waterschappen" are responsible for the surfacewater.

The constructors of the fields have an interest in the proposed follow-up research project by the tyre industry. The tyre industry have committed to take this up in their internal discussions.

The constructors create the impressions that by using other materials than SBR they are working better from a health and environmentally technical point of view. The Workgroup Construction products wishes to warn everybody (Make them aware) at the application of SBR. The tyre sector explicitly pointed out that specifically for SBR a lot of information is available and only very limited information on the other materials. Therefore it remains an open question whether one is better off when using the alternatives for SBR (e.g. Chrome Colored EPDM). Nevertheless it appears that Arcadis has already made its choice for TPE. Who on the basis of the results indicated in the Intron report, would rather like to see a ban on the use of SBR as they see it as their responsibility (duty of care). Grontmij is giving their customers the choice, which they have to take themselves on the basis of the available information.

The attendees have the opinion that the report will raise many questions in respect to the leaching of Zinc. However without the results of the proposed follow-up project, only less concrete information can be made available.

The version of the Intron report (Already circulated in digital format) d.d. 9 February 2007 is to be considered as final. Joeke de Jong will inquire if UEFA (Mr. Timmer) is willing to translate the report into English. The resume has already been translated by Intron (Already circulated in digital format). The Intron report and the English summary will be downloadable from the Intron website as soon as the embargo expires.

Henk Damen and Herman Poos will draft a draft press release on short term. The members of the Shadow group will be able to give their point of view on this draft until Monday 12 March 2007, 12h00. The press release will be spread by Intron. The Embargo on the content of the report will expire on Tuesday, 12h00. The two Gentlemen will also make available to everybody a Q&A

Alberto Dozeman (DSM) Has serious objection that the press release would mention the foreseen follow-up project. As he doesn't consider it useful to perform further research and that he is not involved in the research. It was determined that reference will be made towards the recommendations made in this report.

Leiden, 10 March 2007.

PRESS RELEASE (Concept)

To: Redaction
From: Intron, on behalf of the advisory commission of artificial grass fields
Date: Tuesday 13 March 2007
Concern: Artificial grass fields, filled with rubber particles

Independent research shows:
"No risk for the health playing on artificial grass fields"

There is no risk for the health playing on artificial grass fields that are filled with rubber particles. A thorough investigation showed it. Several substances have thereby been examined for suppliers and producers of artificial grass fields, KNVB and combined Netherlands Olympic Committee and Dutch Sports Federation NOC*NSF.

The environment aspects have also been examined. It appears that 3 up to 20 years after construction of the fields, the standard of the building material decision for the leaching of zinc is exceeded. Intron, which have conducted the investigation, recommend conducting a deepening research project on the impact on the environment of leaching of zinc after erosion of the used material.

The advisory commission of artificial grass fields moreover pleads for normative guideline at the ministry of VROM concerning the way in which those overshootings must be measured.

Representatives of the Ministries of VROM and Health, Welfare and Sport, the association Dutch municipalities, ISA sport and the player trade union VVCS also participated in the advisory commission beside the constituents. The research took place last year.

The research coordinated by Intron makes an important contribution to the discussions concerning the impact of artificial grass fields, both inland country and abroad. Numerous European countries have been already informed of the outcomes and the implications of the research.

In the Netherlands there is meanwhile 300 wide artificial grass fields lying in which ground rubber originating from tyres is processed.

The sport organisation combined Netherlands Olympic Committee and Dutch Sports Federation NOC*NSF and the football association KNVB have with approval taken knowledge of the outcomes. Both the constituents and the players players worried about de possible health risks.

Sports federations attach large value to the fact that it has become clear that no health risk has been linked to playing on this kind of fields.

Full report to be downloaded from www.intron.nl

Not for publication

For more information you can contact Herman Poos, who coordinate press contact within the commission. He is available via at 06 22907374 and hpo@syntens.nl

Section 19:

Environmental Study Report

**ENVIRONMENTAL AND HEALTH EVALUATION OF THE USE OF ELASTOMER
GRANULATES (VIRGIN AND FROM USED TYRES) AS FILLING IN THIRD-GENERATION
ARTIFICIAL TURF**

Background

The production of artificial turf sports surfaces is a market in the throes of expansion. The company FIELDTURF TARKETT, a world leader in third-generation¹ artificial turf for the practice of football and rugby, installs more than 650 large sports pitches per year worldwide (approximately a hundred in France in 2006).

As part of the construction of such sporting surfaces (the earliest production on a global scale dates from 1995), elastic granulates and absorbents have been used as filling materials with the artificial turf fibres. Some of these granulates come from the granulation of used tyres (in France, recycled PUNR²: collected and sorted within the framework of the French Decree no.2002-1563 of 24 December 2002 concerning the elimination of used tyres), while other are manufactured specifically for this purpose (EPDM³ or ETP⁴), and to a lesser extent some result from the recycling of EPDM (washing machine joints, car doors, etc....).

Since the development of its first third-generation artificial turf applications, the company FIELDTURF TARKETT has chosen to favour the use of granulates from recycled materials for their filling needs, thereby permitting the reuse of roughly 11,000 tons of used tyre granulates in France on large sports pitches in 2006.

These third-generation artificial turf playing surfaces present numerous advantages for sports clubs and local authorities. The length of time for which they can be used is just about unlimited, with stable long-term performance levels, and the pitch requires limited maintenance in comparison with natural turf. The qualities of the systems developed by FieldTurf Tarkett are acknowledged by FIFA⁵, UEFA⁶ and national federations. FIFA and UEFA have permitted competition matches to be played on this type of surface since 1st February 2004.

In recent years and during 2006 in particular, press articles, sometimes relayed by certain sports federations, have, due to the presence of certain composites classed as dangerous in the initial manufacture of a tyre, called into question the harmlessness vis-à-vis human health of the use of recycled tyre granulates compared with virgin granulates. Several scientific studies have thus been conducted from an environmental and health perspective in several European countries with the aim of characterising the emissions of pollutants via gaseous and/or aqueous means.

Mindful of the importance of making sure of these aspects and in order to possess objective elements in the face of this type of publication, the main tyre manufacturers through the intermediary of the company jointly founded by them, ALIAPUR⁷, in partnership with Fieldturf Tarkett and the ADEME, have undertaken starting in 2005 a programme of scientific study evaluating the environmental and health impact of the different material used as filling in artificial turf. These studies have been entrusted to the French *Groupement d'Intérêt Scientifique*, EEDEMS, which brings together the skills of the leading public and private bodies in these fields, most notably in the case of construction materials and products.

¹ Third-generation artificial turf appeared on the world market in 1995. Equipped with longer fibres (on average 60 mm), they are particularly characterised by a filling of sand and elastomer granulates of different types. The sporting performance of these surfaces rivals that of regularly maintained natural turf.

² Non-reusable used tyres

³ Ethylene Propylene Diene Monomer

⁴ Thermoplastic Elastomer (TPE)

⁵ Fédération Internationale de Football Association

⁶ Union of European Football Associations

⁷ Company in charge of the recycling of 85% of the tyres on the French market in 2005; that is 31,550,000 tyres corresponding to 283,000 tons

This technical report contains the key facts from the studies and the general conclusions of the different evaluations. The document plan is as follows:

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I. Interest and objectives of studies

The interest of the studies lies in the research and evaluation of possible environmental and health effects linked, on the one hand, to the transfer of meteoric water into the natural environment as a result of its percolation through the components of the sports surface and, on the other, to the gaseous emissions likely to be generated by the substances used in the composition of the sports surface.

Through the procedure adopted, three analytical approaches were carried out:

1. the chemical analysis for the determination of the concentrations of potentially polluting elements and substances present in the percolates collected after their transfer through the different constituent materials of the sporting surface,
2. the measurement of the ecotoxicity of the percolates collected after their transfer through the different constituent materials of the sporting surface,
3. the analysis of the volatile organic compounds (VOC) and formaldehydes emitted and their respective concentrations in an “indoor” sports surface usage scenario.

The concentration values obtained from the physicochemical analysis of the percolates was then compared with reference guide values (decree, acceptability values, etc...). Those obtained by analysis of the VOC and formaldehydes emitted were used to conduct a Health Risk Evaluation study (HRE).

The experiments conducted, in this case the orchestrated monitoring of a football pitch and small-scale pilot studies on an experimental platform, correspond to the usage conditions of the pitches and to the development image of standards concerning other applications⁸.

Eventually, the objectives of this study consist of:

1. obtaining reliable and precise information on the environmental and health impact of these applications,
2. providing responses to the main questions raised by the professionals, the sports federations, the institutions and the local authorities concerning certain elements and substances classed as representing a risk,
3. offering, in terms of the environmental and health effects, elements of comparison relative to the different types of granulates used as filling in artificial turf,
4. obtaining elements permitting the definition of standardised experimental protocols tailored to real usage conditions.

II. Evaluation of environmental impact on water

II.1. - The materials tested

The materials tested correspond to 3rd-generation artificial fibre turf from the FIELDTURF TARKETT range, combined with filling granulates of 3 different types:

- § granulates from used tyres from the French market (PUNR),
- § virgin EPDM granulates,
- § ETP granulates.

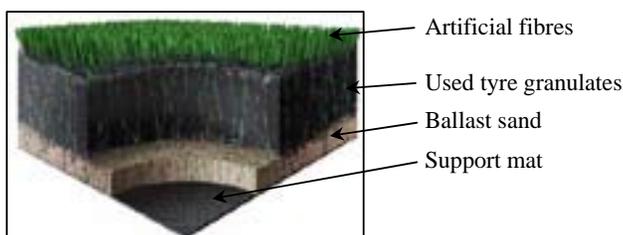


Figure 1: Vertical cross-section of a 3rd-generation sports surface (FIELDTURF TARKETT document).

⁸ For example, the European standard on leaching tests EN 12-920 – Methodology for the determination of the leaching behaviour of a waste under specified conditions

The materials and products such as the ballast sand, the artificial assembly band and the polyurethane glue, used in the installation of a full-size sports pitch, have also been taken into account in the set-up of the experiments. Figure 1 shows the arrangement of the different constituent elements of the artificial turf sports surface.

The volumes of materials implemented per square metre in the different experiments presented below are 17.5 kg for the sand forming the ballast layer and 15 kg for each type of granulate considered.

II.2. - Two complementary approaches necessary for development of analytical protocols

In the aim of developing at the end of this study analytical protocols that correspond with the usage conditions permitting a characterisation of the environmental and health effects of artificial turf sports surfaces, two complementary analytical approaches were conducted in parallel.

The first approach, conducted on the EEDEMS experimental platform, consist of a controlled experiment in pilot scenario (on an intermediate scale between the laboratory and the true size) designed to compare the behaviour, from the point of view of the environmental and health impact, of 3 types of sports surfaces produced from 3 distinct types of granulate. A single type of artificial turf, with no granulates added, is used as control pilot.

The second approach consists of an experiment conducted *in situ* on a football pitch. The pitch, measured by means of a lysimetric box⁹ placed beneath the artificial turf, contains used tyre granulates. This approach is carried out with the aim of providing complementary information as to the behaviour of the materials in the natural environment (subject to weather vagaries) and guaranteeing the representativity of the experiments conducted in pilot scenarios.

II.3. - Methodologies deployed

II.3.1. - Experiment *in situ*

An *in situ* device (Figure 2) was put in place during the construction of a training pitch in the Lyon region (69-France), to the rear of a goal area and on the periphery of the pitch (Figure 3).

This device consists of a lysimetric system made from a stainless steel sheet with a surface area of 2 m² and 10 cm in height covered by grating, buried in the support surface and laid out beneath the artificial turf in such a way as to collect the rain water that percolates through it (Figure 2).

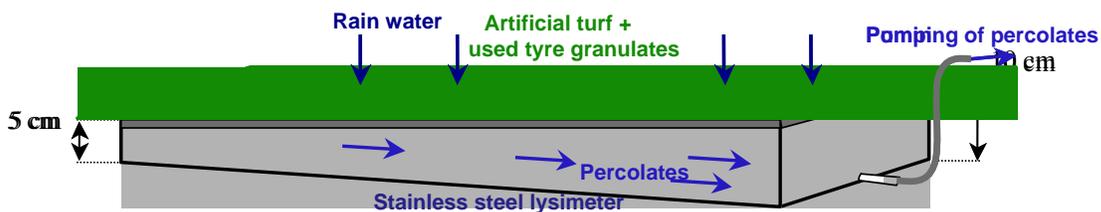


Figure 2: Diagram of the lysimetric system put in place on the football pitch.

⁹ The simple lysimeter is generally presented as a cylinder or a tank, made of metal, concrete or plastic, with watertight sides and a base that allows the water to percolate so that it can be collected while measuring the flow rate and different parameters. It can be placed *in situ* (on the pitch to be studied) or *ex situ* (in the laboratory).

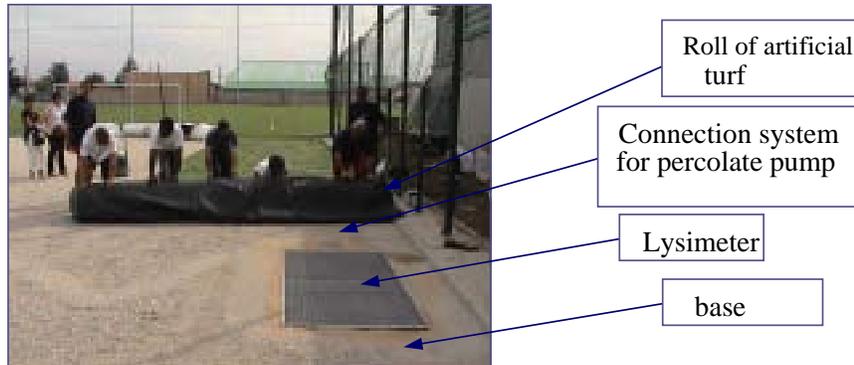


Figure 3: Installation of a roll of artificial fibre turf to cover the lysimetric system.

After full installation of the artificial turf and the filling material (sand and used tyre granulates), the lysimeter is scarcely detectable beneath the playing surface (Figure 4).

Figure 4: Manual filling of the artificial turf situated over the lysimeter with used tyre granulates.

The recovery of the water takes place via a pipe, fixed to a connection orifice located on the base of the lysimeter, which crosses the artificial turf and is then connected to a pump. To take a sample, the pipe is pulled outwards and then after recovery of the water, it is sealed by a cap and pushed back under the turf until the cap is concealed within the granulates (Figure 5).

Figure 5: System for the recovery of the percolates collected in the lysimeter situated under the artificial turf by means of a pipe crossing the artificial turf and connected to a sampling pump.



The monitoring period is **11 months**.

II.3.2. - Experimentation in pilot scenarios

The experimental pilots prepared are made up of rectangular aluminium tanks 2.5 m in length and 1 m in width. The base and sides are made watertight by means of a geomembrane. The tanks are raised to facilitate the collection of the percolates and their base displays a slight inclination towards a low point where the orifice for the emptying and collection of the percolates is located (Figure 6). The supporting floor of the artificial turf is formed by a bed of sand a few centimetres thick which serves as a drain for the percolates, in accordance with what occurs on outdoor pitches.

Environmental and health assesment of the use of elastomer granulates (virgin and from used tyres) as infill in third-generation artificial turf

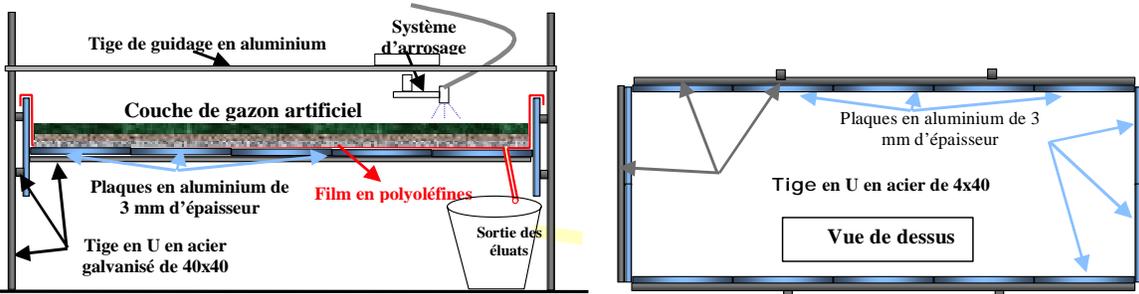


Figure 6 : Cross-section and overhead views of the pilot set-up plan on the EEDEMS experimental platform

The artificial turf mini-pitch is made with 2 rolls of green-coloured fibre separated by a roll of white-coloured fibre (pitch marking lines), all glued with polyurethane glue on the joining strip reserved for this effect. All of the materials correspond to those used on the football field (fibres, granulates of various types, glue) and were supplied to us by FIELDTURF TARKETT.

The implementation of the watering system designed to reproduce the rainfall level consists of a double rack containing 8 dispersion nozzles. The watering rack supplied with drinking water moves back and forth every hour, with 4 of the nozzles watering while going and the other 4 watering while returning, the aim of course being to spread the watering as well as possible. The cycle times and the injection durations are managed by a programmable logic controller. The quantity of water over the entire duration of the experiment has been set in relation to the annual average rainfall levels in the Lyon region, which is 800 mm per year (e.g. Paris: 641 mm; Vienna: 684 mm, Brussels: 833 mm, Budapest: 596 mm, Rome: 828 mm, London: 599 mm, Berlin: 583 mm¹⁰).

Four pilots (with ETP granulates, virgin EPDM granulates and granulates from PUNR and without filling materials) have been carried out (Figure 7) in a configuration comparable with that encountered on the experimental football pitch site.

As for the football stadium, the analytical monitoring period is **11 months**.

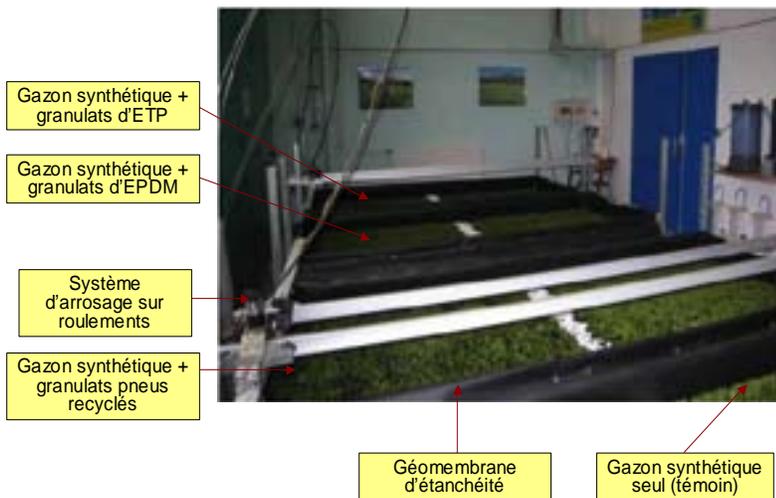


Figure 7: View of the 4 experimental pilots set up on the EEDEMS platform

II.4. - Analytical approaches for evaluation of environmental impact

II.4.1. - Sampling methods

On the four pilots, the percolates are collected each week, stabilised and stored in a cold room. The solutions analysed are reconstituted *pro rata* with the weekly volumes collected according to the volume necessary for the analyses and the period concerned. The analytical schedule is as follows: 7 solutions analysed after 15 days, 1, 2, 3, 6, 9 and 11 months of watering.

¹⁰ <http://www.meteo.fr/temps/monde/climats/3-2.htm>

On the football pitch, the same number of samples was taken over the period of 11 months but, due to the weather conditions, the analytical schedule was established so as to benefit from a representative volume of periods including the rainy episodes of greater intensity between October 2005 and October 2006.

II.4.2. - Types of analyses carried out and reference systems

The evaluation of the environmental impact of the quality of percolation water is arrived at through physicochemical and ecotoxicological analyses.

The elements and chemical substances researched are those entering into the composition of the filling materials, and more particularly those from used tyres. The study has been given this orientation with regard to the debate seen in recent years, and could equally have been aimed at substances of risk entering into the composition of other types of granulates. The exhaustive list comprises 42 physicochemical parameters: total cyanides, phenol index, total hydrocarbons (HCT), 16 polycyclical aromatic hydrocarbons (PAH), total organic carbon (TOC), Al, As, Ba, Cd, Co, Cr, Cu, Hg, Mo, Ni, Pb, Sb, Se, Sn, Zn, fluorides, nitrates, ammonium, chlorides and sulphates, pH and conductivity.

In order to evaluate possible enrichments of the percolates, the rainwater and supply network drinking water of the pilots was also characterised from a physicochemical perspective.

The evaluation of the impact was established by comparing the concentrations obtained in the percolates to the different French and European guide values currently in force (ICPE¹¹ discharge standards, acceptability criteria for Discharges of Inert Waste¹², standards concerning the quality of water destined for human consumption¹³). These 3 reference systems were chosen because the percolates' outlets are the natural environment via the infiltrations into the ground and the discharges into the environment via the urban networks. They were also chosen to obtain a minimum of at least one reference guide value for each of the physicochemical parameters. We should specify that the choice of Decree no. 2001-1220 of 20 December 2001 is nevertheless penalising for our study insofar as the percolates would be regarded as a reserve of drinkable water, without taking into account the phenomena of natural decrease in pollutants in the ground or dilution in the water (used and rain) collection networks.

The ecotoxicological characterisation of the percolates is arrived at by means of a standardised test to determine the acute toxicity (*Daphnia magna*¹⁴ mobility inhibition test) and a standardised chronic toxicity evaluation test (soft water algae growth inhibition test with *Pseudokirchneriella subcapitata*¹⁵).

The ecotoxicological tests are vital complements to the physicochemical analyses and their interpretation. By putting living beings in contact, either with the materials tested or with water in contact with the materials (leachates, percolates, etc.) and observing the effects produced, it becomes possible to give a reasoned opinion on the potential impact of the substance on the environment. Indeed, the ecotoxicological evaluation permits the highlighting of any effects caused by elements or substances not looked for in the chemical analyses, or in the state of traces at concentrations below the detection thresholds but able to display effects by synergy (greater than mere cumulative effects).

A contrario, these standardised tests are means of assessing the conditions under which no ecotoxic risk is run, in both the short and the longer term.

¹¹ Ruling on ICPE Discharges (Classified Installations for the Protection of the Environment) of 02/02/98 (art. 32)

¹² Decision of the council of 19 December 2002 establishing the criteria and procedures for admission of waste in discharges, in accordance with article 16 and appendix II of Directive 1999/31/CE

¹³ Decree no. 2001-1220 of 20 December 2001 and Appendix 13-1 of the Public Health Code (guide values and imperative values for the classification of surface water destined for the production of alimentation water).

¹⁴ Normative reference: NF EN ISO 6341, May 1996 (T90-301)

¹⁵ Normative reference : NF EN ISO 28692, May 1993

II.5. - Results and comments

II.5.1. - Results on the volumes collected

During the course of 11 months of experimentation, the average volume of percolates collected on each of the 4 experimental pilots was approximately 580 litres of water per m². Since the volume of water for each of the 4 pilots is of the order of 800 l/m²/15kg of granulates, it is proven that approximately 27 to 30% of this volume evaporates naturally in the atmosphere.

On the football pitch, the volumes of percolates collected during the experiment period were low in comparison with the local rainfall level data. For example, the total volume collected in the lysimeter was 86 litres of precipitation per m², while the total precipitation recorded in 2006 by the weather station located nearby was 750 mm or 750 litres of water per m². During the course of the 11 months of experimentation *in situ*, taking into account an evaporation rate equivalent to that of the 4 pilots, the volume of rain water which percolated through 15 kg of used tyre granulates is estimated at between 525 and 550 litres of water per m².

The total volume of percolates collected *in situ* therefore only represents approximately 12% of the volume of the precipitations. This finding can be explained by:

- The evaporation into the atmosphere of a part of the rainwater during rainy episodes of low intensity, the hydraulic charge being too low to permit infiltration;
- The preferential flow of water towards the peripheral outlets due to the calculated number of holes in the backing and the inclines of 1% of the supporting base, parameters ensuring good drainage of the pitch.

On the basis of these results, it is possible to estimate the volumes of percolates, on the one hand infiltrated in the ground beneath a large-size artificial turf pitch and, on the other, directed towards the peripheral drainage system. The estimation shows that for a surface area of 8,000 m², the volume of percolates which infiltrates into the supporting ground proves to be inferior to 2 m³ per day and the volume of percolates directed towards the peripheral drainage system is inferior to 11 m³ per day (cf. Table 1).

		Flow in m ³ /m ² /year				
		Precipitations or watering (1)	Evaporation (2)	Percolates passing through artificial turf (3) = (1)-(2)	Percolates directed to drainage system (4)	Percolates infiltrated in supporting ground (5)=(3)-(4)
Results of experiments for 1 m ²	Pilots orchestrated	0,800	0,225	0,575	0	0,575
	Lysimeter in-situ	0,750	0,225	0,525	0,050	0,085
Estimations for a stadium of 8 000 m ²	Stadium	6 000	1 800	4 200	400	680
					Equal to 1.86hour	Equal to 10.74hour

Table 1: Estimation of the flows of percolates infiltrating the ground or directed towards the peripheral drainage network and most often directed towards the waste water collection networks

II.5.2. - Physicochemistry results and report for percolates collected

The pH and conductivity values registered on the percolates from the 4 pilots (7.3 and 8.5; 323 and 637 µS/cm) were generally superior to those recorded on the football pitches (7.1 and 7.85; 72 and 384 µS/cm) but remain without environmental consequences. This finding is explained by the slight difference in chemical composition between the rain water on the one hand and that of the drinking water supply water for the pilots on the other.

Over time and irrespective of the type of filling material, the cyanide, phenol and total hydrocarbon concentrations were very low, most often inferior to the analytical detection limits (cyanide concentration inferior to 60 µg/l, phenol concentration inferior to 20 µg/l and total hydrocarbon concentration inferior to 50 µg/l).

Similarly, the sum of the concentrations of the 6 HAP¹⁶ (Figure 8) proves to be greatly inferior to the guide value from Decree no. 2001-1220 concerning water used for human consumption (1 µg/l).

Graphics Key:

P1 to P7 = No. of samples analysed over 11 months

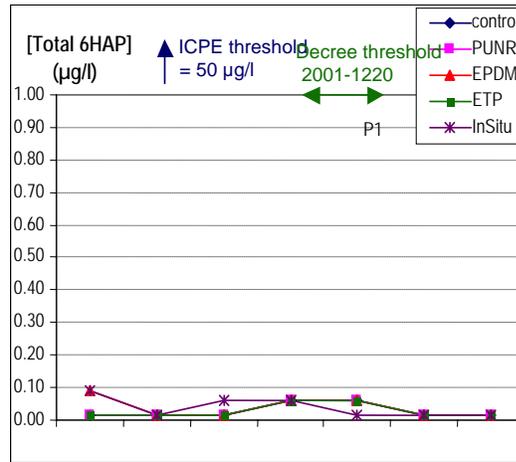
Control: artificial turf pilot only

PUNR: artificial turf pilot + used tyre granulates

EPDM: artificial turf pilot + EPDM granulates

ETP: artificial turf pilot + ETP granulates

In situ: lysimeter sited on the football pitch



P4 P5

Figure 8: Development of the concentrations of the 6 HAP over time in the 5 experiments in relation to the reference guide values

Overall, the organic composites displayed release kinetics which developed globally in a comparable fashion over time on all of the 5 experiments and in very close concentration ranges that were inferior to the guide values taken as a reference.

The metals Sn, As, Mo and Sb presented slight fluctuations in concentration over time but always at low concentrations and below the reference guide values (ex. Figure 9).

In all the experiments, the metals Al, Ba, Cd, Co, Cr, Cu, Hg, Ni, Pb, Sn and Zn showed a drop in concentrations over time, with a maximum at the level of the two first samples, i.e. on the first month (ex.: Figure 10, Figure 11, Figure 12). The concentrations, already very low at origin, continue to fall to reach values close to those of natural water (rain water and pilot water), below the reference guide values and sometimes even below the analytical detection limits, thereby showing that the essential part of the release of potentially polluting substances takes place in the 1st month after the deployment of the granulates in the artificial turf.

If the Selenium can, for its part, present over time concentrations superior to those of the guide values from Decree no.2001-1220 of 20/12/2001, for the reference control pilot and irrespective of the type of filling granulates, these concentrations are always inferior to the limit value from the Inert Waste Discharge Directive which permits the evaluation of the effects of a source term on the subterranean waters. Due to this fact, the Selenium release rates are regarded as being without impact on the water resources.

¹⁶ The 6 HAP concerned by the Decree no. 2001-1220 of 20 December 2001: Benzo(k)fluoranthene, Fluoranthene, Benzo(b)fluoranthene, Benzo(a)pyrene, Indeno(1,2,3-cd) pyrene, Benzo(g,h,i)perylene.

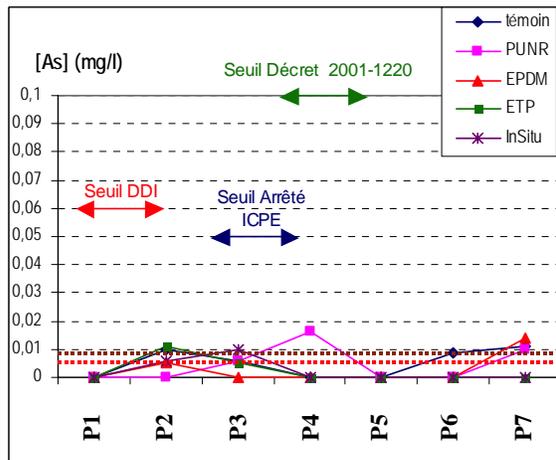


Figure 9: Development of As concentrations over time in the 5 experiments compared to the reference guide values (the red dotted straight line corresponds to the average contents of the pilot supply water and the rain water)

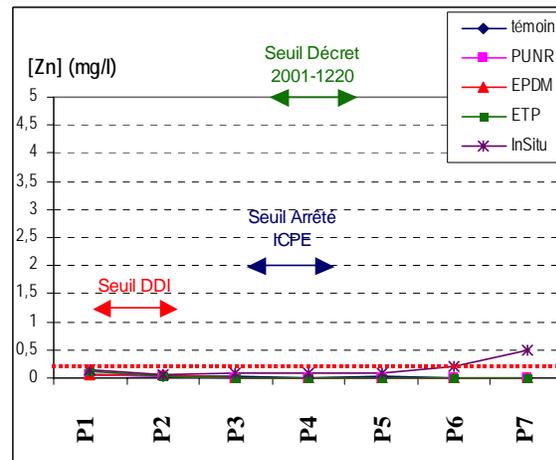


Figure 10: Development of Zn concentrations over time in the 5 experiments compared to the reference guide values (the red dotted straight line corresponds to the average contents of the pilot supply water and the rain water)

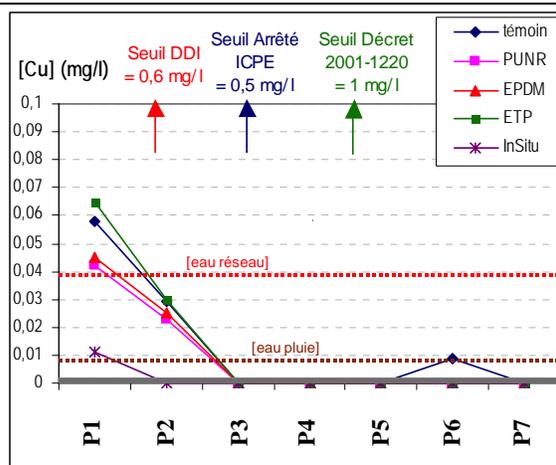


Figure 11: Development of Cu concentrations over time in the 5 experiments compared to the reference guide values (in grey: analytical detection limit)

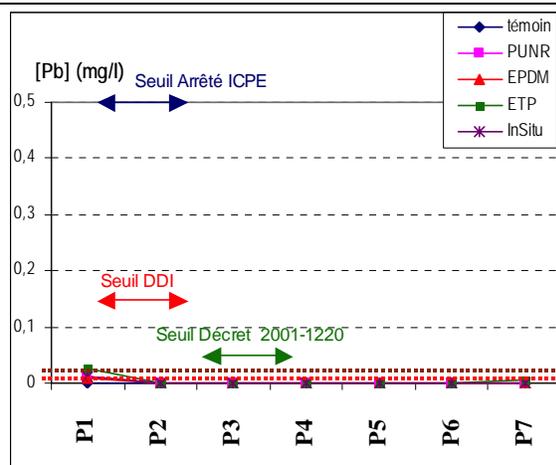


Figure 12: Development of Pb concentrations over time in the 5 experiments compared to the reference guide values (the red dotted straight line corresponds to the average content of the pilot supply water, while the brown dotted line corresponds to the average content of the rain water)

Concerning the anions, despite a value for the sulphates very slightly greater than the reference guide value (Decree no. 2001-1220 of 20/12/2001) at the start of experimentation on the pilot containing the used tyre granulates (1st sampling), the results obtained show low concentrations in the percolates on the 4 pilots but particularly *in situ* (ex. Figure 13 and Figure 14).

The same goes for NH_4^+ on the first month of pilot experimentation.

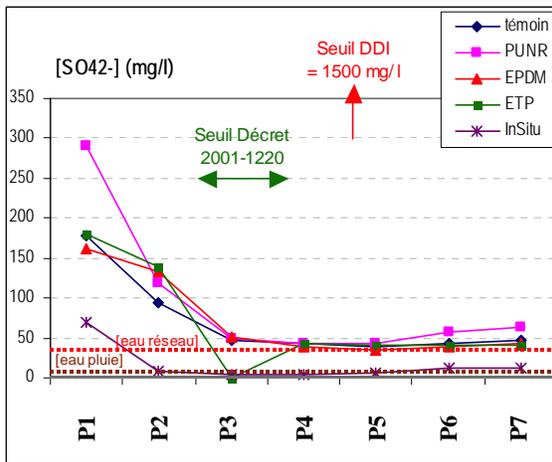


Figure 13: Development of Sulphate concentrations over time in the 5 experiments compared to the reference guide values

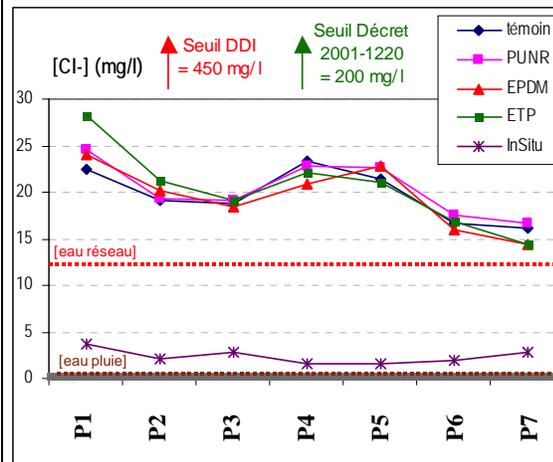


Figure 14: Development of Chloride concentrations over time in the 5 experiments compared to the reference guide values

II.5.3. - Conclusions

All of the results obtained on the percolates from the 3 pilots containing the granulates lead to the observation of a release kinetic comparable over time, with none of the 3 granulates distinguishing itself from the others and pilot no. 1 in artificial turf only taken as control itself displaying release rates fairly close to those of the 3 pilots containing the different granulates. The concentrations recorded are low for the majority of the components and elements researched. Certain elements present slightly stronger concentrations at the start of experimentation, which then fall very rapidly, thereby indicating a very rapid decrease in release rates.

In situ on the football pitch, the concentrations and release kinetic observed are fairly comparable. It is interesting to note that the elements such as the chlorides, fluorides and sulphates are in lower concentrations than in the percolates collected on the pilots, this finding being connected with a difference in chemical composition of the water which percolates through the sports surface (rain water on the site and drinking water supply network water for the 4 pilots).

This analytical approach in the pilot scenarios as *in situ*, based on a comparison with the currently applicable French and European guide values, shows that the concentrations of organic composites, metals and anions of the percolates are compatible with the water resource quality requirements.

II.5.4. -

Ecotoxological study results and report

For the football pitch (Table 2), the tests carried out on the samples (after 3; 3.5; 6 and 7.5 months) did not show toxicity for the daphnies or for the algae, except for the latter in the final sample at 7.5 months. The CE50¹⁷ is in this case just reached (low impact), a fact which, with regard to the results of the chemical analyses and the results of these same tests on the percolates from the pilots, appears to be an artefact linked to the immediate environment of the pitch (external pollution).

Lysimeter on the football pitch		To+3 months	T+3.5 months	T+6 months	T+7.5 months
Sampling date		2-Jan.-06	19-Jan.-06	4-Apr.-06	30-May-06
<i>Daphnia magna</i>	CE50 24h (UT)	< 1	< 1	<1	<1
<i>P. subcapitata</i>	CE50 72h (UT)	Not performed	<1.2	<1.2	1.4
	inhibition at 80%	vol. insufficient	7.5%	1.6%	57.5%

Table 2: Results of the ecotoxological tests on the percolates collected in the lysimeter positioned on the football pitch (Note: UT = 100 / CE50)

Essentially, the results of the physicochemical analyses of the percolates from the 4 pilots on the EEDEMS platform and collected 15 days after their launch show that these percolates are the most heavily charged. However, the ecotoxological tests performed on these same percolates show a very slight toxicity as regards both the daphnies and algae. For these two organisms, the CE50 was never reached. Subsequently, none of the samples (after 3 and 8 months) showed toxicity for these two organisms (Table 3).

		Pilots			
Sampling of 15-Nov-05		Control T+15d	Used tyres T+15d	EPDM T+15d	ETP T+15d
<i>Daphnia magna</i>	CE50 24h (UT)	<1	<1	<1	<1
	inhibition at 90%	25%	15%	30%	0%
<i>P. subcapitata</i>	CE50 72h (UT)	< 1,2	<1,2	<1,2	<1,2
	inhibition at 80%	10.3%	15.0%	33.3%	14.9%
Sampling of 30-Jan-06		Control T+3 months	Used tyres T+3 months	EPDM T+3 months	ETP T+3 months
<i>Daphnia magna</i>	CE50 24h (UT)	<1	<1	<1	<1
	inhibition at 90%	0%	0%	0%	0%
<i>P. subcapitata</i>	CE50 72h (UT)	< 1.2	<1.2	<1.2	<1.2
	inhibition at 80%	0.0%	0.0%	0.0%	0.0%
Sampling of 15-05-06		Control T+ 8 months	Used tyres T+ 8 months	EPDM T+ 8 months	ETP T+ 8 months
<i>Daphnia magna</i>	CE50 24h (UT)	<1	<1	<1	<1
	inhibition at 90%	0%	5%	0%	0%
<i>P. subcapitata</i>	CE50 72h (UT)	< 1.2	<1.2	<1.2	<1.2
	inhibition at 80%	0.4%	0.0%	1.0%	0.0%

Table 3: Results of the ecotoxological tests on the percolates collected on the 4 pilots set up on the EEDEMS platform (Note: UT = 100 / CE50)

¹⁷ The CE50 is the effective concentration of percolates that leads to the immobilisation of 50% of a batch of daphnies subjected to the test for an exposure period of 24 hours.
The CE50 is the effective concentration of percolates which leads to 50% inhibition of the growth of a population of algae in relation to a control without percolates after an exposure period of 72 hours.

The placing in pilot scenarios in a room with a controlled atmosphere and supervised human intervention consequently permits the avoidance of the external vagaries inherent to an outdoor football pitch (pollution from various sources: weeding in the neighbourhood, urine, etc.) likely to have even very slight repercussions on the quality of the percolates vis-à-vis certain organisms.

II.5.5. - Conclusions

From an ecotoxicological point of view, the nature of the percolates having passed through a 3rd-generation artificial pitch are proven to be without impact on the environment, irrespective of the type of filling granulates.

III. Evaluation of the health risks linked to gaseous emissions

III.1. - Characterisation of the VOC and formaldehyde emissions by artificial turf sports surfaces

The characterisation and measurement of the volatile organic compound (VOC) and aldehyde (including formaldehyde) emissions by the sports surfaces considered during the environmental impact evaluation study (previous §) was performed by the Centre Scientifique et Technique du Bâtiment (CSTB¹⁸), with the aid of the emission method test rooms used for the characterisation of chemical emissions in indoor air of construction products.

III.1.1. - Materials used

As for the experiments relating to the environmental evaluation, the different materials tested are: an artificial turf with green artificial fibres including a band of white artificial fibres; polyurethane glue; sand; elastomer granulates of 3 different types.

The proportions of the different constituents (stored in watertight bags until the experiment) are still 17.5 kg of sand and 15 kg of granulates per m², which for samples of 0.15 m², equals 2.625 kg of sand and 2.25 kg of granulates.

III.1.2. - Methodology

Each test sample is prepared by installing the artificial turf in a stainless steel box (Figure 15), adding a thickness of approximately 1 cm of sand (Figure 2) then approximately 4-5 cm of elastomer granulates. The test sample prepared in this way is then placed in the emission test chamber.

For the 4 tests performed at 23 ± 2°C, the samples were prepared in stainless steel tanks of a dimension of 0.78 m x 0.19 m. The effective emission surface of these test samples was 0.15 m².

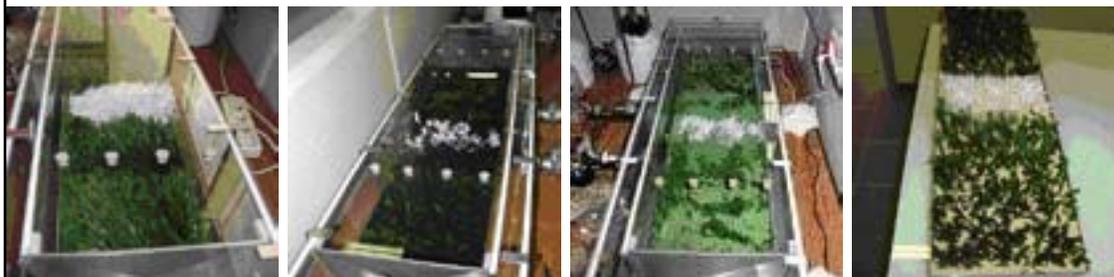


Figure 15: Test samples. From left to right: artificial turf only; artificial turf with ballast sand and used tyre granulates; artificial turf with ballast sand and EPDM granulates; artificial turf with ballast sand and ETP granulates

¹⁸Centre scientifique et technique du bâtiment (*scientific and technical building centre*): a public establishment of an industrial and commercial nature under the supervision of the minister for Housing, Directorate of Town Planning, the Environment and Construction

III.1.3. - Analytical conditions

Each of the test samples prepared was placed in an emission test chamber under controlled conditions of temperature (23 ± 2 °C) and relative humidity (50 ± 5 %), as per the recommendations of the standard project taken as a reference: prEN ISO 16000-9: *Indoor air – Part 9: Determination of the emission of volatile organic compounds from building products and furnishing – Emission test chamber method* (ISO, 2005).

The 5 tests were performed in accordance with a so-called “ground” emission scenario (specific ventilation rate: $q = 1.25 \text{ m}^3 \cdot \text{m}^{-2} \cdot \text{h}^{-1}$). The samples of VOC and aldehydes by pumping on special adsorbent support were performed in duplicate before the start of the test (D0) then after 24 ± 2 hours (D1), 72 ± 2 hours (D3) and 28 ± 2 days (D28) of conditioning of the sample in an emission chamber.

The samples and analyses of the VOC were performed as per the recommendations of the NF ISO 16000-6 standard: *Indoor air – Part 6: Dosage of volatile organic compounds in the indoor air of premises and test enclosures by active sampling on the sorbant Tenax TA, thermal desorption and chromatography in gaseous phase using MS/FID* (AFNOR, 2005).

The samples and analyses of the aldehydes were performed as per the recommendations of the NF ISO 16000-3 standard: *Indoor air – Part 3: Dosage of formaldehyde and other carbonylated compounds – Method by active sampling* (AFNOR, 2002).

III.1.4. - Results

The experiments conducted with the aid of emission chambers used for the characterisation of chemical emissions in indoor air of construction products permitted the identification of 112 substances (cf. table 4 in appendices).

The emission kinetic represented by Figure 16 shows that the concentration of Total VOC (TVOC) decreased very rapidly in the 4 samples. The fall is significant between D1 and D3. Between D3 and D28, the curve displays a lower incline and at end of testing on D28, the samples containing the used tyre and EDP granulates display comparable concentrations, slightly greater than that of the turf only, while those from the sample with the EPDM granulates are still relatively high.

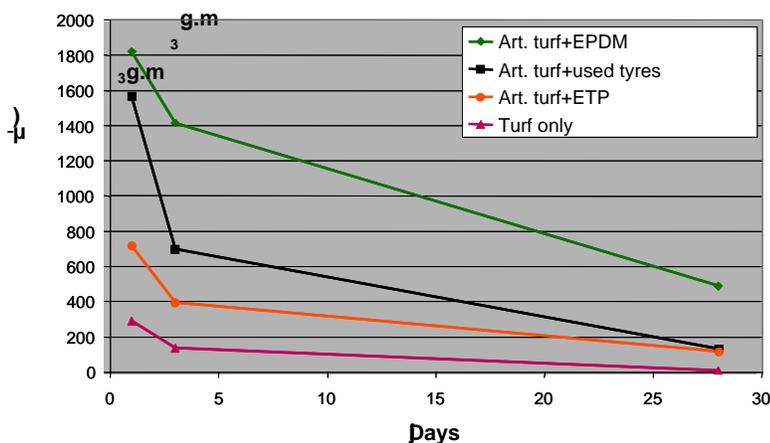


Figure 16: Comparison of the Total VOC concentrations issued between D1 and D28 by the 4 samples

The concentrations of VOC and aldehydes obtained correspond to the arithmetical average of the 2 samples taken and analysed, corrected from the chamber blank value measured at D0. These concentrations are the exposure concentrations for the product tested in its emission scenario.

The approach adopted permits a direct comparison of the VOC and formaldehyde emissions of the different elastomer granulate-based sports playing surface, under controlled conditions of temperature, relative humidity and air renewal.

The results of the tests were also expressed in specific emission factor form (SER_a in $\mu\text{g}\cdot\text{m}^{-2}\cdot\text{h}^{-1}$), calculated according to the following formula (as per prEN ISO 16000-9) : **$SER_a = C \cdot q$**

Where **C** represents the individual VOC (or TVOC) concentration in time t (in $\mu\text{g}\cdot\text{m}^{-3}$) and **q** the specific ventilation rate of the test ($q = 1.25 \text{ m}^3\cdot\text{m}^{-2}\cdot\text{h}^{-1}$ for the “ground” scenario).

III.1.5. - Conclusions

The emissions of VOC and formaldehydes by elastomer granulate-based sports playing surfaces was characterised with the aid of the standards applicable to the characterisation of emissions in indoor air of construction products (prEN ISO 16000-9, NF ISO 16000-6 and NF ISO 16000-3) and permitted the highlighting of the emission of 112 substances. It emerges from this that:

- 1 – The emissions from the artificial turf only are very low (TVOC = $8.3 \mu\text{g}\cdot\text{m}^{-3}$ at 28 days) compared with those from other construction products (ex: parquet flooring);
- 2 – The emissions from the artificial turf containing used tyre granulates are relatively low (TVOC = $134 \mu\text{g}\cdot\text{m}^{-3}$ at 28 days).
- 3 – The issues from the artificial turf containing ETP granulates are also relatively low (TVOC = $118 \mu\text{g}\cdot\text{m}^{-3}$ at 28 days). The compounds identified in the emission are overall comparable with those identified in the used tyre granulate emissions.
- 4 – The emissions from the artificial turf containing EPDM granulates are greater (TVOC = $490 \mu\text{g}\cdot\text{m}^{-3}$ at 28 days).

III.2. - **Study of the Health Risk Evaluation (HRE)**

A HRE was performed by INERIS¹⁹, in order to evaluate more precisely in indoor situation the health risks linked to the inhalation of the substances identified (112 substances) as per the reference protocol implemented by the CSTB (cf. previous §).

This evaluation and its conclusions only concern the inhalation of the VOC and aldehydes of which the emissions have been quantified by the CSTB. The possible health risks associated with the emissions of other substances in normal situations or due to ageing or accidental damage of the surfaces were not evaluated.

This type of study meets a strong current demand for the improvement of knowledge concerning emissions of chemical substances by construction materials and the characterisation of the associated health and environmental effects. On a European scale, within the framework of the European Directive “Construction products” (89/106/EEC), essential requirement no.3, “Hygiene, health and environment”, addresses the characterisation of emissions of gaseous, particulate or radioactive substances from products placed on the community market. Due to the lack of harmonised methods at European level permitting the evaluation of these characteristics, this requirement is currently scarcely taken into account. Work aimed at harmonising these methods was launched in 2003 under the aegis of the European Commission. An inventory of the national systems for the determination of emissions from materials in indoor air was carried out and published in December 2005 [EU, 2005]. The protocol implemented for the characterisation of the gaseous emissions (previous §), on the results of which this evaluation of health risks is based, belongs to the list of reference protocols.

In France, the Plan National Santé Environnement (PNSE – *national plan for health & the environment*) announced in June 2004 by the ministries of health, ecology, employment and research, set 45 actions, 12 of them priorities. Among the latter, action 15 aims to “put in place a labelling of the health and environmental characteristics of construction materials.” The target set by the PNSE is a labelling rate of 50% to be reached by 2010. This evaluation of the health risks and the characterisation study of the emissions on which it is based therefore fit into a framework that fully meets current health requirements.

¹⁹ Institut National de l'environnement industriel et des risques : Établissement Public à caractère Industriel et Commercial placé sous la tutelle du ministère de l'Écologie et du Développement durable

The evaluation of the health risks corresponds to a rigorous scientific initiative put forward during the 1980s by the American National Research Council. In Europe, it constitutes the benchmark tool for evaluations of the health and environmental risks of chemical substances. Formalised in methodological guides (*Technical Guidance Document* of the European Commission, INERIS guide for classified installations [INERIS, 2003-a], for example.), it unfolds as per the following stages: 1) inventory of substances; 2) identification of the danger and research into dose-response relationships; 3) evaluation of exposures, then quantification of the health risks.

III.2.1. - Exposure scenarios

The artificial turf sports surfaces studied are almost exclusively used outdoors. Nevertheless, some usages can be encountered in closed gymnasias, generally of a large size. The exposure levels of persons (athletes and spectators) are then higher in the absence of atmospheric dispersion permitted by the wind and photochemical degradation of the compounds emitted, phenomena occurring *a contrario* outdoors.

The results of the French “Listing of Sporting Equipment” (LSE), constructed before 31 December 2005, have been available since July 2006. It confirms the highly heterogeneous character of the dimensions of these infrastructures. Consequently, in this study, it is impossible to take as a basis types of gymnasias representative of the French reality.

By virtue of the principle of prudence (these exposure situations being rare but still likely to have taken place), this evaluation of the health risks is limited to an unfavourable situation in terms of exposure, namely **indoor usage**, in closed gymnasias. It fits well into a context of first-level approach of the HRE where the most extreme situations are envisaged (worst-case scenario).

Moreover, the evaluation of exposure outdoors appears more complex. Study models for the atmospheric dispersion of gaseous or particulate compounds emitted by a surface exist, but they only permit the modelling of the concentrations in the air within a radius of 100 m to 10 km around the emitting surface. Their implementation in the present context would not permit the evaluation of the exposure of persons who train on the sporting surface. This constitutes an additional element that prompted the conducting of a study in an indoor scenario. The conclusions of the study, peculiar to this usage in an indoor scenario, shall be put into the perspective of general usage on outdoor sports surfaces.

For reasons of feasibility and by virtue of the principle of prudence in the first-level approach of the HRE, an unfavourable situation in a gymnasium has been chosen, rather than exposure on an open-air playing surface. The choice was therefore made of a worst-case situation by considering a gymnasium of the smallest size possible (in this way, the substances emitted will be less diluted in the volume of air). Among the different categories from the INSEE inventory of 1988, the smallest gymnasias (category A) have a surface area of 230 m². Moreover, the French Ministry of Youth and Sports has set minimum free heights above the floor: the lowest height is 7 m. Furthermore, two indoor structures constructed in 2006 (source: FIELDTURF TARKETT) with 3rd-generation artificial turf, have a surface area of 2,500 m², 1,800 m² of which is covered by artificial floor with an average under-ceiling height of 8 m. Insofar as a study conducted in 13 Parisian gymnasias produced one hall with a height of 6 m (the smallest gymnasium having a volume of 3,600 m³), this value was chosen as the lowest height possible.

The standard gymnasium chosen in this study therefore has a surface area of 230 m² and a height of 6 m, giving a volume of 1,380 m³. The air renewal rate chosen is 0.5 vol.h⁻¹.

The choice was also made to consider all of the substances for which emission data is available and not to exclude any *a priori*. Only the chemical health risks were taken into consideration, as the biological, physical or radiological risks were not concerned in the present context.

The emission factors, determined by the characterisation study in § III.1.4, permitted the modelling of the interior concentrations in the gymnasium for each of the types of granulate associated with artificial turf and for artificial turf only. In parallel to this, the dangers by inhalation and the reference toxicological values (RTV) of all of the VOC and aldehydes measured, that is 112 substances (cf. Table 5 in appendix), were searched for in the reference international toxicological databases. For 16

compounds with an RTV (in bold in table 5 in the appendices), the quantitative evaluation of exposure levels and of the associate health risks was carried out.

Uncertainties exist concerning the dangers of the substances studied: uncertainties in the toxicological data and the RTV proposed (possible exacerbation or inhibition of toxicity in the case of mixing of pollutants emitted by the artificial surfaces, possible products of transformation of the pollutants emitted, reactions in heterogeneous phase by adsorption on the materials present in the building). These are inherent to any evaluation of the health risks according to current scientific knowledge and practice and cannot be quantified.

Acute and chronic exposure scenarios were developed for 4 population groups:

- the workers responsible for installing the surfaces. In a gymnasium, the installation of an artificial floor takes 10 days, devoted to the profiling of the ground, the laying of the mat and the installation of the sports surface with the granulates, which last 3 days (source: FIELDTURF TARKETT),
- the professional athletes and coaches present in the gymnasium throughout the day,
- the amateur athletes training regularly in the gymnasium. A fairly severe scenario was envisaged whereby the dedicated athlete trains twice during the week and once at the weekend (training of a duration of 2 hours). Moreover, it was considered that he would take part in an amateur competition at weekends (4 hours' presence in the gymnasium),
- the spectators at sporting events, attending the gymnasium regularly, namely every weekend (2 hours' presence in the gymnasium each time).

Each of these population groups may be exposed (Table 4):

- Š in an acute fashion when a new floor has just been laid. For the workers, the results of the measurements at D1 were used, while for the general public, who are presumably not authorised to enter the gymnasium on the very day of the new floor's laying, the measurements at D3 were used;
- Š in a chronic fashion, since it was considered that the exposure is repeated throughout the year. The workers are permanently exposed to the concentrations emitted during installation, so the concentrations measured at D1 are used. For the general public, the chronic exposure (the most frequent in addition) is calculated on the basis of the surface's emissions measured at D28. In the absence of measurement of the emissions some months after the laying of the floor, it was considered that the measurement at 28 days (D28) is representative of the residual emissions for the remainder of the surface's lifespan.

	Acute exposure	Chronic exposure
Workers laying artificial turf	At time of laying of artificial turf è emissions at D1	8h per day, 71 days per year ⁽¹⁾ $f_{workers} = 0.07$ è emissions at D1
Professional athletes and coaches		8h per day, 365 days per year ⁽²⁾ $f_{athletes} = 0.33$ è emissions à J28
Amateur athletes	At the opening of the gymnasium after the laying of new floor è emissions at D3	10 h per week, 44 weeks per year ⁽³⁾ $f_{amateurs} = 0.05$ è emissions at D28
Spectators		Dedicated spectator present at all the compétions ⁽⁴⁾ $f_{spectators} = 0.009$ è emissions at D28

Table 4: Overview of exposure scenarios studied for chosen population groups

Key: f = fraction of annual time spent in gymnasium

- Notes:**
- (1) It was considered that 236 days are worked annually, corresponding to 365 days from which were subtracted the 2 days of the 52 weekends and the 5 x 5 days of paid leave. Given that, for the laying of a surface that takes 10 days, 3 days are devoted to the laying of the sporting surface containing the granulates, the annual exposure duration is 71 days ($71 = 236 \Delta 3/10$).
 - (2) It was considered that a top-level athlete would train every day.
 - (3) It was considered that training and competitions take place throughout the year except during the 8 weeks of the months of July and August.
 - (4) 40 competitions per year were envisaged.

As the calculation of the concentration inhaled does not involve physiological parameters, the results obtained apply equally to exposure by inhalation of an adult as of a child.

The concentrations inhaled were calculated so as to permit *in fine* the calculation of the risk indices (for the health effects with a threshold) and of the individual risk (for the effects without threshold, carcinogenic effects).

The non-carcinogenic effects are those for which an effect threshold exists (deterministic phenomenon). The US-EPA expresses this mechanism by a reference dose (RfD) or concentration (RfC) (for ingestion or inhalation respectively). These reference doses are determined on the basis of the Doses Without Noxious Effect (DSENO or NOAEL) or Minimum Doses resulting in the Observation of a Noxious Effect (DMENO or LOAEL), divided by the safety factors (factor 10 taking account of the inter-species variability, factor taking account of the existence of sensitive persons, etc.).

The carcinogenic effects are those for which the relationship between the exposure and the appearance of the effect is without threshold (probabilistic phenomenon). The US-EPA expresses this mechanism by an excess of unitary risk (EUR) corresponding to the excess risk for an individual exposed throughout his life to a dose unit (inhalation of $1 \mu\text{g}/\text{m}^3$ or ingestion of $1 \text{ mg}/\text{kg}/\text{j}$). For example, an EUR_i of $6.10^{-6} (\mu\text{g}/\text{m}^3)^{-1}$ (case of benzene) signifies that an exposure of 1 million persons during 70 years to a concentration of $1 \mu\text{g}/\text{m}^3$ of benzene is likely to result in 6 additional cases of leukaemia during the same period (compared with a non-exposed population of the same size).

The evaluation of the health risks was performed for a normal use of the artificial turf sports surfaces, namely in the absence of taking into account of the ageing of the surface or their accidental damage and any associated emissions.

The standard gymnasium chosen having a surface area of 230 m^2 , denoted as S, and a height of 6 m, giving a volume of $1,380 \text{ m}^3$, denoted as V, the parameters chosen for the modelling of the concentration in the gymnasium were as follows:

- the entire surface area of the gymnasium was covered with artificial floor made either from granulates or not from granulates. The emitting surface was therefore equal to the surface of the gymnasium, which in this case was 230 m^2 ;
- the emissions from the artificial floor are spread uniformly throughout the volume of the gymnasium's air; in other words, the interior concentrations in the gymnasium are homogeneous;
- the air renewal rate in the gymnasium was average, or even mediocre. This rate was set at 0.5 volume/hour, as the literature did not provide data regarding the ventilation in the gymnasium. This rate (denoted as ϑ) was regarded as constant throughout the day, whether the gymnasium was empty or occupied.

The calculation of the concentrations in the gymnasium was made according to the equation (1):

$$C_{\text{gymnasium}} = (\text{SER}_{\text{JX}} \Delta S) / (\vartheta \Delta V)$$

With:

- § SER_{JX} , the specific emission factor established during the characterisation of the emissions (in $\mu\text{g}\cdot\text{m}^{-2}\cdot\text{h}^{-1}$). According to the scenarios chosen, this factor is that measured at D1, D3 or D28. The SER_{JX} at the detection threshold are taken as equal to this threshold.
- § ϑ , the gymnasium's air renewal rate (h^{-1})
- § S and V, respectively the surface area of the artificial floor, taken as equal to the surface area of the gymnasium (m^2) and the volume of the gymnasium (m^3)

The calculation of the concentrations inhaled was made:

- Within a context of acute exposure, with the concentration inhaled being taken as equal to the gymnasium's interior concentration, calculated as per the equation (1) with the emissions measured at D1 (workers installing the floor) or D3 (other population groups).
- For chronic exposure, the concentration inhaled (CI) is calculated according to the equation (2):

$$CI = C_{\text{gymnasium}} \times f$$

With:

- § C gymnasium, the interior concentration in the gymnasium calculated as per the equation (1) with the emissions measured at D1 (workers installing the floor) or D28 (other population groups).
- § f = fraction of annual time spent in the gymnasium

∄ The quantification of the health risks is evaluated for the effects with thresholds and for the effects without thresholds.

The characterisation of the risk for toxics with threshold effects by inhalation (acute or chronic exposure) is expressed by a risk index (IR) as per the equation (3): $IR = \frac{CI}{VTR}$

With:

- § CI, the Concentration Inhaled ($\mu\text{g}/\text{m}^3$)
- § RTV, the Reference Toxicological Value ($\mu\text{g}/\text{m}^3$)

The IR is calculated for each of the health risk tracers. The benchmark for the assessment of the health risk is set at 1. When the IR is inferior to the value of 1, the risk is regarded to be of no cause for concern within the current status of knowledge.

In the first HRE approach [INERIS, 2003-a], the sum of the IR is also calculated. However, strictly speaking, it can only provided an indication on the combined effects of the risks if the respective effects of each of the substances contributing to the risk concern the same target organ.

∄ The characterisation of the risk linked to an exposure to carcinogens (effects without thresholds) is expressed by an excess of individual risk (EIR).

This EIR represents the probability of the individual developing the effect associated with the substance during his life due to the exposure concerned.

$$ER_{\text{linh}} = CI \times ERU_i \times T / T_m \text{ equation (4)}$$

With:

- § ER_{linh}, the Excess Individual Risk by inhalation
- § CI, the Concentration Inhaled ($\mu\text{g}/\text{m}^3$)
- § ERU_i: Excess of Unitary Risk by inhalation ($(\mu\text{g}/\text{m}^3)^{-1}$)
- § T: duration of exposure (years)
- § T_m: period of time over which the exposure is averaged (70 years according to convention)

The benchmark for the assessment of the health risk is set at 10^{-5} . When the EIR is inferior to the value of 10^{-5} , the carcinogenic risk is generally regarded as acceptable according to current knowledge.

The excess of global risk of cancer (all cancer types) can be estimated by adding the EIR associated with each carcinogenic substance.

The results described in the next section correspond to a modelling which fits in well to a context of first-level HRE approach where the most extreme situations are envisaged (worst-case scenario), that is to say a small, poorly ventilated gymnasium and without taking into account the ventilation rate of individuals.

In order to be positioned as close as possible to the real usage conditions on the basis of the results acquired, the INERIS has also carried out sensitivity tests on:

∄ The dimension of the gymnasium: by considering a realistic situation (emitting surface of 1,800 m² and gymnasium volume of 20,000 m³; the air renewal rate remaining unchanged),

∄ The average air renewal rate chosen for the HRE was set at 0.5 vol.h⁻¹. A study conducted in a French gymnasium [Air Normand, 2000] showed an average air renewal rate of between 0.54 vol.h⁻¹ in summer and 1.2 vol.h⁻¹ in the winter period. This confirms that the context for the calculation of the interior concentrations in the gymnasium and for the concentrations inhaled resulting from this is *a priori* fairly significant. The ventilation is a parameter that has a significant effect on the results.

∄ The ventilation rates of individuals (male and female) were not taken into account. A sensitivity test was conducted on the professional athletes group. This test shows that if an approach is chosen that takes account of respiratory rates, the risk indices turn out to be higher but the conclusions of the study are nevertheless not modified.

III.2.2. - Results and recommendations

The interior concentrations modelled in the standard gymnasium chosen (volume of 1,380 m³) were compared to the average ubiquitous concentrations in the ambient exterior and interior air in France. This placing in perspective indicates that, for the 9 VOC and aldehydes concerned and on the basis of the results acquired during the characterisation of the emissions, the maximum concentrations in the gymnasium, modelled at D28, are of approximately the same magnitude as the ubiquitous concentrations in the ambient air (exterior and interior), or even inferior in certain cases.

The results of the INERIS HRE based on the concentration of the substances identified and on the previous hypotheses (worst-case scenarios) indicate that, according to current knowledge and on the basis of the information transmitted by the manufacturers (regarding exposure levels of workers responsible for installation in particular), the VOC and aldehyde emissions from the three types of artificial floors studied in indoor situation (small and poorly ventilated gymnasia) are of no cause for concern for human health, for the workers installing the surfaces as well as for the general public, professional or amateur athletes, adults and children, with the exception of the case of workers installing artificial surfaces in small and poorly ventilated gymnasia who are exposed for over 5 years. In this case, it is recommended that during installation, an air renewal rate of *at least* 2 vol.h⁻¹ is assured.

This type of recommendation corresponds to that of the Observatoire français de la Qualité de l'Air Intérieur (OQAI), which recommends to private individuals several days' ventilation of rooms of a building which have just been constructed or renovated or after the installation of new furniture or decoration (page 5 of the "Les bons gestes pour un bon air" (*good moves for good air*) guide.

Concerning ventilation, moreover, it is appropriate to refer to the minimum fresh air intake rates imposed in France by the departmental health regulation (RSD) required irrespective of the ventilation system (these are the only regulatory provisions currently in force in terms of building ventilation). The INERIS recommends that this air renewal rate is maintained outside competitions, from the moment that professional or amateur athletes train on this type of indoor surface.

In conclusion to its study, the INERIS stipulates that the health risks associated with the inhalation of VOC and aldehydes emitted by artificial surfaces on pitches in outdoor situations give no actual cause for concern as regards human health.

IV. General conclusions

Evaluation of the environmental impact on water:

The analytical approaches as regards the environmental evaluation of water passing through artificial turf were conducted over a period of one year: on the one hand, by orchestrating representative pilots on the EEDEMS environmental platform (three types of filling granulates tested: TPE, EPDM, granulates recycled from used tyres) and on the other, *in situ* on a football pitch (recycled PUNR granulates). At the end of the experiments, the results showed that:

1 – All of the physicochemical results (42 parameters analysed) obtained on the percolates from the 3 2.5-m² pilots leads to the observation of a release kinetic for potentially polluting substances comparable to the course of time irrespective of the type of granulate used (7 percolate samples analysed at one year). The artificial turf pilot without filling granulates used as a control also displayed release rates fairly close to those of the 3 pilots. The concentrations recorded were low for the majority of the compounds and elements searched for. While certain elements displayed slightly higher concentrations at the start of experimentation, these fell very rapidly, thereby indicating a very rapid reduction effect in terms of release rates.

2 - *In situ* on the football pitch orchestrated in the Lyon region (France), the concentrations and release kinetics are fairly comparable to those observed on the pilots. The chlorides, fluorides and sulphates are even in lower concentrations than in the percolates collected on the pilots, a finding to be linked with the difference in chemical composition of the water that has percolated through the sports surfaces (rain water *in situ* and drinking water on the pilots).

3 – On the basis of a comparison with the French and European limit values currently in force, the concentrations of organic compounds, metals and anions from the percolates are without impact on water resources.

4 – From an ecotoxicological viewpoint, the results obtained show that the nature of the percolates likely to infiltrate into the ground underlying the artificial turf sports surface proves to be without impact on the aquatic environment in the short and medium term (standardised tests carried out on the first percolates and repeated several times during the year).

According to current research, after a year's experimentation, the results on the 42 physicochemical parameters identified and on the ecotoxicological tests show that water passing through artificial turf using as filling either virgin TPE or EPDM or granulates resulting from the recycling of PUNR are not likely to affect water resources in the short and medium term.

Evaluation of the health risks linked to gaseous emissions

The characterisation of the emissions of Volatile Organic Compounds and aldehydes by elastomer granulate-based sports surfaces has been conducted by the CSTB (Centre Scientifique et Technique du Bâtiment - France) using the standards in force for the characterisation of the emissions in indoor air of construction products (emission chamber). The results show that:

1 – Emissions from the artificial turf only (control with no granulate filling) are very low in relation to those from other construction products;

2 - Emissions from the artificial turf containing used tyre granulates are relatively low;

3 - Emissions from the artificial turf containing ETP granulates are also relatively low. The compounds identified as being emitted is comparable overall to those identified in the used tyre granulate emissions;

4 - Emissions from the artificial turf containing the EPDM granulates are the most significant.

A Health Risk Evaluation (HRE) was conducted by the Institut National de l'Environnement Industriel et des Risques (France). This HRE was based on the values of the concentrations of 112 substances identified in the emission chambers and their comparison to the international toxicological reference values (RTV). According to the HRE methodology, a “worst-case scenario” was modelled (small,

1,380-m³ gymnasium (6 m x 230 m²) and poorly ventilated (0.5 vol.h⁻¹) taking into account four population groups (public, amateur athletes, professional athletes and coaches, artificial pitch installers).

According to current knowledge, the results of the HRE show that the VOC and aldehyde emissions identified for the three types of artificial floors and for the reference control present no cause for concern as regards human health in an indoor situation, for the workers responsible for laying the floors or for the general public, professional or amateur athletes, whether adults or children, with the exception of the case of workers installing artificial surfaces in small and poorly ventilated gymnasiums who are exposed for over 5 years (worst-case scenario). In this case, it is recommended, when the floors are installed, that a minimum air renewal rate of 2 vol.h⁻¹ is assured.

This type of recommendation corresponds to that of the Observatoire français de la Qualité de l'Air Intérieur (OQAI), which recommends to private individuals several days' ventilation of rooms of a building which have just been constructed or renovated or after the installation of new furniture or decoration (page 5 of the "Les bons gestes pour un bon air" (*good moves for good air*) guide.

In conclusion to its study, the INERIS stipulates that the health risks associated with the inhalation of VOC and aldehydes emitted by artificial surfaces on pitches in outdoor situations present no actual cause for concern as regards human health.

Initiated in 2005, this study was conducted with the scientific aim of getting as close as possible to the pitch usage conditions (representativity of the pilots conducted, quantities of materials tested, choice of limit thresholds, evaluation of effects over a year) and based on approaches and experimental protocols recognised on a European scale. The results of the evaluation of the environmental impact on the water and of the health risk evaluation (gaseous emissions) on the population groups show:

- ∄ comparable behaviour irrespective of the type of filling granulate (virgin TPE and EPDM, used tyre granulates),
- ∄ an absence of impact of this type of work on water resources,
- ∄ no effect worthy of concern on the health associated with the inhalation of VOC and aldehydes emitted by artificial surfaces.

This data consequently provides vital information on the environmental and health effects linked to the use of elastomer granulates (virgin and from used tyres) as filling in 3rd-generation artificial turf. These results offer elements of response to the principal questions raised by the professionals and sports federations.

On a French and European scale, the results of these studies will be able to be used in order to confirm or develop tailored sampling protocols and laboratory tests permitting the innocuousness in terms of the environment and health of 3rd-generation artificial turf under usage conditions.

APPENDICES

Compound	CASE No.
VOC	
acetophenone	98-86-2
alpha-methylstyrene	98-83-9
aniline	62-53-3
benzene	71-43-2
benzothiazole	95-16-9
butan-1-ol	71-36-3
butylcyclohexane	1678-93-9
1,5,9-cyclododecatriene	4904-61-4
cyclohexane	110-82-7
cyclohexanone	108-94-1
cymene	99-87-6
decahydro-2-methylnaphtalene	?
decane	124-18-5
1,4-diacetylbenzene	1009-61-6
1,2-dichlorobenzene	95-50-1
diethylbenzene	135-01-3
1,2-dihydro-2,2,4-trimethylquinoline	147-47-7
diisopropenylbenzene	3748-13-8
diisopropylbenzene	99-62-7
2,4-diisopropyl-1,1-dimethylcyclohexane	?
dimethylcyclohexane	2207-01-4
dimethylcyclopentane	?
dimethylethylbenzene	98-06-6
dimethylethylcyclohexane	3178-22-1
dimethylhexene	?
dimethylpentanol	?
dimethylphenylmethanol	617-94-7
2,4-dimethylquinoline	1463-17-8
dimethyltrisulfide	3658-80-8
2,6-ditertbutyl-p-benzoquinone	?
2,6-ditertbutyl-4-methylphenol	?
dodecane	112-40-3
dodecene	25378-22-7
1,2-ethanediol	107-21-1
ethanone, 1-[4-(1-hydroxy-1-methylethylphenyl)]	?
ethylbenzene	100-41-4
ethylcyclohexane	1678-91-7
5-ethylidihydro-5-methyl-2(3H)-furanone	?
2-ethylhexanol	104-76-7
5-ethyl-2,2,3-trimethylheptane	?
ethyltoluene	622-96-8
2,2,3,5,5,6,6-heptamethyl-3-heptene	?
heptane	142-82-5
heptene	592-76-7
2,5-hexanedione	110-13-4
1-hydroxycumene	617-94-7
hydroxydiisopropylbenzene	4779-94-6
isobutene tetramere	115-11-7
1-isopropoxy-2-methyl-2-propanol	?
isopropenylacetophenone	?
isopropylacetophenone	?
Isopropylbenzene (or cumene)	98-82-6
isothiocyanato-cyclohexane	1122-82-3
1-methoxy-2-propanol	107-92-8
(1-methoxy-1-methylethyl)-benzene	?
methyldecane	6975-98-0

Environmental and health assesment of the use of elastomer granulates (virgin and from used tyres) as infill in third-generation artificial turf

Compound	CASE No.
3-methylheptane	589-81-1
methyl-2-hexanone	?
methylcycloheptane	4126-78-7
methylcyclohexane	108-87-2
3-methylcyclohexen-1-one	?
methylcyclopentanol	1462-03-9
methylethylcyclohexane	1678-82-6
methylethylcyclopentane	?
methyisobutylcetone (MIBK)	108-10-1
2-methyl-2-(1-methylethoxy)-propane	?
methylpropylbenzene	99-87-6
4-methyl-pyridine	1333-41-1
naphthalene	91-20-3
octahydro naphthalene methanol	?
octane	111-65-9
octenone	4312-99-6
pentadecane	629-62-9
2,2,4,6,6-pentamethylheptane	13475-82-6
2,2,4,6,6-pentamethyl-3-heptene	123-48-8
phenol	108-95-2
4-phenylcyclohexene	4994-16-5
1,2-propanediol	57-55-6
propylbenzene	103-65-1
propylcyclohexane	1678-92-8
styrene	100-42-5
4-tert-butylacetophenone	?
4-tert-butylcyclohexanone	98-53-3
tert-butylformamide	2425-74-3
tetradecane	629-59-4
tetraisobutylene	15220-85-6
tetramethylcyclopentane	<i>isomers</i>
3,3,6,6-tetramethyl-1,4-cyclohexadiene	?
2,2,6,6-tetramethyleneheptane	?
trichloroethylene	79-01-6
tridecane	629-50-5
1,2,3-trimethylbenzene	526-73-8
1,2,4-trimethylbenzene	95-63-6
1,3,5-trimethylbenzene	108-67-8
trimethylcyclohexane	<i>isomers</i>
3,5,5-trimethyl-2-cyclohexen-1-one	78-59-1
trimethylcyclopentane	<i>isomers</i>
1,3,3-trimethyl-2-methylene-indoline	118-12-7
toluene	108-88-3
undecane	1120-21-4
xylenes	1330-20-7
acetaldehyde	75-07-0
benzaldehyde	100-52-7
butyraldehyde	123-72-8
crotonaldehyde	123-73-9
decanal	112-31-2
formaldehyde	50-00-0
hexaldehyde	66-25-1
nonanal	124-19-6
propionaldehyde	123-38-6
m/p-tolualdehyde	620-23-5
valeraldehyde (pentanal)	110-62-3

Table 5: List of substances studied (in bold: the 16 substances with a RTV)

V. Bibliographic and normative references

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Section 20:

**Investigation and Assessment of Synthetic
Sports Surfaces in Switzerland Including
Athletic and Soccer Facilities**

Investigation and Assessment of Synthetic Sports Surfaces in Switzerland Including Athletic and Soccer Facilities

Hans J. Kolitzus, IST Switzerland

Switzerland had developed a concept for synthetic Surfaces (athletic) in respect to environment similar to Germany. Partly, the two committees had common meetings. The result was published in the mid 90ies as a recommendation "Kunststoffbeläge und Umwelt (Synthetic Surfaces and Environment) by BASPO, the Swiss Federal Authority of Sports at Magglingen. The Swiss document (BASPO 105) was more complicated than the German document (first RAL later DIN 18035-6). The use of this document was not obligatory, but more incidental acc. to the deliberation of the various States of Switzerland.

Unfortunately, the document was applied to Artificial Turf also although its scope was limited to synthetic athletic surfaces. The application was done without modification and considerations. When it was realized that there was a discrepancy or inadequate use of the document, BASPO decided to completely reconsider the issue. A new committee was founded including experts from various Swiss authorities, companies and lab experts. As discussions and activities are still going on I can only report the design of the programme and first results. I am authorized to do this but cannot publish any data available today.

The common view of the committee is that the real effect of sports surfaces on site to the environment cannot be determined by using lab tests as used by the former concept or the DIN. They are regarded totally non suitable for assessment of artificial turf. In order to receive real data, a practical study programme has been prepared and started. The aim is to get data of what is really released from sports surfaces to water running off the surfaces and probably contaminating rivers or the underground. The test program was started last year and will be continued until spring time of next year.

For this, a variety of typical sports surfaces have been installed in so called Lysimeters (see appended pictures). These are well known in horti- and agriculture to investigate the exchange of nutrients of plants. These are reinforced Polyester tubes. They are about 1m wide and 1.5m high. They are equipped with an automatic water sampling system. Thus, the total amount of rain water seeping through or running off the sports surface can be collected and analyzed.

In Bern, 10 such Lysimeters are equipped with the following set of surfaces:

List of surfaces

1. Artificial Turf with EPDM infill and Quartz sand on a permeable asphalt base and elastic layer 25mm
2. Artificial Turf with SBR rubber and Quartz sand infill on mineral sub base
3. Artificial Turf with EPDM infill and Quartz sand on mineral subbase and elastic layer
4. Artificial Turf without infill on mineral sub base
5. Permeable Synthetic Surface EPDM 12mm on an asphalt base + elastic layer
6. Permeable Synthetic Surface EPDM + SBR (6mm + 9mm) with Spray Coat 1.5kg/m²

7. Sandwich Surface PUR coating + SBR (5mm + 10mm)
8. Mineral Supporting Layer = 0-sample no. 1
9. Bituminous Supporting Layer on mineral subbase = 0-sample no. 2
10. Elastic Layer of recycled SBR granules 25mm on mineral subbase

All containers were filled with an unbound (mineral) supporting layer as commonly used in Switzerland. Only the upper 65cm are used. Beneath an impermeable layer (concrete) is installed so that the water can flow into the collection containers. The design of the surfaces is rather similar to real surfaces. The analysis of the collected water is performed after 300mm precipitation.

Searched Substances

- Rubber chemicals: various aromatic Amines and Benzothiazoles
- Polycyclic aromatic hydrocarbons (16 PAH)
- Sum of organic nitrogen compounds (total N-org)
- Sum of dissolved organic substances (DOC)
- Zinc

Progress of Investigation

Due to adverse weather conditions the main test series could not be started until May 2006 . Thus, test data are available for the time from May to September.

The Lysimeter device was checked in December 2005 already with the installation of an artificial turf filled with EPDM granules and Quartz sand on top of a permeable asphalt sub base and an elastic layer.

It is intended to observe the substances released to the run-off water for a minimum of 1 year. Special interest is drawn on the decrease of their concentrations over time.

Zinc

With all surface types, including the 0-sample no. 1 consisting of the mineral supporting layer, Zinc was found in concentrations of 0.009 to 0.003 mg/l. In rain water which was also investigated a concentration of 0.02 mg/l was found. We will see how the Zinc concentration will change in the course of time.

Polycyclic Aromatic Hydrocarbons (PAH)

In all samples, also in the 0-sample no. 1 which consists of the unbound supporting layer only, the various PAHs were determined in the range of analytic determination limit which is 0.02 µg/l, whereas the sum of all 16 PAHs is about 0.1 to 0.3 µg/l. None of the surface systems including the surfaces with recycled granules showed any noticeable PAH concentration. PAHs are ubiquitous substances in the environment and in water. They are present in any street sewage and also in purified sewage from communal sewage purification plants as well as sewage sludge in partly much higher concentrations.

DOC

Reliable conclusions about DOC concentrations are not possible yet. Especially not because the 0 sample (i.e. unbound supporting layer without a sports surface) had a DOC concentration of 6 mg/l. Due to the results of the pre-test it is expected that the DOC concentration will decrease in the course of time.

Various Substances

In surface systems with EPDM and recycled rubber infill several aromatic Amino complexes and Benzothiazoles were determined in the range of 10 – 300 µg/l. According to the results of the pre-test it is expected that similar concentrations will be found in all street sewage waters as a consequence of abrasion of car tires. These complexes and substances are also ubiquitous in the aquatic environment.

Already today, BASPO has notified the communities and states of Switzerland that the BASPO document 105 is not relevant any longer and should especially not be applied to artificial turf.

Swiss Federal Authority of Health July 6, 2006

This authority was challenged to provide a statement regarding health risk caused by PAH in artificial turf. The issue refers to recycled rubber granules i.e. SBR granules from car tires. It is considered the question of abraded particles being inhaled as dust and being washed out and ending up in waters and in the subsoil. PAHs can be substances added to softeners of tires, but are also generated by burning processes, from traffic exhaust fumes and heating systems; they also come from tobacco smoking and chimneys.

Assessment and Recommendation for Switzerland

Although a final assessment of the health risks is not possible acc. to the data available today, the estimatable PAH stress is low even in worst case scenarios compared with stress from other sources. The health risk for players and spectators is classified low. Thus, from the health point of view no urgent need of action is seen.

Lysimeter



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Section 21:

Artificial turf pitches – an assessment of the health risks for football players

Artificial turf pitches

an assessment of the health risks for football players

Prepared by:
**Norwegian Institute of Public Health and the
Radium Hospital**

Oslo, January 2006

Artificial turf pitches – an assessment of the health risks for football players

Introduction

Sports halls with artificial turf pitches are used for indoor football. Artificial turf pitches consist of artificial turf fibre and rubber granulates. Rubber granulates can be one of several main types: recycled rubber (ground car tyres), thermoplastic elastomer or EPDM rubber. Recycled rubber granulates can be produced in a variety of qualities (coarse-ground/fine-ground, different chemical compositions/different additives). Two types of artificial turf fibre are also used (split fibre and monofibre). Information on the occurrence and concentrations of chemical substances in rubber granulate and in sports hall air is based on the report by the Norwegian Institute for Air Research (NILU) entitled “Measurement of air pollution in indoor artificial turf sports halls” of January 2006 (TA number: TA-2148/2006). The assessment of the potential risk of cancer and genotoxicity was undertaken by Tore Sanner of the Radium Hospital.

Given the large number of substances which were identified in the rubber granulates and during the degassing of volatile organic compounds (VOC), it was decided to use worst case scenarios where quantities within each substance category (PCBs, PAHs, phthalates, alkyl phenols and VOCs) were summed and the lowest no observed adverse effect (NOAEL) value was used (when available) for the most relevant biological end points (e.g. cancer, reproductive damage, organ damage). Such an approach will clearly overestimate the health risk. We have chosen the highest analysis values as regards recycled rubber granulate because this type of rubber granulate contains the largest quantities of potentially hazardous substances and leads to the highest measured values in sports hall air. An analytical detection limit was chosen in cases where no measured value was available.

Nine exposure scenarios were used: adults, juniors, older children and children.

- inhalation exposure: adults, junior, older children and children (Scenarios 1-4)
- skin exposure: adults, junior, older children and children (Scenarios 5-8)
- oral exposure: children (Scenario 9).

Exposure levels were based on inhalation values (inhalation volumes during training sessions/matches) and skin exposure (mg/cm² deposited on the skin). As regards oral exposure (swallowing), we have assumed that up to 1.0 gram of rubber granulate can be swallowed per training session/match.

Exposure duration and frequency are based on information from the managers of the Valhall and Manglerudhallen sports halls in Oslo and Nordlandshallen and Skarpehallen in Tromsø. On the basis of this information, we selected worst case scenarios for the various age groups. These worst case scenarios are based on the highest measured values and the longest/most frequent training/match periods that are used.

Exposure scenarios

As regards the choice of exposure scenarios, four main types of scenario were used for training sessions and matches on artificial turf pitches: adults (20 years, 20-40 years was used for the assessment of cancer risk), juniors (16-19 years), older children (12-15) and children (7-11 years). Exposure times and the type of activity (training and matches) were based on information obtained from the following sports halls: Valhall and Manglerudhallen in Oslo and Nordlandshallen and Skarpehallen in Tromsø. The pattern of use will vary from pitch to pitch and geographic location will be an important factor as regards the times of the year during which indoor pitches are used. Exposure will take place through the inhalation of volatile compounds and particles, through particles coming into contact with the skin (skin exposure is of little importance as

regards volatile compounds) and to some extent through swallowing (assumed to apply largely to children).

Inhalation

The exposure characterisation covers four main scenarios: adults who play/train, juniors who play/train, older children who play and train and children who play/train and play cup tournaments. The respiration volumes are based on information from the Norwegian University of Sport and Physical Education and assume maximum exertion during training sessions. The inhalation volumes used are: adults 6 m³/hour, junior 4.8 m³/hour, older children 3.6 m³/hour and children 1.8 m³/hour. For comparative purposes, the US EPA uses a figure of 3.63 m³/hour for physically demanding work for adults and 2.23 m³/hour for children (6-13 years). The EU uses a figure of 2.6 m³/hour for physically demanding work. The scenarios are described below and are based on information concerning patterns of use of sports halls with artificial turf.

- *Scenario 1: Adults who train and play matches indoors (Skarphallen, Tromsø):*
 - o Body weight = 70 kg
 - o Inhalation volume during training/match = 6 m³/hour
 - o Duration per week = 20 hours
 - o Duration in months = 6 months

In addition to the above, there are also six hours of matches per week for six months.

This indicates a weekly exposure volume (m³/week) of: 156 m³/week for a total of 6 months, 2.23 m³/kg body weight/week, 0.32 m³/kg body weight/day.

- *Scenario 2: Juniors who train and play matches indoors (2 x Valhall):*
 - o Body weight = 65 kg
 - o Inhalation volume during training/match = 4.8 m³/hour
 - o Duration per session = 2 hours
 - o Number of sessions per week = seven sessions per week
 - o Duration in months = 4 months (2 x Valhall) + 1.5 mths (1 x Valhall, three sessions per week)

In addition to the above, there are also two matches of two hours per month for three months.

This indicates a weekly exposure volume (m³/week) of: 75 m³/week for a total of 16 weeks, 1.11 m³/kg body weight/week, 0.16 m³/kg body weight/day.

- *Scenario 3: Older children who train and play matches indoors (Nordlandshallen and Skarpehallen in Tromsø):*
 - o Body weight = 50 kg
 - o Inhalation volume during training/match = 3.6 m³/hour
 - o Duration per week = 10 hours
 - o Duration in months = 6

In addition to the above, there are also two hours of matches per week for six months.

This indicates a weekly exposure volume (m³/day) of: 43.2 m³/week for a total of six months. 0.86 m³/kg body weight/week, 0.12 m³/kg body weight/day.

- *Scenario 4a: Children who train and play matches indoors (Nordlandshallen and Skarpehallen in Tromsø):*
 - o Body weight = 30 kg
 - o Inhalation volume during training/match = 1.8 m³/hour
 - o Duration per week = 10 hours
 - o Duration in months = 6

In addition to the above, there are two hours of matches per week for six months.

This indicates a weekly exposure (m³/day) of: 21.6 m³/week for a total of six months. 0.72 m³/kg body weight/week, 0.10 m³/kg body weight/day.

- *Scenario 4b: Children who play cup tournaments indoors (Valhall):*
 - o Body weight = 30 kg
 - o Inhalation volume during matches 1.8 m³/hour
 - o Inhalation volume with light exertion = 0.8 m³/hour
 - o Time spent in hall, light exertion per cup tournament = 17 hours
 - o Time spent in hall, playing matches per cup tournament = 7 hours
 - o Number of cup tournaments per year = 2 cups
 - o Duration of cup tournament: 2.5 days

This indicates an average exposure volume of: 10.48 m³/day for a total of 5.0 days per year. 0.35 m³/kg body weight/day, five days per year.

Skin contact

During training sessions and matches on artificial turf pitches, there may also be some uptake via the skin. Dust/particles which are released from the rubber granulate (primarily during use) will come into contact with bare skin. Some exposure from covered skin can also be expected, but this will be significantly lower than for bare skin. The skin area which is assumed to be exposed on an adult is: parts of the legs (25% of 2070 cm²), thigh (1980 cm²), arms (2570 cm²), hands (840 cm²) and head (face, 1180 cm²). In total, this represents approximately 7100 cm². If it is assumed that the body area approximately correlates with body weight, juniors and older children have a skin surface which could potentially be exposed of 6600 and 5100 cm² respectively, while the corresponding figure for children (30 kg) is 3000 cm². Where there is no clear evidence that lower skin uptake levels are likely (e.g. for phthalates, 5%), an uptake of 100% is used as a worst case.

One problem when calculating uptake through the skin of chemicals in particles/dust is determining the quantity of particles/dust that is deposited on the skin (specified as mg/cm²). The worst case scenario for children playing on soil has been specified as being 10 mg/cm². As regards exposure of the hands from soil in connection with rugby matches for example, the default value is specified as being 0.2 – 1.0 mg/cm². It is not entirely clear what value should be used for people who use artificial turf pitches. In this study, 1.0 mg/cm² has been chosen as regards the calculation of skin exposure. In addition, 100% skin absorption has been used for chemicals for which there is no specific information concerning skin uptake. A realistic uptake is probably of the order of < 1% to 10% depending on the substance. This means that the uptake that is calculated here is clearly higher than the actual value.

- Scenario 5: Adults who train and play matches indoors:
 - o Body weight = 70 kg
 - o Skin surface which is exposed = 7100 cm²
 - o Duration per session = 4 hours
 - o Number of sessions per week = 5 sessions
 - o Duration in months = 6 months

In addition to the above, there will be six hours of matches per week for six months. It is assumed that these matches are played during the same period in which the training sessions take place. Total skin exposure per week: 42 600 mg rubber granulate/week and 608 mg rubber granulate/kg body weight/week, 87 mg rubber granulate/kg body weight/day.

- Scenario 6: Juniors who train and play matches indoors:
 - o Body weight = 65 kg
 - o Skin surface which is exposed = 6600 cm²
 - o Duration per session = 2 hours
 - o Number of sessions per week = 7 sessions per week
 - o Duration in months = 4 months (2 x Valhall) + 1.5 mths (1x Valhall, three sessions per week)

In addition to the above there will be two matches of two hours per month for three months. It is assumed that these matches are played during the same period in which the training sessions take place.

Total skin exposure per week: 49 500 mg rubber granulate/week and 762 mg rubber granulate/kg body weight/week, 109 mg rubber granulate/kg body weight/day.

- Scenario 7: Older children who train and play matches indoors:
 - o Body weight = 50 kg
 - o Skin surface which is exposed = 5100 cm²
 - o Duration per session = 2.5 hours
 - o Number of sessions per week = 4 sessions per week
 - o Duration in months = 4 months (2 x Valhall) + 1.5 mths (1x Valhall, three sessions per week)

In addition to the above there are two hours of matches per week for six months. It is assumed that these matches are played during the same period in which the training sessions take place.

Total skin exposure per week: 25 500 mg rubber granulate/week and 510 mg rubber granulate/kg body weight/week, 73 mg rubber granulate/kg body weight/day.

- Scenario 8a: Children who train and play matches indoors:
 - o Body weight = 30 kg
 - o Skin surface which is exposed = 3000 cm²
 - o Duration per session: 2.5 hours
 - o Number of sessions per week: 4
 - o Duration in months: 6

In addition to the above there are two hours of matches per week for six months. It is assumed that these matches are played during the same period in which the training sessions take place.

Total skin exposure per week: 15 000 mg rubber granulate/week and 500 mg rubber granulate/kg body weight/week, 71 mg rubber granulate/kg body weight/day.

- Scenario 8b: Children who play cup tournaments indoors:
 - o Body weight = 30 kg
 - o Skin surface which is exposed = 3000 cm²
 - o Time spent in hall, light exertion per cup tournament = 17 hours
 - o Time spent in hall, playing matches per cup tournament = 7 hours
 - o Number of cup tournaments per year = 2 cup tournaments
 - o Number of matches per cup tournament: 7
 - o Duration per cup tournament: 2.5 days

It is assumed that the children will shower between each match, so that their skin is exposed on seven occasions during a cup tournament. Normal time spent in the hall is not considered to lead to significant skin exposure. This indicates an average exposure (mg/day) of: 280 mg rubber granulate/kg body weight/day for a total of five days.

Oral intake

It is assumed that children who play and train on artificial turf pitches can also be exposed to the rubber material that is used by placing it in their mouth and then chewing and possibly also swallowing it. We do not have any indication of how much rubber material may be involved, but it will probably be of the order of 0.5-1 grams per match/training session. In a worst case assessment, it is reasonable to assume a value of 1 gram per match/training session and that 100% of what is swallowed is taken up via the gastrointestinal tract.

- Scenario 9a: Children who train and play matches indoors:
 - o Body weight = 30 kg
 - o Quantity swallowed per training session/match = 1.0 gram
 - o Assumed uptake = 100%
 - o Number of sessions per week = 4
 - o Duration in months = 6
 - o Total number of times per year = 64

In addition to the above, there will be one match per week for six months.

This indicates a repeated exposure per week of: 5 grams of rubber granulate and 0.71 grams/day, and 23.7 mg/kg body weight/day with a duration of six months.

- Scenario 9b: Children who play cup tournaments indoors:
 - o Body weight = 30 kg
 - o Quantity swallowed per match = 1.0 gram
 - o Assumed uptake = 100%
 - o Number of exposures per year = 14 times (7 matches per cup tournament, two cup tournaments per year)

This indicates an acute exposure per cup tournament of: 7.0 gram, 2.8 gram/day (one cup tournament lasts 2.5 days) and 93.4 mg rubber granulate/kg body weight/day for five days a year.

Measurements and calculations

Many different chemical substances have been demonstrated in samples of rubber granulate and during the degassing of these samples which are classified as hazardous.

The results of analyses of two different types of elastomer, one type of recycled rubber granulate, one type of EPDM rubber granulate, one type of thermoplastic elastomer and two types of artificial turf fibre are available. Leaching studies have also been carried out on various types of rubber granulate and artificial turf fibre, in addition to the degassing from rubber granulate. As the content of hazardous chemicals in the EPDM rubber was clearly lower than that for the recycled rubber granulates, it was decided not to include EPDM rubber granulate in the following risk assessment.

Based on the content of hazardous substances to health and the degree of exposure, it is concluded that oral exposure resulting from training/playing on pitches based on artificial turf fibre will not cause any increased health risk. The assessment of health risk is therefore related to exposure which is due to particles/dust and degassing from the rubber granulate itself. To assess the health risk, data from the sample of recycled rubber granulate which showed the highest concentrations of hazardous substances was used.

Analyses of rubber granulates and artificial turf fibres were undertaken by AnalyCen AS whilst at NILU analyses were carried out for selected elements and organic compounds. Leaching from artificial turf fibre and rubber granulates was carried out using standardised methods. The leaching of heavy metals into water was measured by adding 200 grams of rubber granulate or artificial turf fibre to 2 litres of water and leaving the solid material in contact with the water for 24 hours. To measure the leaching of organic compounds, 1 litre of water and 100 grams of rubber granulate were used with a contact time between the water and granulate of 48 hours. As regards degassing from rubber granulate, 2 grams of rubber granulate heated to 70°C for 30 minutes were used. The quantity of airborne dust was determined gravimetrically after it had been collected on a quartz filter. A distinction was made between particle sizes (PM10 and PM2.5). For more information on the analyses, see the NILU report of January 2006. Uncertainty in the measurements is of the order of 10 – 30%.

Inhalation

Degassing of volatile organic compounds (VOC)

The degassing of organic compounds was measured for recycled rubber granulate and one type of EPDM rubber granulate. Selected alkylated benzenes and two chlorinated compounds were measured. Degassing from the EPDM rubber was clearly lower than that from the other rubber granulates. In total, this was in the order of 250-400 µg/kg of granulate. The degassing was investigated at a temperature of 70°C, which is well above the likely temperature of the hall. The values quoted are therefore higher than would be expected during normal use of artificial turf pitches. These values will not be used in the risk assessment because measurements of indoor air are available for artificial turf pitches.

Measurements are available for VOC from a number of indoor artificial turf pitches during training sessions. In Manglerudhallen, 234 chemical compounds were found (concentration > 0.1 µg/m³, of which 29 were identified), which gave a total VOC of approx. 716 µg/m³. Four-fifths of the sampling period was carried out with full ventilation in the hall, which means that the concentration of VOC must have been higher before ventilation was commenced, possibly as high as 1000 µg/m³. This is the result from just one measurement. Concentrations varied from approx. 85 to 0.8 µg/m³. For 14 of these compounds, the concentration was in the range 10-85 µg/m³. 4-Methyl-2-pentanone, benzothiazole, isomers of xylene, toluene, octenal, acetone,

styrene and dodecane were among these compounds. During the second sampling period, a total VOC of approx. 230 µg/m³ was measured. People often begin to complain about the air quality when the total VOC is higher than 100-200 µg/m³. It can be concluded that the rubber granulate is the main source of the VOCs which were measured in the hall. Subsequent samples in the hall (roof hatches and windows closed, temperature of 15^o C showed a total VOC of 255 µg/m³. Under conditions where the temperature inside the hall was again 20^o C, a total VOC of 732 µg/m³ was measured.

In Østfoldhallen, where new factory-made granulate was used, the concentration of VOC was relatively low (approx. 150 µg/m³), even during exertion. This level is not uncommon in general indoor environments. A number of sources are assumed to contribute to the VOC measured inside the hall (artificial turf, rubber granulate, timber in the hall and road traffic outside the hall).

For the Valhall artificial turf pitch, a mean total VOC of 234 µg/m³ was measured, whilst in the second half of the measurement period, 290 µg/m³ was measured. It is concluded that the main source of VOC in the hall is the rubber granulate.

In the subsequent risk assessment, a total VOC concentration in the hall air of 716 µg/m³ was chosen as a worst case scenario. This value was chosen because it is based on measurements taken under conditions which can occur in the hall. Measurements in both Østfoldhallen and Valhall indicate values 2.5 to 3 times lower however.

Based on these scenarios, the total uptake of VOC through inhalation (assuming 100% uptake) has been calculated. The resulting figures are shown in the table below.

Table 1: Uptake of total VOC via the lungs

Scenarios	Exposure weeks	Inhalation volume m ³ /kg body weight/day	Concentration of VOC in hall air µg/m ³	Uptake %	Uptake VOC µg/kg body weight/day
Adults	26*	0.32	716	100	229
Junior	16*	0.16	716	100	115
Older children	26*	0.12	716	100	86
Children training + matches	26*	0.10	716	100	72
Children Cup tournament	0.7**	0.35	716	100	251

* Repeated exposure

** Single exposure

The table below shows the measured concentrations and classification of volatile organic compounds (VOC) in artificial turf halls with recycled rubber granulate. Many of these substances are not classified. This does not however mean that the substances cannot constitute a health risk; simply that no toxicological information is available or the substance has not been assessed with regard to classification. The substances which have been identified vary from hall to hall, and there is no clear link between the concentrations of total VOC which have been measured in a hall and the concentrations of many of the individual volatile compounds.

Table 2: Concentrations $< 2.0 \mu\text{g}/\text{m}^3$ of volatile compounds (VOC) in artificial turf halls with recycled rubber granulate

Substance	CAS no.	Classification (health)	Concentration $\mu\text{g}/\text{m}^3$
Toluene	108-88-3	R38-48/20-63-65-67	85.0*, 15.3**
Butenylbenzene (isomers)	-	-	82.5*
Benzoic acid	65-85-0	-	81.0*, 19.3**
Diethenylbenzene (isomers)	-	-	65.7*
<i>p</i> - and <i>m</i> -Xylene	106-42-3	R20/21-38	25.5*, 9.6**
Ethylbenzene aldehyde (isomers)	53951-50-1	-	34.7*
Benzothiazole	95-16-9	-	15.7*, 31.7**
1,1'-Biphenyl	92-52-4	R36/37/38	15.6*
Acetone	67-64-1	R36-66-67	15.3*, 9.5**
<i>o</i> -Xylene	95-47-6	R20/21-38	13.1*
4-Methyl-2-pentanone	108-10-1	R20-36/37	12.7*, 12.7**
3-Phenyl-2-propenal	104-55-2	-	10.2*
Pentenylbenzene (isomers)	-	-	7.3*
Pentanedioic acid dimethyl ester	1119-40-0	-	6.8*
Ethylbenzene	100-41-4	R20	6.7*, 3.3**
Styrene	100-42-5	R20-36/38	6.1*, 3.2**
Hexenylbenzene (isomers)	-	-	15.5*
Ethylcyclohexane	1678-91-7	-	5.6*
Formaldehyde	50-00-0	R23/24/25-34-40-43	5.5*, 6.5**
2-Butoxyethanol	111-76-2	R20/21/22	5.3*
Unidentified naphthalene derivative	-	-	9.3*
Octane	111-65-9	R38-65-67	4.6*
Undecane	1120-21-4	-	4.6*, 3.1**
Acetaldehyde	75-07-0	R36/37-40	4.3*, 2.9**
Nitromethane	75-52-5	R22	4.1*
1-Propylbenzene	673-32-5	-	4.0*
Alpha-pinene	80-56-8	-	10.5**
Cyclohexanone	108-94-1	R20	9.8**
Junipene	475-20-7	-	7.2**
Acetic acid	64-19-7	R35 < 0% no class.	4.3**
Decane	124-18-5	-	5.0**

Dodecane	112-40-3	-	3.7**
1,2,3-Trimethylbenzene	95-63-6	R20-36/37/38	3.2**
Limonene	138-86-3	R38-43	2.6**
2-Methylnaphthalene	91-57-6	-	2.5**
Benzene	71-43-2	R45-46-36/38-48/23/24/25-65	2.4**
3-Carene	13466-78-9	-	2.2**
Pentadecane	629-62-9	-	2.2**
2,3-Dihydro-1,1,3-trimethyl-3-phenyl-1H-indene	3910-35-8	-	2.1**
Hexanal	66-25-1	-	2.0**
1,2-Propanediol	57-55-6	-	2.0**
1-Methoxy-2-propanol	107-98-2	-	2.0**

* Total identified VOC 590 µg/m³, Manglerudhallen

** Total identified VOC 190 µg/m³, Valhall

As is apparent from the table above, most of the substances which have been classified have been classified on the basis of acute toxicity and irritation. Only a few substances have been classified with regard to possible long-term effects and allergies.

Table 3: Estimated uptake through inhalation of selected volatile compounds based on concentrations measured in the hall air for artificial turf pitches in which recycled rubber granulate is used.

Compounds	Concentration µg/m ³	Estimated uptake through inhalation µg/kg body weight/day				
		Adults (0.32 m ³ /kg/day)	Juniors (0.16 m ³ /kg/day)	Older children (0.12 m ³ /kg/day)	Children training (0.10 m ³ /kg/day)	Children cup tournaments (0.35 m ³ /kg/day)
Toluene	85.0	27.2	13.6	10.2	8.5	29.8
Butenylbenzene	82.5	26.4	13.2	9.9	8.3	28.9
Benzoic acid	81.0	25.9	13.0	9.7	8.1	28.4
Diethenylbenzene	66.7	21.3	10.7	8.0	6.7	23.3
<i>p</i> - and <i>m</i> -Xylene	25.5	8.2	4.1	3.1	2.6	8.9
Ethylbenzene aldehyde	34.7	11.1	5.6	4.2	3.5	12.0
Benzothiazole	31.7	10.1	5.1	3.8	3.2	11.1
1,1'-Biphenyl	15.6	5.0	2.5	1.9	1.6	5.5
Acetone	15.3	4.9	2.5	1.8	1.5	5.4
<i>o</i> -Xylene	13.1	4.2	2.1	1.6	1.3	4.6
4-Methyl-2-pentanone	12.7	4.1	2.1	1.5	1.3	4.5
3-Phenyl-2-propenal	10.2	3.3	1.7	1.2	1.0	3.6
Styrene	6.1	2.0	1.0	0.7	0.6	2.1
Formaldehyde	6.5	2.1	1.1	0.8	0.7	2.3
Acetaldehyde	4.3	1.4	0.7	0.5	0.4	1.5
Alpha-pinene	10.5	3.4	1.7	1.3	1.1	3.7
Limonene	2.6	8.3	4.2	0.3	0.3	0.9
Benzene	2.4	0.8	0.4	0.3	0.2	0.8

Amongst the substances in the table above, there are compounds which have either been classified as allergy-triggering through skin contact or where on the basis of structural similarity with known allergens it is reasonable to assume that they could lead to contact allergy. Many of the substances can act as an irritant to the skin, eyes and mucous membranes. The concentration of volatile irritating compounds is however so low that it is unlikely that they would cause irritation during training, matches or other time spent in the halls. As regards acute effects, the estimated uptake via the lungs is of the order of 1 – 40 µg/kg body weight/day. For comparative purposes, the doses which have been shown to lead to acute poisoning are more than 1000 times higher than those estimated for exposure as a result of inhalation in indoor halls.

Our assessment is that exposure (through inhalation) to volatile organic compounds (VOC) as a result of using halls in which recycled rubber granulate is used will not cause an increased health risk as regards the harmful effects of short-term exposure (acute poisoning and irritation). The degree to which repeated exposure (inhalation) could constitute a health risk has been assessed on the basis of information concerning NOAEL values and the type of harmful effect for each individual substance and the degree of exposure.

Airborne dust

The quantity of airborne dust in indoor environments is influenced by many factors such as level of exertion and the room’s shape, ventilation and building materials. In Manglerudhallen, a PM10 of 40 µg/m³ and a PM2.5 of 17 µg/m³ were measured during ventilation. The corresponding mean values for outdoor air in the Oslo study are 21 µg/m³ and 7 µg/m³ respectively. In Østfoldhallen, the PM10 level was 31 µg/m³ whilst the PM2.5 level was 10 µg/m³. In Valhall, the PM10 level was 32 µg/m³ whilst the PM2.5 level was 19 µg/m³. By comparison, it is noted that the average concentration of PM10 in homes, nurseries and schools is of the order of 20 µg/m³. In both Manglerudhallen and Valhall, it is assumed that the main source of airborne dust is recycled rubber granulate. In Manglerudhallen, 30% of the PM10 fraction and 50% of the PM2.5 fraction was rubber dust.

In the subsequent risk assessment, the highest measured level for PM10 of 40 µg/m³ was selected as regards respirable dust (particles).

The table below shows estimated intake scaled up in relation to the PM10 fraction through the inhalation of dust/particles.

Table 4: Estimated intake of PM10 via the lungs

Scenarios	Exposure weeks	Inhalation volume m ³ /kg body weight/day	Concentration of PM10 in hall air µg/m ³	Intake %	Intake PM10 µg/kg body weight/day
Adults	26*	0.32	40	100	12.8
Junior	16*	0.16	40	100	6.4
Older children	26*	0.12	40	100	4.8
Children training/matches	26*	0.10	40	100	4.0
Children cup tournaments	0.7**	0.35	40	100	14.0

* Repeated exposure

** Single exposure

Table 5: Estimated intake via the lungs of PCBs, PAHs, phthalates and alkyl phenols in the PM10 based on the concentration of these substance groups in recycled rubber granulate

Scenarios	Exposure weeks	Intake PM10 $\mu\text{g}/\text{kg}$ body weight/day	Total content in recycled rubber granulate $\text{pg}/\mu\text{g}$ rubber granulate				Estimated uptake pg/kg body weight/day			
			PCBs	PAHs	Phthalates	Alkyl phenols	PCBs	PAHs	Phthalates	Alkyl phenols
Adults	26*	12.8	0.202	76	118	55	2.6	973	1510	704
Junior	16*	6.4	0.202	76	118	55	1.3	486	755	352
Older children	26*	4.8	0.202	76	118	55	1.0	365	566	264
Children training/matches	26*	4.0	0.202	76	118	55	0.8	304	472	220
Children cup tournaments	0.7**	14.0	0.202	76	118	55	2.8	1064	1652	770

* Repeated exposure

** Single exposure

Table 6: Estimated intake of PAHs based on measured values of PAHs in the PM10 fraction in artificial turf halls where recycled rubber granulate is used (uptake set at 100%)

Scenarios	Exp. weeks	Inhalation volume m^3/kg body weight/day	Concentration of PAH in PM10 in hall air ng/m^3	Concentration of phthalates in PM10 in hall air ng/m^3	Intake PAH pg/kg body weight/day	Intake phthalates pg/kg body weight/day
Adults	26*	0.32	10.8	134.4	3456	43 000
Junior	16*	0.16	10.8	134.4	1728	21 500
Older children	26*	0.12	10.8	134.4	1296	16 130
Children training/matches	26*	0.10	10.9	134.4	1080	13 400
Children cup tournaments	0.7**	0.35	10.8	134.4	3780	47 000

* Repeated exposure

** Single exposure

It appears that the quantity of PAH based on measurements of PAH in the PM10 fraction is approximately three times higher than the figure estimated on the basis of total PM10 and the concentration which was measured in the recycled rubber granulate. The extent to which this is due to actual differences, or differences in the analysis results as regards concentrations of PAH in the granulate and in the PM10 fraction of the granulate or the result of other sources contributing PAH to the PM10 fraction has not been clarified. If the measurements of PAH in the PM10 fraction are used as a basis, the uptake of PAH is of the order of 2-5 µg/kg body weight/day. There are no specific PM10 values as regards PCBs or alkyl phenols. For these, values estimated on the basis of concentration in the rubber granulate and the total quantity of PM10 which is assumed to be taken up via the lungs must be used.

A daily uptake of 3800 pg PAH/kg body weight is used as a worst case scenario in the subsequent risk characterisation. For PCB, a value of 3 pg/kg body weight was used, whilst values of 47000 pg/kg and 800 pg/kg body weight were used for phthalates and alkyl phenols respectively. Given the very small quantities of this type of compounds which are taken up per day, it can be concluded that they do not constitute an increased health risk.

Phthalates

Measurements in hall air of phthalates in µg/m³ taken from the NILU report is shown in table 7.

Table 7: Measurements of phthalates in hall air

Phthalate	µg/m ³
di-butylphthalate (DBP)	0.38
di-ethylphthalate (DEP)	0.09
di-isobutylphthalate (DIBP)	0.13
Total	0.6

Total content of phthalates in rubber granulates from Byggforsk (worst case measurement from 2-4 samples) is shown in table 8.

Table 8: Content of phthalates in rubber granulates

Phthalate	Rubber granulate (mg/kg)
Di-methylphthalate (DMP)	< 1.0
Di-ethylphthalate (DEP)	< 1.0
Di-butylphthalate (DBP)	3.9
Benzylbutylphthalate (BBP)	2.8
Di-ethylhexylphthalate (DEHP)	29.0
Di-n-octylphthalate (DOP)	< 1.0
Di-isononylphthalate (DINP)	78.0
Di-isodecylphthalate (DIDP)	< 1.0
Total	117.7

- *Scenario 1: adults who train and play matches indoors:*

They inhale 0.32 m³/kg body weight/day.

Based on NILU, the quantity of phthalates in the air was 0.6 µg/m³:

The quantity of phthalate inhaled per day is therefore 0.19 µg/kg body weight/day.

- *Scenario 2: Juniors who train and play matches indoors:*

They inhale 0.16 m³/kg body weight/day.

Based on NILU, the quantity of phthalates in the air was 0.6 µg/m³:

The quantity of phthalate inhaled per day is therefore 0.10 µg/kg body weight/day.

- *Scenario 3: Older children who train and play matches indoors:*

They inhale 0.12 m³/kg body weight/day.

Based on NILU, the quantity of phthalates in the air was 0.6 µg/m³:

The quantity of phthalate inhaled per day is therefore 0.07 µg/kg body weight/day

- *Scenario 4a: Children who train and play matches indoors:*

They inhale 0.10 m³/kg body weight/day.

Based on NILU, the quantity of phthalates in the air was 0.6 µg/m³:

The quantity of phthalate inhaled per day is therefore 0.06 µg/kg body weight/day

- *Scenario 4b: Children who play cup tournaments indoors:*

They inhale 0.35 m³/kg body weight/day for five days a year.

Based on NILU, the quantity of phthalates in the air was 0.6 µg/m³:

The quantity of phthalate inhaled per day is therefore 0.21 µg/kg body weight/day for five days a year.

Alkyl phenols

Alkyl phenols were below the detection limit in the air measurements from Manglerudhallen, Valhall and Østfoldhallen undertaken by NILU. In the calculations, the detection limit of 0.01 to 0.05 µg/m³ was used as a starting point (the detection limit for phthalates has been used).

Total content of alkyl phenols in rubber granulates, Byggforsk (worst case measurement from two-four samples) is shown in table 9.

Table 9: the content of alkyl phenols in rubber granulates

Alkyl phenol	Rubber granulates (µg/kg)
4-t-octylphenol	33700
4-n-nonylphenol	< 5
Iso-nonylphenol	21600
Total	55305

- *Scenario 1: adults who train and play matches indoors:*

They inhale 0.32 m³/kg body weight/day.

Measurements of alkyl phenols were below the detection limit in all three halls. The detection limit for alkyl phenols is assumed by NILU to vary from 0.01 – 0.05 µg/m³:

The quantity of alkyl phenols inhaled per day is therefore 0.016 µg/kg body weight/day based on the detection limit of 0.05 µg/m³.

- *Scenario 2: Juniors who train and play matches indoors:*

They inhale 0.16 m³/kg body weight/day.

Measurements of alkyl phenols were below the detection limit in all three halls. The detection limit for alkyl phenols is assumed by NILU to vary from 0.01 – 0.05 µg/m³:

The quantity of alkyl phenols inhaled per day is therefore 0.008 µg/kg body weight/day based on the detection limit of 0.05 µg/m³.

- *Scenario 3: Older children who train and play matches indoors:*

They inhale 0.12 m³/kg body weight/day.

Measurements of alkyl phenols were below the detection limit in all three halls. The detection limit for alkyl phenols is assumed by NILU to vary from 0.01 – 0.05 µg/m³:

The quantity of alkyl phenols inhaled per day is therefore 0.006 µg/kg body weight/day based on the detection limit of 0.05 µg/m³.

- *Scenario 4a: Children who train and play matches indoors*

They inhale 0.10 m³/kg body weight/day.

Measurements of alkyl phenols were below the detection limit in all three halls. The detection limit for alkyl phenols is assumed by NILU to vary from 0.01 – 0.05 µg/m³:

The quantity of alkyl phenols inhaled per day is therefore 0.005 µg/kg body weight/day based on the detection limit of 0.05 µg/m³.

- *Scenario 4b: Children who play cup tournaments indoors:*

They inhale 0.35 m³/kg body weight/day for five days a year.

Measurements of alkyl phenols were below the detection limit in all three halls. The detection limit for alkyl phenols is assumed by NILU to vary from 0.01 – 0.05 µg/m³:

The quantity of alkyl phenols inhaled per day, over a total of five days per year, is therefore 0.018 µg/kg body weight/day based on the detection limit of 0.05 µg/m³.

Skin contact

Of the total quantity of chemicals which exist in the form of particles/dust, only a limited proportion will be available for uptake into the body through the skin. Studies of leaching from rubber particles have been carried out on behalf of Byggforsk in which leaching from 100 grams of rubber granulate/fibre was measured after contact for 48 hours with 1 litre of deionised water. If it is assumed that the quantity of chemical substances which is available for uptake via the skin corresponds to what has been found for leaching into water, it is possible to estimate approximately how much will be available for skin uptake. The degree of leaching into water will depend on how the substance is bound to the rubber granulate (strongly

bound or not) and the substance’s physical-chemical properties (e.g. water solubility). In our calculation of skin exposure, we chose to use the leaching factor which gives the most leaching. Based on analyses carried out on behalf of Byggforsk and results for total organic carbon, it was decided to use a leaching figure of 60 mg/litre/100g of rubber granulate. This corresponds to 0.06% of the weight of the rubber granulate. Based on the analysis data, leaching has been calculated at $0.8 \times 10^{-6}\%$ for total PCBs, $1 \times 10^{-6}\%$ for total PAHs, $30 \times 10^{-6}\%$ for total phthalates and $5 \times 10^{-6}\%$ for total alkyl phenols.

Table 10 shows the estimated quantities of PCBs, PAHs, phthalate and alkyl phenol which are assumed to be available for skin uptake following exposure to rubber granulate particles and dust

Scenario	Particle/dust exposure (mg/kg body weight/day)	PCBs ng/kg body weight/day	PAHs ng/kg body weight/day	Phthalates ng/kg body weight/day	Alkyl phenols ng/kg body weight/day
		Bioavailability $0.8 \times 10^{-6}\%$	Bioavailability $1 \times 10^{-6}\%$	Bioavailability $30 \times 10^{-6}\%$	Bioavailability $5 \times 10^{-6}\%$
Adults	87	0.7	0.87	26.10	4.35
Junior	109	0.87	1.09	32.70	5.45
Older children	73	0.58	0.73	21.90	3.65
Children training/matches	71	0.57	0.71	21.30	3.55
Children cup tournaments	280*	2.24*	2.8*	84.00*	14.00*

* Short-term exposure (total of approximately five days per year)

As is apparent from the table above, exposure via the skin is extremely low. In reality, it will be much lower still for many of the substances. This particularly applies to phthalates, where uptake through the skin is of the order of 5% of the component which is available for uptake.

Oral intake

It must be assumed that children in particular could swallow some rubber granulate during matches or training sessions. It has been assumed that this will amount to no more than approximately 1 gram per training session/match. 100% uptake from the gastro-intestinal tract is also assumed. The oral intake for children has been estimated on the basis of these assumptions.

Phthalates

Scenario 9a, children who train and play matches indoors swallow 23.7 mg of rubber granulate/kg body weight/day. The quantity of phthalate in rubber granulate is 118 ng/mg rubber granulate. Children are therefore exposed to **2.8 µg phthalate/kg body weight/day** over 6 months.

Scenario 9b, children who play cup tournaments indoors swallow 93.4 mg of rubber granulate/kg body weight/day over five days a year. The quantity of phthalate in rubber granulate is 118 ng/mg of rubber granulate. Children are therefore exposed to **11.0 µg phthalate/kg body weight/day** over five days a year.

Alkyl phenols

Scenario 9a, children who train and play matches indoors swallow 23.7 mg of rubber granulate/kg body weight/day. The quantity of alkyl phenols in rubber granulate is 55.3 ng/mg of rubber granulate. Children are therefore exposed to **1.3 µg alkyl phenols/kg body weight/day** over 6 months.

Scenario 9b, children who play cup tournaments indoors swallow 93.4 mg of rubber granulate/kg body weight/day over five days a year. The quantity of alkyl phenols in rubber granulate is 55.3 ng/mg of rubber granulate. Children are therefore exposed to **5.2 µg of alkyl phenols/kg body weight/day** over five days a year.

Assessment of harmful effects

VOC

Volatile organic compounds can cause a variety of adverse effects on health. The effect will depend on whether one is exposed sufficiently and the duration/frequency of the exposure. Unfortunately, there is little or no information available on the potential health hazards posed by many of these substances. Examples of harmful effects include damage to the nervous system, liver, kidney, blood-forming organs, genetic material and reproductive organs as well as allergy and cancer. The table below shows the classification and relevant NOAEL values for a number of VOCs which have been identified in the gas phase (the hall air) in artificial turf pitches in which recycled rubber granulate is used.

Table 11: Classification and NOAEL (C) values for selected VOCs

Substance	Classification	NOAEL(C)	Effect
Toluene	R38-48/20-63-65-67	340 mg/kg/day* 390 mg/kg/day* 150 mg/m ³ **	Reduced sperm quality in rats Neurological effects in rats (hearing) Headaches, irritation and tiredness in humans
Buteny/benzene	No information found.	No information found.	No information found.
Benzoic acid	No information found.	550 mg/kg/day* (one dose) 5 mg/kg/day†	Inhalation causes irritation in the nose and throat, and particles in the eyes and on the skin of humans. Reduced weight in rats, otherwise no effects concerning neurotoxicity. Increased number of resorptions in rats
Xylenes	R20/21-38	20 ppm* (87 mg/m ³) 50 – 100 ppm* (220 – 440 mg/m ³) 50 ppm* (220 mg/m ³)	Irritation of eyes and airways in humans Neurological effects in humans Reduced number of red and white blood cells in rats

Styrene	R20-36/38	150 ppm* (640 mg/m ³)	Reduced body weight and delayed development in offspring
Formaldehyde	R23/24/25-34-40-43		<i>Effects on humans</i>
		0.5 mg/m ³ * 0.06 mg/m ³ ** 0.12 mg/m ³ ** 0.45 mg/m ³ * 1.0 – 1.8 mg/m ³ *	Effect in the nasal cavity Eye irritation Airway irritation Airway contractions Nasal cancer
Benzene	R45-46-36/38-48/23/24/25-65	Acceptable air concentration for life-long exposure (RfC) = 30 µg/m ³ ; RfD = 4 µg/kg/day	Effects on bone marrow, reduced number of red and white blood cells. Neurological and reproductive effects at slightly higher doses
Limonene	R38-43	5.6-6.6 g/kg body weight** 10 mg/kg/day*	Liver toxicity Irritation
Benzothiazole	The substance is assumed to cause allergic reactions	Intravenously in mice = 95 mg/kg body weight**	Moderate acute toxicity, no chronic toxicity data found.

* Repeated exposure

** Single exposure

Total VOC

Total VOC (the sum of the concentrations of selected organic compounds defined on the basis of their volatility and analysis and estimation method) were used in assessments of indoor air quality. The levels of this collective parameter vary considerably between indoor environments and is also strongly affected by static and variable indoor sources. As total VOC represents the sum of many different chemical compounds with different properties, total VOC levels do not provide a basis for a health risk assessment. In normal indoor air assessments, abnormally high levels will however result in an assessment of whether there are specific sources and if so how these sources can be reduced on the basis of a general desire to minimise exposure to chemicals. In the analyses that are available, total VOC levels are significantly higher than those which NILU found in general indoor environments without any special sources which liberate volatile organic compounds to the atmosphere. It is also concluded in the NILU report that the composition of individual chemicals in the total VOC samples indicates that the rubber granulate used in the pitches is an important contributor to total VOC. This is because small particles on the pitch surface give the rubber granulate a large surface area, enabling volatile chemicals in the material to evaporate into the air over time. Other common examples which contribute to elevated total VOC levels as in this case are rooms with wooden panels on the walls and rooms with recently carpeted floors. Total VOC levels also remain high for a long time after rooms have been refurbished.

As the air samples taken from these halls also indicate a mixture of many organic compounds, none of the individual substances will occur in concentrations which give cause for concern over health effects. It is however possible that individual substances or mixtures of substances could contribute to odours or mucous membrane irritation which particularly sensitive individuals may notice even at these relatively low levels. This could contribute to the perception of poor, heavy or “dry” air. As smell is part of mankind’s warning system for possible dangers, the possibility of some people reacting with symptoms such as tiredness or headaches must be kept open. In this type of indoor area, where people voluntarily spend time on enjoyable activities, such links must be assumed to be unlikely.

There is no adequate scientific basis for concluding that short or extended periods of time spent in an atmosphere with total VOC levels equivalent to those which were measured in indoor halls with artificial turf could lead to adverse effects on health.

The most important reason for “poor air” in sports halls is body odour linked to physical activity. This is the reason why sports halls have more demanding requirements for ventilation than other premises.

PCBs

PCB (polychlorinated biphenyls) is a complex group of chemicals, some of which have dioxin-like effects. Exposure to PCBs is associated with a broad spectrum of health effects in animals. Amongst the harmful effects of PCB exposure in animals are cancer and effects on the immune, reproductive, nervous and hormonal systems. PCBs are classified as harmful (Xn) and can be accumulated in the body as a result of repeated exposure (R33). The IARC (International Agency for Research on Cancer) classifies PCBs as possibly being carcinogenic in humans. We have chosen to compare the exposure levels for PCBs with a no observed adverse effect level based on reproductive effects (NOAEL = 5 µg/kg body weight/day).

Benzene

Benzene is a carcinogenic substance which has been found to cause leukaemia in humans. The WHO Air Quality Guidelines for Europe (WHO Regional Publications, European Series, No. 91, Copenhagen 2000) has recommended that when estimating lifetime cancer risk, a level of 1.7 µg/m³ benzene should be assumed to cause a lifetime cancer risk of 10⁻⁵. As regards cancer risk, it has been assumed that it is impossible to identify a threshold risk value, i.e. any exposure will cause a certain degree of risk.

PAHs

Polycyclic aromatic hydrocarbons (PAHs) or tar compounds is a collective term for a large number of chemical substances which are formed during combustion. The substance group PAH contains a number of mutagenic substances, some of which are demonstrably or probably carcinogenic. Benzo(a)pyrene (BaP) is the most studied PAH compound. It has been shown to be carcinogenic in animal experiments both after inhalation and as a result of intake through food. When assessing the cancer risk due to exposure to PAH, it is therefore common to use BaP as an indicator and calculate the cancer risk on the basis of the concentration of BaP in air or food.

Many PAHs are classified as carcinogenic substances in cancer category 2, whilst B(a)P is classified as carcinogenic R45 category 2, R46 Mut. category 2. and Repro category 2 R60 and R61. We have chosen B(a)P as a worst case and used the measured values and a NOAELBaP = 40 mg/kg/body weight/day for fertility as a basis.

Phthalates

Some of the most harmful phthalates are DEHP, DBP and BBP. In animal experiments, these have been shown to cause adverse effects on reproduction, particular in young male animals, covering both reproductive ability and embryo development. In the EU, DEHP, DBP and BBP are classified in category 2 for reproductive effects, which means that the use of these phthalates in consumer products is regulated. As phthalates are present in many consumer products which are used indoors, a possible link has been found between exposure to phthalates in house dust and asthma/allergy illnesses in children, but this link has yet to be clarified. In table 12 below the No Observed Adverse Effect Levels (NOAEL) for testicular toxicity/fertility and effects on the development of embryos for DEHP, DBP and BBP are shown.

Table 12: NOAEL for testicular toxicity/fertility and embryo development

Phthalate	NOAEL Fertility/testicular toxicity mg/kg body weight/day	NOAEL Embryo development mg/kg body weight/day
DEHP	4.8	4.8
DBP	52	50.0
BBP	100	50.0

A NOAEL of 4.8 mg/kg body weight is used in the subsequent risk characterisation of phthalates.

Alkyl phenols

In animal experiments, alkyl phenols such as 4-nonylphenol and 4-t-octylphenol have been shown to have properties equivalent to the female sex hormone oestrogen. This means that it can disrupt the hormonal balance in animals, which in turn can affect development of the experimental animals' ability to reproduce. In the EU, 4-nonylphenol is classified in category 3 for effects on reproduction, whilst 4-t-octylphenol is not classified in the EU with regard to possible effects on reproduction. Classification in category 3 means that the use of alkyl phenols in consumer products is not regulated. As 4-nonylphenol is the alkyl phenol which is associated with the most concerns, the no observed adverse effect level (NOAEL) for this alkyl phenol will be used in the risk assessment. In accordance with the EU's risk report for 4-nonylphenol, the NOAEL value for effects on the development of reproductive organs is 15 mg/kg body weight/day. In animal experiments, it has been assumed that only 10% of 4-nonylphenol is absorbed, and is thus bioavailable. The NOAEL value used in the risk assessment for exposure to alkyl phenols will therefore be 1.5 mg/kg body weight/day.

Allergy

With regard to contact allergy (allergic contact dermatitis), for the substances which are assumed to be contact allergens, the decisive exposure factor is not body dose, but the dose per unit area of the skin (i.e. a dose which sensitises if it is applied in a concentrated form over a small area of the skin will not sensitise if it is spread over a larger skin area). In general, at the exposure levels that apply to artificial turf pitches the dose will be low and distributed over most of the body. The only exception could be in shoes, where dust can collect over time, so the changing/cleaning of footwear could be one aspect to remember in connection with training on artificial turf.

As regards airway allergies, latex (natural rubber) is a potent allergen and latex allergy is not uncommon. Car tyres can contain large quantities of latex, and emissions of latex from road traffic due to tyre wear are very high compared to other allergens. However, no increased occurrence of latex allergy has been

demonstrated in individuals who live near busy roads compared with people who live further away from such roads. The explanation given is that the bioavailability of latex is low in car tyre dust and/or that the latex allergens are deactivated during the vulcanisation process, etc. Sensitisation to IgE-mediated allergy can take place via the skin, but probably mostly occurs via the mucous membranes in the airways. Much of the dust that is deposited in the nose/throat will probably be swallowed. The effect of swallowing allergen-carrying dust in an allergy context is uncertain; it will probably induce tolerance/reduce the development of an allergy rather than promote allergy development. The quantity of dust which is deposited in the airways will depend on the size distribution. The estimated uptake of PM10 via the lungs is of such an order of magnitude that even if only a small proportion consists of an immune-active latex allergen, the dose in an allergen context would be large and the risk of sensitisation would be real (1 µg of allergen deposited on the mucous membranes represents a significant individual dose). No data is available on the immune-active latex allergen content of the dust, and the data that is available concerning latex from car tyre wear must be said to be reassuring. In the absence of data on the latex allergen content of dust, the possibility of a risk of latex allergy development as a result of regular training on artificial turf pitches cannot however be eliminated on the basis of the information that is available on car tyres. Similarly, the possibility that people who already have a latex allergy could suffer an acute asthma attack and other allergy symptoms as a result of inhaling dust from such artificial turf pitches cannot be eliminated. This can be of particular concern when it occurs in connection with vigorous physical activity.

Latex in dust can be measured to some extent, although it is open to discussion as to whether and if so how much biologically active latex allergen (the natural rubber allergen) is present even if latex is demonstrated. Experience of asthma and allergies caused by the use of such artificial turf pitches will therefore be of considerable importance for the assessment, if such experience exists.

However, a recently published study found slightly higher concentrations of individual phthalates in dust at home in children with asthma or allergy symptoms. This has resulted in considerable attention being directed at phthalate exposure. The results are important and provide interesting information, but at the present time there is no certain evidence on which to claim that phthalates can contribute to the development of asthma and allergies in the population.

Risk assessment

Inhalation

VOC

Table 13: MOS values for exposure scenarios 1-4

Substance	NOAEL(C)	Effect	Exposure/scenario/VOC Scenarios 1-4 (µg/kg body weight/day)	Margin of Safety /MOS Scenarios 1-4
Toluene	340 mg/kg/day*	Reduced sperm quality in rats	Scenario 1: 27.2 Scenario 2: 13.6 Scenario 3: 10.2 Scenario 4a: 8.5 Scenario 4b:29.8	Scenario 1: 12 500 Scenario 2: 25 000 Scenario 3: 33 300 Scenario 4a:40 000 Scenario 4b:11 400
Butenylbenzene	No values found	No data found		

Benzoic acid	5 mg/kg/day*	Increased number of resorptions in rats	Scenario 1: 25.9 Scenario 2: 13.0 Scenario 3: 9.7 Scenario 4a: 8.1 Scenario 4b: 28.4	Scenario 1: 193 Scenario 2: 385 Scenario 3: 515 Scenario 4a: 617 Scenario 4b: 176
Xylenes	50 ppm* (220 mg/m ³) Scenario 1: 70.4 mg/kg/day Scenario 2: 35.2 mg/kg/day Scenario 3: 26.4 mg/kg/day Scenario 4a: 22.0 mg/kg/day Scenario 4b: 77.0 mg/kg/day	Neurological effects in humans	Scenario 1: 12.3 Scenario 2: 6.2 Scenario 3: 4.7 Scenario 4a: 3.9 Scenario 4b: 13.5	Scenario 1: 5700 Scenario 2: 5700 Scenario 3: 5600 Scenario 4a: 5600 Scenario 4b: 5700
Styrene	150 ppm* (640 mg/m ³) (42.9 mg/kg body weight/day***)	Reduced body weight and delayed development in offspring.	Scenario 1: 2.0 Scenario 2: 1.0 Scenario 3: 0.7 Scenario 4a: 0.6 Scenario 4b: 2.1	Scenario 1: 21 500 Scenario 2: 43 000 Scenario 3: 61 300 Scenario 4a: 71 500 Scenario 4b: 20 400
Formaldehyde	0.5 mg/m ³ * Scenario 1: 0.16 Scenario 2: 0.08	Effects on humans	Scenario 1: 2.1 Scenario 2: 1.1 Scenario 3: 0.8	Scenario 1: 76* Scenario 2: 73* Scenario 3: 75*

* repeated exposure

** single exposure

*** Conversion values for rats: respiration frequency 85.5/min, tidal volume 0.86 ml, weight 400 grams, exposure 6 hours/day

Total VOC

It is impossible to carry out a health risk assessment on the basis of measurements of total VOC. It is possible that individual substances or mixtures of substances could contribute to odours or mucous membrane irritation which sensitive individuals are able to detect even at these relatively low levels. This could lead to the perception of “poor”, heavy or “dry” air. As smell is part of mankind’s warning system for possible dangers, the possibility of some people reacting with symptoms such as tiredness or headaches must be kept open.

Allergy

On the basis of the analysis data, substances were found in the VOC fraction which are classified as contact allergens. However, the concentrations of these substances are so low that they could not cause a contact allergy in individuals using the halls. One possible exception is the deposition of rubber dust on shoes where dust can collect over time.

As regards airway allergies, latex (natural rubber) is a potent allergen and latex allergy is not unusual. Car tyres can contain large quantities of latex, and emissions of latex caused by road traffic due to tyre wear are very high in an allergen context. However, no increased occurrence of latex allergy has been found in individuals who live near busy roads compared with people who live further away from such roads. The explanation given is that the bioavailability of latex in car tyre dust is low and/or that latex allergens are deactivated during the vulcanisation process, etc. No data on the concentration of immune-active latex allergen in the dust is available, and the data that is available concerning latex from the wear of car tyres must be considered to be reassuring. In the absence of data on concentrations of latex allergen in the dust,

the possibility of a risk of developing a latex allergy as a result of regular training on artificial turf pitches cannot be eliminated on the basis of the available information on car tyres. Similarly, the possibility that people who already have a latex allergy could suffer an acute asthma attack and other allergy symptoms as a result of inhaling dust from such artificial turf pitches cannot be eliminated. This can be of particular concern when it occurs in connection with vigorous physical activity.

As regards exposure to phthalates in indoor air, some studies indicate that some phthalates could have an adverse effect on the health of those who are exposed, but there is currently insufficient evidence to claim that phthalates contribute to the development of asthma and allergies in the population.

Cancer

Benzene

The total inhalation volume during training in sports halls has been estimated as a “worst case” exposure for the age group 7 – 40. For all age groups, it has been assumed that individuals train for six months a year in indoor halls.

Children 7 – 11 years: $1.8 \text{ m}^3/\text{hr} \times 10 = 18 \text{ m}^3/\text{week}$ for 26 weeks = 468 over 5 years. Total: 2340 m^3
Juniors 12 – 15 years: $3.6 \text{ m}^3/\text{hr} \times 12 = 43.2 \text{ m}^3/\text{week}$ for 26 weeks = 1123 over 4 years. Total: 4492 m^3
Juniors 16 – 19 years; $4.8 \text{ m}^3/\text{hr} \times 15.6 = 75 \text{ m}^3/\text{week}$ for 26 weeks = 1950 over 4 years. Total: 7800 m^3
Adults 20 – 40 years: $6.0 \text{ m}^3/\text{hr} \times 26 = 156 \text{ m}^3/\text{week}$ for 26 weeks = 4056 over 20 years. Total: 81120 m^3

In October 2005, NILU took three measurements of benzene in Manglerudhallen (1.7 , 2.2 and $2.3 \mu\text{g}/\text{m}^3$), two measurements in Valhall (2.1 and $2.4 \mu\text{g}/\text{m}^3$) and two measurements in Østfoldhallen (1.8 and $2.0 \mu\text{g}/\text{m}^3$). When these measurements are corrected for benzene in the surrounding air, it is apparent that the “worst case” exposure based on benzene released from artificial turf in the hall is $1.4 \mu\text{g}/\text{m}^3$

benzene. The US EPA’s new guidelines for estimating cancer risk assume that children in the age group 2 - 15 are three times more sensitive than adults. In the calculations below we have taken this into account by multiplying the inhalation volume by three. The WHO’s risk estimate is based on the inhalation of $1.7 \mu\text{g}/\text{m}^3$ of benzene for 70 years. If it is assumed that the average air intake is 20 m^3 per day, inhalation of a benzene quantity of $(20 \times 365 \times 70 \times 1.7) 8.7 \times 10^5 \mu\text{g}$ of benzene would correspond to a lifetime leukaemia risk of 10^{-5} . In connection with training in sports halls with artificial turf, the “worst case” inhaled benzene would be $(\{2340 + 4492\} \times 3 + 7800 + 81120) \times 1.4) 1.5 \times 10^5$. The maximum “worst case lifetime cancer risk” is therefore $(1.5 \times 10^5 / 8.7 \times 10^5) 0.2 \times 10^{-5}$. It is generally accepted that calculations performed in this way represent a maximum risk and that the actual risk will very probably be lower. A risk as low as that calculated above is considered by the authorities of most countries who carry out quantitative cancer risk assessments to be negligible or tolerable.

PAHs

The Norwegian Pollution Control Authority (SFT) commissioned NILU to analyse 38 individual PAH compounds, including BaP, in three sports halls. These analyses were carried out on both the gas phase and airborne dust, PM10. BaP was substantially demonstrated in PM10. No measurements were taken outside the halls. NILU has however stated that the tar compounds which were measured including BaP in the PM10 fraction were in all probability caused by PAH penetrating from the surroundings through open windows or by being sucked into the ventilation system. The results of the BaP measurements in the sports halls are shown in Table 14.

Table 14: Measurements of BaP in sports halls

Sports hall	BaP in PM10 (ng/m ³)	BaP in gas phase (ng/m ³)
Valhall	0.56	< 0.01 ^x
Østfoldhallen	0.38	0.01
Manglerudhallen	1.15	0.02

x Detection limit 0.01 in the gas phase

The WHO Air Quality Guidelines for Europe (WHO Regional Publications, European Series, No. 91, Copenhagen 2000) state that the annual average level of BaP in major European cities is in the range 1 – 10 ng/m³. The EU has set a limit for BaP of 1 ng/m³ which will apply from 2010 (?). The WHO Air Quality Guidelines for Europe has recommended that, when estimating lifetime cancer risk, it should be assumed that a level of 1.2 ng/m³ BaP will give a lifetime cancer risk of 10⁻⁴.

NILU concludes that the PAH values measured are due to PAH in the surrounding air. This means that using halls with artificial turf does not cause any additional risk of cancer caused by PAH exposure.

Airborne dust

A daily uptake of 3800 pg PAH/kg body weight was used as a worst case scenario. A daily uptake of 3 pg/kg body weight was used for PCB, with the corresponding values for phthalates and alkyl phenols being 47 000 pg/kg body weight and 800 pg/kg body weight respectively. On the basis of the very small quantities of this type of compound which are taken up per day, it can be concluded that this type of compound does not cause any increased health risk.

Phthalates

The exposure calculations were based on the total exposure measurements for phthalates taken by NILU. As a worst case scenario, the lowest NOAEL value was used, i.e. 4.8 mg /kg body weight/day based on effects on fertility and embryo development in experimental animals exposed to DEHP. In table 15 the Margin of Safety (MOS) for the various scenarios is shown.

Table 15: The MOS values for scenarios 1-4 following exposure to phthalates

Scenario	Total-phthalate mg/kg body weight/day	NOAEL fertility/embryo development mg/kg body weight/day	MOS
Adults (1)	0.00019*	4.8	25 000
Junior (2)	0.0001*	4.8	48 000
Older children (3)	0.00007*	4.8	69 000
Children (4a)	0.00006*	4.8	80 000
Children (4b)	0.00021**	4.8	23 000

*Repeated exposure

** Single exposure

Alkyl phenols

The detection limit for phthalates/alkyl phenols of 0.05 µg/m³ was used as exposure. The NOAEL value for 4-nonylphenol of 1.5 mg/kg body weight/day was used. This is based on the disruption of genitalia development. The table shows the Margin of Safety (MOS) for the various scenarios.

Table 16: The MOS values for scenarios 1-4 following exposure to alkyl phenols

Scenario	Detection limit alkyl phenols µg/kg body weight/day	NOAEL disruption of genitalia development mg/kg body weight/day	MOS
Adults (1)	0.016*	1.5	94 000
Junior (2)	0.008*	1.5	190 000
Older children (3)	0.006*	1.5	250 000
Children (4a)	0.005*	1.5	300 000
Children (4b)	0.018**	1.5	83 000

*Repeated exposure

**Single exposure

Skin contact

As Table 10 shows, exposure to PCBs, PAHs, phthalates and alkyl phenols via the skin is extremely low and is measured in ng/kg body weight/day. No risk characterisation was therefore carried out for this exposure path for effects other than cancer.

Skin exposure to benzene will be far less than inhalation exposure and will not represent a cancer risk. During activity on artificial turf, players may be exposed to tar compounds through direct contact. It is well known that tar compounds (PAHs) can cause cancer through skin exposure. The small quantities of tar compounds that players could come into contact with are however so small that they would not represent a cancer risk.

Oral intake

Phthalates

Scenario 9a, children who train and play matches indoors are assumed to swallow a maximum of 2.8 µg phthalate/kg body weight/day over 6 months. This gives a Margin of Safety (MOS) value of 1700.

Scenario 9b, children who play cup tournaments indoors are assumed to swallow 11.0 µg phthalate/kg body weight/day over five days a year. This is assumed to be as a single exposure and not a repeated exposure as in scenario 9a. The estimated phthalate exposure of 11.0 µg /kg body weight/day is well below LD50 values for phthalates.

Alkyl phenols

Scenario 9a, children who train and play matches indoors are assumed to swallow 1.3 µg alkyl phenols/kg body weight/day over 6 months. This gives a Margin of Safety (MOS) value of 1150.

Scenario 9b, children who play cup tournaments indoors are assumed to swallow a maximum of 5.2 µg alkyl phenols/kg body weight/day over five days a year. This is assumed to be a single exposure and not a repeated exposure as in scenario 9a. The estimated alkyl phenol exposure of 11.0 µg /kg body weight/day is well below the exposure levels which have been shown to cause damage through a single exposure to alkyl phenols.

Summary

Inhalation

VOC

It is concluded that exposure to (inhalation of) volatile organic compounds (VOC) as a result of using halls in which recycled rubber granulate is used will not cause any increased health risk as regards acute harmful effects (acute poisoning and irritation). The extent to which repeated exposure (inhalation) could cause an elevated risk of other types

of harmful effects was assessed specifically on the basis of information concerning NOAEL values and the harmful effects of selected individual substances which have been identified in the VOC fraction. Unfortunately, no information is available on harmful effects for many of the substances which were identified in the VOC fraction. It is therefore not possible to carry out a complete risk assessment for VOCs, but on the basis of the total VOC measured in the halls, there would appear to be no cause for concern. As regards selected substances, MOS values range from 71 500 to 72. It is not possible to draw an unequivocal conclusion as to whether the concentrations of VOC in the hall could cause an increased risk of asthma/allergy. Substances have been identified which are classified as allergens, but these occur in extremely low concentrations (see the specific section on allergies below).

Total VOC

It is not possible on the basis of the information on total VOC to carry out a complete health risk assessment, but the levels of this parameter that were measured indicate that the health risk is insignificant. It is however possible that individual substances or mixtures of VOCs could contribute to odours or mucous membrane irritation which some hypersensitive people could perceive as unpleasant even at these relatively low levels. These are reversible effects and would not cause any permanent discomfort.

Airborne dust/PAH/PCB

As a worst case scenario, a daily uptake of 3800 pg PAH/kg body weight was used. A value of 3 pg/kg body weight was used for PCB, whilst the corresponding value for phthalates was 47000 pg/kg body weight and for alkyl phenols 800 pg/kg body weight. Given that such small quantities of this type of compound can be taken up each day, it can be concluded that these compounds do not constitute any elevated health risk.

Phthalates

For adults, juniors, older children and children with repeated exposure to phthalates, the MOS values were 25 000, 48 000, 69 000 and 80 000 respectively. The exposure to total phthalates in measurements by NILU and the lowest NOAEL value for reproductive toxicity in animal studies were used in this calculation. It can be concluded that this exposure will not cause any elevated health risk for adults, juniors, older children or children. For children who are exposed to phthalates in connection with cup tournaments five days a year (single exposure), it is concluded that this exposure will not cause any increased health risk.

Alkyl phenols

For adults, junior, older children and children with repeated exposure to alkyl phenols, the MOS values were 94 000, 190 000, 250 000 and 300 000 respectively. The detection limit for alkyl phenols of 0.05 µg/m³ and the lowest NOAEL value for reproductive toxicity in animal studies were used in this calculation. It can be

concluded that this exposure will not cause any increased health risk for adults, juniors, older children or children. For children who are exposed to alkyl phenols in connection with cup tournaments five days a year (single exposure) it is concluded that this exposure will not cause any increased health risk.

Skin contact

As is apparent from Table 10, exposure to PCBs, PAHs, phthalates and alkyl phenols via the skin is extremely low and is measured in ng/kg body weight/day. It is therefore concluded that skin exposure to recycled rubber granulate will not cause any increased health risk.

Oral intake

Phthalates

For children who put in their mouth and chew/swallow recycled rubber granulate during training sessions/matches (repeated exposure), the MOS value was 1700 for phthalates. The worst case exposure for total phthalates in recycled rubber granulate and the lowest NOAEL value for reproductive toxicity in animal studies were used in this calculation. On the basis of this it can be concluded that this exposure will not cause any elevated health risk. For children who put in their mouth and chew/swallow recycled rubber granulate during cup tournaments lasting five days a year (single exposure), it is concluded that exposure to phthalates will be low and that this will not cause any elevated health risk.

Alkyl phenols

For children who put in their mouth and chew/swallow recycled rubber granulate during training sessions/matches (repeated exposure) the MOS value was 1150 for alkyl phenols. The worst case exposure to total alkyl phenols in recycled rubber granulate and the lowest NOAEL value for reproductive toxicity in animal studies were used in this calculation. On the basis of this it can be concluded that this exposure will not cause any increased health risk. For children who put in their mouth and chew/swallow recycled rubber granulate during cup tournaments lasting five days a year (single exposure), it is concluded that exposure to alkyl phenols will be low and that this will not cause any increased health risk.

Allergy

It is unlikely that the low levels of contact allergens which have been measured in the halls could lead to the development of a contact allergy.

As regards possible airway allergies, it is known that latex (natural rubber) is a potent allergen and latex allergy is not uncommon. Car tyres can contain large amounts of latex. However, it would appear that the bioavailability of latex in car rubber dust is low and/or that latex is deactivated during the vulcanisation process. The analyses that were carried out do not contain any information on immune-active latex allergen. Due to the quantities of dust which were measured in the halls, the possibility that there is a risk of individuals developing latex allergy or that individuals who have already developed a latex allergy could suffer acute asthma attacks when using the halls cannot be eliminated.

Relatively low concentrations of phthalates have been demonstrated in the hall air. Our present knowledge of a possible link between exposure to phthalates and the development of asthma/allergy is very inadequate and it is not possible to carry out a risk assessment in this area.

Cancer

It has been concluded that exposure to benzene and PAHs in the quantities in which they have been measured in the halls will not cause any increased risk of cancer in people using the halls.

Conclusion

Recycled rubber granulate contains many chemical substances which are potentially harmful to health. The concentrations of these substances are however extremely low, they are only leached from the rubber granulate in very small quantities and they are only present in low concentrations in the hall air. The quantities of this type of substance are consistently lower than in the other types of rubber granulate which are used. The assessment of health risk was therefore based on measurements (concentrations in the rubber granulate and in airborne dust, PM10, and VOC in the hall air) in halls in which recycled rubber granulate is used.

A number of worst case scenarios were prepared which are used in the risk characterisation. These scenarios are based on information concerning the use of the halls (matches and training sessions; frequency and duration); physiological parameters (skin surface area, inhalation volumes during exertion and body weight) and analyses (content in rubber granulate, airborne dust/PM10 and VOC). Exposure calculations were performed for adults, juniors, older children and children based on measurements of VOC, airborne dust, concentrations of chemicals in recycled rubber granulate and leaching from the granulate.

On the basis of estimated exposure values and the doses/concentrations which can cause harmful effects in humans or in animal experiments, it is concluded that the use of artificial turf halls does not cause any elevated health risk. This applies to children, older children, juniors and adults. The estimated Margins of Safety (MOS) also give no cause for concern.

As regards total VOC, higher values were measured than are normally found in homes. Values of up to 200-400 µg/m³ fall within the normal range for housing. It is concluded that the values which were measured for total VOC do not constitute any elevated health risk but our knowledge of this area is rather inadequate. It is reasonable to assume that the relatively high VOC values could contribute to the hall air being perceived as "poor" without this in itself actually causing any elevated health risk.

As regards allergies, it is concluded that exposure to the low concentrations which were measured does not constitute any elevated risk with respect to the development of contact allergies. It is known that car tyres can contain relatively high concentrations of latex and therefore possibly also latex allergens. Latex is a potent airway allergen, but it would appear that latex in car rubber dust is either less available for uptake and/or deactivated. As no information is available concerning levels of latex in the rubber granulate that is used, it is not possible to assess the risk of developing an airway allergy. The possibility that the use of car tyres could cause exposure to latex allergens and thus lead to the development of airway allergies cannot be entirely eliminated. Studies have been carried out which indicate a link between exposure to phthalates and the development of asthma/allergies. At the present time, it is not possible to carry out a risk assessment in this area because of a lack of available knowledge.

Worst case calculations based on air measurements carried out by NILU and exposure values from the Norwegian Institute of Public Health indicate that training in sports halls does not cause any increased risk of leukaemia as a result of benzene exposure or any elevated risk as a result of exposure to polycyclic aromatic hydrocarbons.

On the basis of the exposures which have been calculated in connection with the use of indoor halls with artificial turf in which recycled rubber granulate is used, there is no evidence to indicate that the use of such halls causes an elevated health risk. A reservation must however be issued as regards the development of asthma/airway allergies, where the knowledge that is currently available is limited. This particularly applies to exposure to latex allergens, as no information is available on the occurrence of

latex allergens in hall air, yet such allergens have been demonstrated in car tyre rubber. It should also be noted that little or no toxicological information is available for many of the volatile organic compounds which have been demonstrated as being present in the air in the halls. The concentrations of most substances for which insufficient information is available concerning harmful effects are extremely low and for this reason they are not expected to cause any increased health risk. However, not all organic compounds in the hall air have been identified. It is concluded that the exposure quantities which have been calculated for benzene and PAHs do not represent a cancer risk.

On the basis of the knowledge that is currently available concerning health effects and exposure linked to the use of indoor artificial turf pitches, we do not see any necessity to replace the recycled granulate at the present time. Due to a lack of knowledge as regards the possible induction of latex rubber, we recommend that recycled rubber granulate should not be used when rubber granulate is supplemented/replaced

Section 22:

**Rubber – Its Implications to Environmental
Health**

(Hydrocarbon Rubbers)

RUBBER – ITS IMPLICATIONS TO ENVIRONMENTAL HEALTH

(HYDROCARBON RUBBERS)

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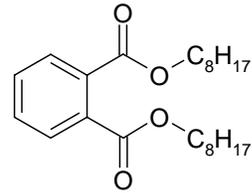
SULPHUR VULCANISATION USED IN TYRE RUBBERS

- Well established
 - for fine tuning product properties
 - for good control in processing
- Chemistry relies on a cocktail of chemicals:
 - vulcanising agent (sulphur)
 - accelerators and activators
 - inhibitors or retarders (stop premature reaction)
 - antioxidants (protect against heat)
 - antiozonants (protection in service)
- Other ingredients include:
 - fillers (carbon black) for reinforcement
 - softeners (process oils)

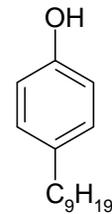


INGREDIENT MIX WELL ESTABLISHED - IT DOES NOT INCLUDE

- Phthalate plasticisers
 - used in PVC and nitrile rubbers
 - don't function in hydrocarbon rubbers



- Monoalkylphenols
 - used to make non-ionic surfactants
 - surfactants not used in tyres



- Cadmium
 - Zinc oxide is 99% pure

LOW MW SPECIES IN VULCANISED RUBBER

Include

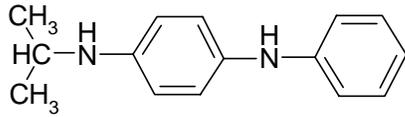
- original ingredients of mix
- by-products of vulcanisation

All encapsulated in a molecular network

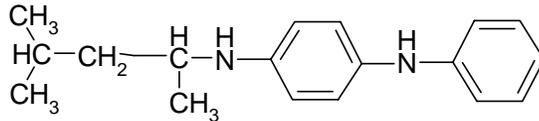
- which may hold some species in
 - i.e. organics well-solvated by network
- and squeeze other species out
 - i.e. those that try to crystallise out from solvation

*Elastic properties of network force crystallisable species
to the surface – vulcanised rubbers “bloom”*

COMPONENTS OF BLOOM CAN INCLUDE....



IPPD



6PPD

Aromatic amine antioxidants

- N-isopropyl-N'-phenyl-*p*-phenylenediamine (IPPD)
- N-1,3-dimethylbutyl-N'-phenyl-*p*-phenylenediamine (6PPD)

Tyre rubber has a basic surface

Zinc salts

- Zinc dimethyldithiocarbamate (Me₂NCS₂)₂Zn

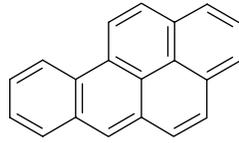
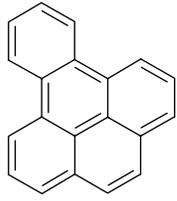
Water leaches zinc from tyre rubber

SURFACE CHARACTER OF RUBBER

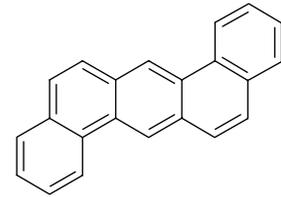
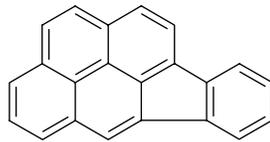
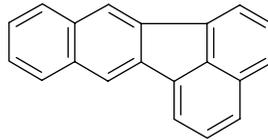
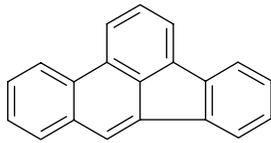
Contact dermatitis linked with skin contact with rubber

- Causative agents include the components of bloom
- Effect depends on individual sensitivity and extent of contact
- Not normally associated with transient contact
 - e.g. not associated with handgrips, matting, dinghies, etc.
- Usually seen in somebody wearing rubber
 - e.g. goggles, elasticated clothing, etc
- Contact dermatitis not expected with rubber granulate

Nilsson et al. (2005) looked at extraction by (synthetic) sweat
– found health risks insignificant



Polycyclic aromatic hydrocarbons



POLYCYCLIC AROMATIC HYDROCARBONS

- Lubricating oils are (solvent) extracted to remove aromatics
- These extracts – ‘aromatic process oils’ – are excellent plasticisers/softeners for tyre rubbers
- Improve processing and product performance (wet grip etc.)

- But they are rich in PAHs
- PAH content in the range 20-30%
- And they do contain the carcinogenic (e.g. five-ring) types
- Aromatic process oils carry labelling

T Toxic
R45 May cause cancer

Occupational health issues will see replacement of these oils

PAHs ARE IN TYRE RUBBER – DO THEY COME OUT?

1973-75 BRMA survey of airborne benzo[a]pyrene in ten UK tyre factories found:

- concentrations from zero to 28 ng/m³
- no correlation with process or factory area
- strong correlation with seasons and weather

Nutt (1984) repeated this with simultaneous measurements of inside (tyre factory) and outside air

- found no excess of B[a]P in factory air

Willoughby (1994) analysed PAHs from laboratory vulcanisations at up to 200°C

- found only two-to-four ring PAHs in volatiles

PAHs ARE IN TYRE RUBBER – CAN THEY LEACH OUT?

Norwegian Institute for Water Research (2005) carried leachate tests on granulate:

- found only two-to-four-ring PAHs in leachate

Log K_{ow} values

- ca. 3-4 for three-ring
- ca. 4-5 for four-ring
- ca. 6 for five-ring

- So five-ring PAH is ca. 10^6 time more likely to partition in an organic phase rather than in water
- Five-ring PAHs will stay in the vulcanised rubber

WHAT IS “RUBBER”?

- A range of different types
 - commodity or specialised
 - both natural and synthetic
- Easily recognised - soft and compliant
 - compared with ceramics, metals or plastics
- Strong (usually) and very tough
 - resistant to fracture, tear, abrasion, etc.
- Capable of large-strain elasticity
 - recoverable extensions of several hundred percent possible
- Properties a result of unique molecular structure

PAHs ARE ALREADY IN THE ENVIRONMENT

- **PAHs are in the air from combustion processes**
 - transport, power generation, cigarettes, etc.
- **Routinely monitored in ambient air**
 - Annual avs. for benzo[*b*]fluoranthene and benzo[*a*]pyrene ca. 1 ng/m³ in Manchester UK
- **Carried on soot particles and washed out of air by rain**
- **Pass into rivers and lakes – and then into sediments**

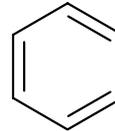
Nilsson et al (2005) studied PAHs in sand in a children's playground with used tyre components

- Found distribution of PAHs did not reflect that in tyre rubber
- Concluded that the PAHs arose from deposition from the air

Additional risks from PAHs in tyre granulate judged insignificant

BENZENE

- Present in original vulcanisate from polymer/carbon black interaction
 - polymer displaces adsorbed benzene from black surface
- May also be taken up by tyre rubber in service
 - benzene and rubber will have a strong affinity
 - affinity will work against elastic forces
 - so benzene will 'push' its way in
- Benzene has been found in air above tyre granulate



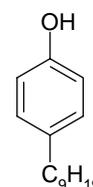
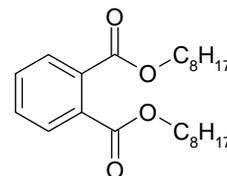
Dye et al. (2003) monitored several species in air of indoor sports halls. The smallest margin against WHO guidance values was for benzene.

Benzene max. found, 2.3 $\mu\text{g}/\text{m}^3$ WHO/EC limit, 5.0 $\mu\text{g}/\text{m}^3$

Is there a cause for concern?

PHTHALATES AND ALKYLPHENOLS

- Not ingredients of tyre rubber
- But various researchers have found them in leachates from tyre granulate
- Environmental concerns (endocrine disruptors)
- These must be picked up from the environment in service
 - i.e. tyres are an environmental fate for phthalates and alkylphenols
- A reminder that scrap tyre granulate will be a variable product
- Standards/testing important



ZINC

- ZnO is an activator in sulphur vulcanisation
- Forms zinc salts as a by-product of vulcanisation chemistry
- Zinc salts can bloom in vulcanisates
- Expect zinc in leachates from any sulphur vulcanisate
 - and it is found
- But care is needed to avoid spurious data from background contamination (e.g. from galvanising)

ZINC LEACHING

Lab trials - effect of pH (Liu et al., 1998)

pH 3.5	pH 5.0	pH 7.0
23.5 mg/l	17.5 mg/l	3.38 mg/l

Field trials (Humphrey and Katz, 2001)

Levels (mg/l) in trench with granulate (background in parenthesis)

	Peat	Clay	Glacial Till
Unfiltered	2.39 (0.04)	0.75 (0.18)	0.57 (0.13)
Filtered	0.065 (0.009)	0.12 (0.007)	0.076 (0.004)

Away from trench, Zn levels rapidly decay to background levels

ZINC LEACHING

Overall conclusions are:

- Tire sheds placed above or below the water table have a negligible impact on water quality
- There may be a localised environmental impact

Zinc testing should figure in quality standards

RISKS FROM RUBBER GRANULATE IN SPORTS SURFACES

- A number of species are present in rubber granulate
 - from the ingredients used
 - from reactions of vulcanisation
 - from exposure in previous use (tyres)
- Many are held in tightly within the rubber
- Some are expelled to the surface (bloom)
- There is no demonstrable health risk
- There may be a localised environmental impact

SUSTAINABILITY

SBR & EPDM polymers are products of oil industry

**NR polymer is sustainable
- but vulcanisate requires synthetic chemicals**

A different way?



SUSTAINABILITY



400k tons per year of scrap tyres generated in the UK alone
Unsightly, unhealthy, a fire risk – and a wasted resource
If it's a suitable feedstock for sports surface granules – use it

DIFFERENT RUBBERS

- **Commodity (hydrocarbon)**
 - natural rubber (NR)
 - styrene-butadiene rubber (SBR)
 - ethylene-propylene rubbers (EPM, EPDM)
 - butadiene rubber (BR)
- **High/low permeability rubbers**
 - silicone rubber MQ, VMQ, PVMQ, FVMQ, etc) – high permeability
 - butyl (IIR), halobutyl rubbers (CIIR, BIIR) – low permeability
- **Oil-resistant rubbers**
 - nitrile (NBR), hydrogenated nitrile (HNBR) rubbers
 - acrylic rubber (ACM)
- **Fire-resistant rubbers**
 - chloroprene (“neoprene”) rubber (CR)
 - epichlorohydrin rubber (ECO)
- **High temperature rubbers**
 - fluorocarbon rubbers (FKM, FFKM)
- **Liquid castable rubbers**
 - polyurethane (EU)
 - polysulphide (T)

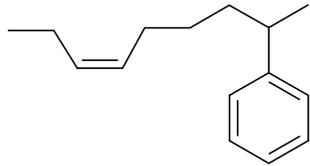


SUBTLE CHANGES IN MOLECULE CAN PROVIDE EITHER PLASTIC OR RUBBER

- Polyethylene, $(\text{CH}_2 \text{CH}_2)_n$
 - very flexible molecule,
 - but regular structure introduces crystallinity
 - polyethylene is a plastic
 - softer than many plastics
 - used in packaging, etc
- Polypropylene, $(\text{CH}_2 \text{CHMe})_n$
 - stiffer than polyethylene
 - regular structure – hence crystalline
 - polypropylene is a plastic
 - good combination of stiffness, strength (and price)
 - widespread applications
- Ethylene-Propylene Copolymers
 - Irregular structure disrupts crystallinity
 - 50:50 E:P to 75:25 E:P (by wt) are rubbers
 - the basis of EPDM rubber
 - used in hose, car door & boot seals, etc.

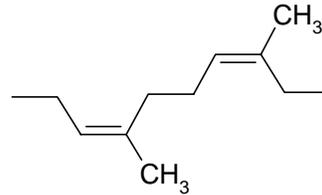


OTHER HYDROCARBON RUBBERS



styrene-butadiene rubber

SBR



natural rubber

NR

- NR polymer (a polyterpene) is obtained from the latex of the Hevea Brasiliensis tree
- SBR polymer is product of the oil industry
- Average MW can be around 500k for NR, around 100k for SBR
- These are the principal tyre rubber polymers

*But why is rubber elastic?
Why the exceptional large-strain elasticity?*

ELASTICITY

- Elasticity is the ability to recover from a deformation
 - when applied stress is removed, an elastic material will recover completely its original shape
- Many materials show elasticity up to a limit – beyond this additional stress causes irreversible 'plastic' flow
 - elastic limit may be measured in terms of applied strain (ϵ /l)
 - for metals and ceramics, elastic limit may be <0.001% strain
 - for plastics, limit may lie at percentage values
 - for rubber limit may be at strains of several hundred of percent

But ultimate elastic performance only with **vulcanised rubbers**

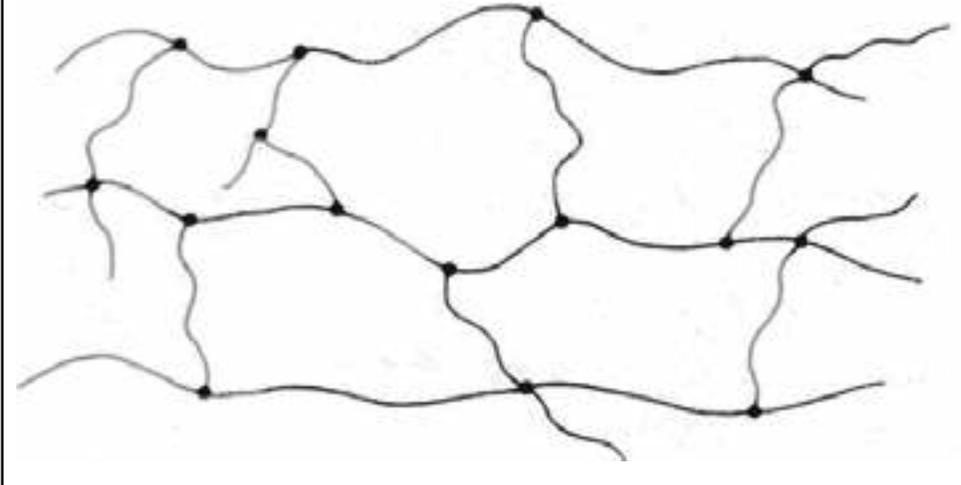
Vulcanisation is post-polymerisation chemical treatment
Prior to vulcanisation, rubber is visco-elastic

EFFECT OF VULCANISATION

- Physical - vulcanisation suppresses viscous behaviour and enhances elastic behaviour
 - removes tack and reduces temperature sensitivity
 - remarkable elasticity develops
- Chemical – vulcanisation links molecules together ('crosslinking')
 - e.g. with sulphur (simplistically)
$$RH + S_x + RH \rightarrow R S_y R + H_2S$$
- Linking all the molecules together creates a single molecule of infinite molecular weight

POLYMERS OF INFINITE MW

Cannot flow, cannot be melted or dissolved
Will recover elastically from imposed strains



Section 23:

Study of the Incidences of Recycled Rubber from Tyres in Environment and Human Health



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LEGAL FRAMEWORK (2)

3. The used methodology is defined in

R.D. 363/1995, of March 10, by which the regulation is approved on notification of new substances and classification, packed and labeled of dangerous substances.

Order on October 13, 1989 on methods of characterization of the toxic and dangerous residues.

4. The criteria used to evaluate the dangerousness of the analyzed parameters are gathered for:

Order MAM/304/2002, of February 8, by that are published the operations of appraisal and elimination of residues and the European list of residues.

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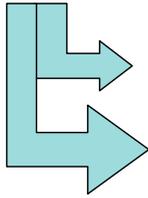


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Applus⁺



There are no studies
that relate particles of tires to problems of human health.



MATERIAL BEHAVIOUR ON HUMAN HEALTH AND ENVIRONMENT.

LEACHING EFFECT ON SOIL.

RECYCLED MATERIAL EFFECTS ON AIR.



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GENERAL CRITERIA FOLLOWED TO SELECT THE LEGISLATION TO APPLYING IN THE STUDY



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LEGAL FRAMEWORK

- 1. In order to evaluate the dangerousness of the material **two types of tests** are realized:**

Analysis of metallic and organic compounds capable of enduring risks for the health and the environment.

Tests physicist - chemist who determine the characteristics of dangerousness of the material.

- 2. The **analyzed parameters** are gathered in:**

R.D. 952/1997, of June 20 by which the regulation is modified for the execution of the Law 20/1986, of May 14, basic of Toxic and Dangerous Residues, pass by means of R.D. 833/1988, of July 20.

R.D. = Real Decree in Spain

LEGAL FRAMEWORK (2)

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STAGE I: MATERIAL BEHAVIOUR ON HUMAN HEALTH AND ENVIRONMENT.



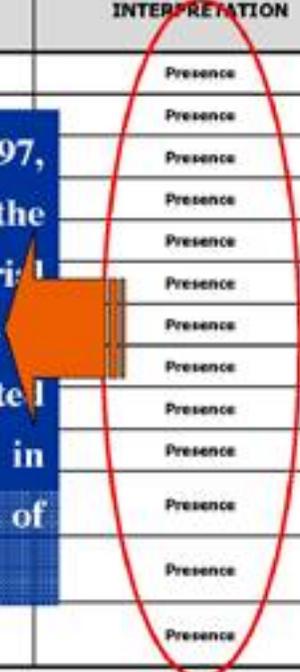
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ANALITICAL RESULTS

ANALITO	RESULT	INTERPRETATION
Barium	4 mg / Kg m.s.	Presence
		Presence
Polycyclic Aromatic Hydrocarbons (1)**	192 mg / Kg m.s.	Presence

➤ According to the R.D. 952/1997, though it is not a residue, since the last purpose of this recycled material is not the elimination, the presence of anyone of the substances detected (metals and organic compounds) in the sample awards character of dangerousness



STAGE I: MATERIAL BEHAVIOUR ON HUMAN HEALTH AND ENVIRONMENT.



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ANALITICAL RESULTS (2)

ANALITO	RESULT	INTERPRETATION
Agents oxidizers / reactivities in contact with water	Negative	H1 y H2. NEGATIVE Not explosive / Not comburent
Ignition point	> 75° C	H3. NEGATIVE Not flammable
pH	6.77 U pH	H4. NEGATIVE Not irritant
		H4. NEGATIVE Not irritant
		H5 Y H6. NEGATIVE Not harmful / Not toxic
		H7. NEGATIVE Not carcinogenic
		H10 Y H11. NEGATIVE Not toxic for reproduction / Not mutagenic
		H12. NEGATIVE Absence of substances that emit toxic or very toxic gases
Leaching study		H13. Studied in Stage III
Echotoxicity test	5488 mg/L	H14. NEGATIVE Not dangerous for the environment

➤ **The characteristics of dangerousness studied in the STAGE I are **NEGATIVE****



STAGE I CONCLUSIONS

Due to the fact that the final use of the recycled rubber object of study is the landfill of sports surfaces installed in the exterior and before the absence of positive characteristics of dangerousness in environmental normal conditions, we can conclude that the behavior of the above mentioned material, in spite of its composition, does not induce any danger on the human health and the environment

LEGAL FRAMEWORK

- **In order to evaluate the leaching effects on soil that recycled tires rubber could generate, it is appealed to:**

Decision 2003/33/CE, of the Council, of December 19, 2002 by that there are established the criteria and procedures of admission of residues in the dumps according with the article 16 and to the attached II of the Board 1999/31/CEE (TWELVE núm. L 11, of January 16, 2003).

R.D. 849/86, by that the quality is regulated of spilt realized to Public Hydraulic Authority.

U.E.F.A. Design and Construction Recomendations

ANALITICAL RESULTS

1. Effects on soil: study on solid

ENSAYO	RESULTADO	CLASIFICACIÓN 2003/33/CE
Carbono orgánico	15000 mg/Kg	Inferior a 30000 mg/Kg. INERTE
Suma de BTEX	0.137 mg/Kg	Inferior a 6 mg/Kg. INERTE
		Inferior a 1 mg/Kg. INERTE
		Superior a 500 mg/Kg NO INERTE

➤ The material overcomes the content in aliphatic hydrocarbons (C10-C40) to be considered as Inert Solid

ANALITICAL RESULTS (2)

2. Effects on soil. Study of leaching

ENSAYO	RESULTADO	CLASIFICACIÓN 200.333/CE. Inertes	CLASIFICACIÓN 200.333/CE. No Peligrosos
Ambrosia	~0.02 mg/Kg	0.00 mg/Kg	0.7 mg/Kg.
Acetato			
Bario			
Calcio			
Cofee			
Cromo			
Metilbromo			
Niquel			
Plomo	~0.02 mg/Kg	0.2 mg/Kg	10 mg/Kg.
Selenio	~0.02 mg/Kg		0.2 mg/Kg.
Zinc	2.20 mg/Kg		10 mg/Kg.
Strovanio	~0.001 mg/Kg		0.3 mg/Kg.
Cálcico			
Oxígeno	237.0 mg/Kg		500 mg/Kg.
Fosforo	1.20 mg/Kg	1 mg/Kg	-
Sulfuro (Humedad)	500 mg/Kg	5000 mg/Kg	10000 mg/Kg.
Cloruro	~10 mg/Kg	500 mg/Kg	10000 mg/Kg.
Fluoruro	~1 mg/Kg	10 mg/Kg	100 mg/Kg.
Sulfuro	74 mg/Kg	1000 mg/Kg	20000 mg/Kg.

➤ The material overcomes the content in phenols to be considered as Inert Solid



STAGE II CONCLUSIONS

The material overcomes the maximum concentrations allowed in phenols and aliphatic hydrocarbons (C10-C40) to be considered as Inert Solid, And past to consider non danger material.

The analyzed parameters carry out the limits stipulated by the R.D. 849/86, considering leaching as public hydraulic dump even in the most restrictive conditions gathered in the above mentioned national legislation.

STAGE II CONCLUSIONS (2)

The composition of recycled rubber presents an high contain in zinc and carbon, among other compounds. In the first leaching is observed that none of the parameters listed in the UEFA recommendations exceeds the maximum values, with the exception of the carbon. The UEFA establishes a value limit for this parameter, following the methodology gathered in the norm CASH 18035-7:2002-06.

Estudio del lixiviado bajo la norma DIN 18035-7:2002-06.

ENSAYO	RESULTADO	U.E.F.A.
Zinc	0.31 mg/L	0.5 mg/L
Carbono orgánico disuelto	11.59 mg/L	<20 mg/L

STAGE II CONCLUSIONS (2)

- The composition of recycled rubber presents an high contain in zinc and carbon, among other compounds. In the first leaching is observed that none of the parameters values, with the for this parame 18035-7:2002-06.
- The material does not overcome the values limit of the UEFA recommendations
- the maximum as a value limit norm CASH

Estudio del lixiviado bajo la norma DIN 18035-7:2002-06.

ENSAYO	RESULTADO	U.E.F.A.
Zinc	0.31 mg/L	0.5 mg/L
Carbono orgánico disuelto	11.59 mg/L	<20 mg/L

LEGAL FRAMEWORK

- **To evaluate the sports surface effect on the environment, they are considered two legislation or regulation types :**

European Legislation in force or proposal where values establish limit of the compounds analyzed in air environment.

Proposal of Board of the European Parliament and of the Council, relative to As, Cd, Hg, Ni and HAP's in air environment

Board 2000/69/CE of the European Parliament and of the Council, of November 16, 2000, about the values limit for benzene and monoxide of carbon in air environment. And transposition to the Spanish legislation

Limit values relative to public health published by international recognized agencies: ACGIH, OSHA, NIOSH, DFG and HSE.

SAMPLING PLAN



SAMPLING PLAN (2)

ANALYZED PARAMETERS SELECTION

The studied compounds have been selected according with tests already realized on this material type, references provided by the client, where stands out the presence of organic origin parameters due to the nature of the rubber, and high contain in sulphur, that makes admissible to determine the possible presence of hydrogen sulphur. Therefore the analyzed parameters have been the following ones:

Polycyclic aromatic hydrocarbons (HAP's), Picked up in PUF filter by means of captator (containers) of high volume.

Volatile Organic Compounds (VOCs), Picked up in passive captators (containers).

Hydrogen sulphide measured “in situ” using Dräger tubes.

ANALITICAL RESULTS

VOLATILE ORGANIC COMPOUNDS

Parámetro	Resultados Obtenidos ($\mu\text{g}/\text{m}^3$)					V.L. (I.E.A.A.) ($\mu\text{g}/\text{m}^3$)	V.L. (N.E.S.I.) ($\mu\text{g}/\text{m}^3$)
	P-2	P-3	P-4	P-5	P-6		
Benceno	0.28	0.38	<0.01	0.19	0.19	5	-----
Tolueno	0.66	3.14	2.26	1.61	1.13	-----	TLV=188000 MAK=190000
Etilbenceno	1.13	2.17		1.32	0.94	-----	
m,p-xileno	3.48	4.42		3.11	3.39	-----	TLV=434000 MAK=440000
o-xileno	2.54	2.66		2.79	2.17	-----	

➤ benzene does not overcome the limit value in air according to the Board 2000/69/CE= $5\mu\text{g}/\text{m}^3$

ANALITICAL RESULTS

POLYCYCLIC AROMATIC HYDROCARBONS

Parámetro	Resultados Obtenidos (ng/m ³)						V.L. (L.E.A.A) (ng/m ³)	V.L. (N.E.S.L.) (ng/m ³)
	P-1	P-2	P-3	P-4	P-5	P-6		
Acenafteno	0.32	0.21	0.14	0.16	0.03	0.27	-----	-----
Acenaftileno	0.21	0.13	0.07	0.07	0.03	0.09	-----	-----
Antraceno	0.46	0.43	0.25	0.22	0.02	0.19	-----	-----
Benzo-(g,h,i)-perileno	<0.52	<0.53	<0.54	<0.52	<0.52	<0.55	-----	-----
Benzo-a-antraceno	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	-----	-----
Benzo-a-pireno	<0.52	<0.53	<0.54	<0.52	<0.52	<0.55	1 ^{ab}	MAK=2000
Benzo-b-fluoranteno	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	-----	-----
Benzo-k-fluoranteno	<0.35	<0.35	<0.36	<0.35	<0.35	<0.37	-----	-----
Criseno	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	-----	-----
Dibenzo-(a,h)-antraceno	<0.35	<0.35	<0.36	<0.35	<0.35	<0.37	-----	-----
Fenantreno	6.93	6.40	4.00	3.07	0.64	4.87	-----	-----
Fluoranteno	1.14	0.83	0.86	0.51	0.10	0.75	2 ^c	-----
Fluoreno	0.61	0.77	0.43	0.92	0.05	0.81	-----	-----
Indeno-(1,2,3-c,d)-pireno	<0.87	<0.88	<0.90	<0.87	<0.87	<0.92	-----	-----
Naftaleno	0.33	0.30	0.13	0.12	0.10	0.23	-----	-----
Pireno	4.17	2.20	2.22	1.51	0.30	2.06	-----	-----

ANALITICAL RESULTS

POLYCYCLIC AROMATIC HYDROCARBONS

Parámetro	Resultados Obtenidos (ng/m ³)						V.L. (L.E.A.A.) (ng/m ³)	V.L. (N.E.S.L.) (ng/m ³)
	P-1	P-2	P-3	P-4	P-5	P-6		
Acenafleeno	0.32	0.21	0.14	0.16	0.03	0.27	-----	-----
Acenafileno	0.21	0.13	0.07	0.07	0.03	0.09	-----	-----
Antraceno	0.46	0.43	0.28	0.22	0.02	0.19	-----	-----
Benzo-cg,k,l)-perileno	<0.52	<0.53	<0.54	<0.52	<0.52	<0.55	-----	-----
Benzo-a-antraceno	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	-----	-----
Benzo-a-pireno	<0.52	<0.53	<0.54	<0.52	<0.52	<0.55	-----	MAX:2000
Benzo-b-fluoranteno	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	-----	-----
Benzo-k-fluoranteno	<0.38	<0.38	<0.38	<0.38	<0.38	<0.37	-----	-----
Crieno	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	-----	-----
Dibenzofl(a,h)-antraceno	<0.35	<0.35	<0.35	<0.35	<0.35	<0.37	-----	-----

➤ The benzo(a)pyrene does not overcome the limit value proposed by the European parliament = 5µg/m³ (maximum value legislated in Italy)

Promo	4.17	2.20	2.22	1.81	0.30	2.06	-----	-----
-------	------	------	------	------	------	------	-------	-------

ANALITICAL RESULTS

HYDROGEN SULPHIDE

Parámetro	Resultados Obtenidos (mg/m ³)					
	P-1	P-2	P-3	P-4	P-5	P-6
Hidrógeno sulfurado en aire "in situ"	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3



➤ It is not detected hydrogen sulphide emission



STAGE III CONCLUSIONS

Section 24:

**Environmental and Health Study
SBR Rubber Granulates**

Environmental and Health Study SBR Rubber Granulates

The Netherlands

Nicole Salzmann
ISA Sport

ISA Sport - general

- Instituut voor Sportaccommodaties (started in 1959)
- 3 departments: research, field testing, consultancy

↙

Laboratory:

- sports floors
- materials for sports floors
- attributes
- development

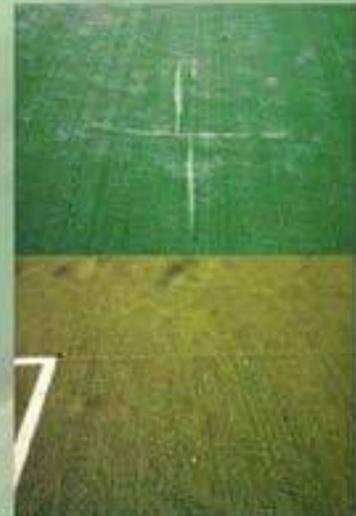
↘

On-site:

- quality monitoring
- certification

↘

Sports facilities





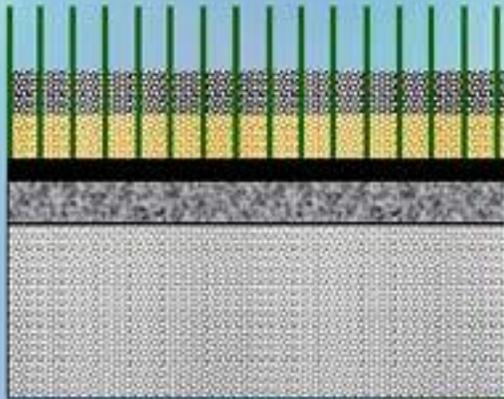
ISA Sport - Accreditations

- FIFA
- UEFA
- IAAF
- FIH
- ITF
- Quality:
ISO 9001 : 2000
ISO 17025 : 2000



Artificial Turf for Football

Schematic view relevant layers:



sand / rubber filled turf

option: shock absorbing layer

base layer, e.g.:

- crushed stone
- asphalt
- lava stone
- lava / rubber crumb mixture

Artificial Turf - aims

Standards

- *Single countries*: dependent on local football associations

end 2006 (?): one CEN standard

- *International*:

UEFA and FIFA adopt one common standard
"FIFA Quality Concept"



- *General (except Italy, Germany)*:
no environmental or health requirements;
"local regulations"

Rumours...

“Giftige gassen boven kunstgrasvelden”

Kunstgras is risic

“mogelijk toch kankerverwekkend”

“Voetballen op kunstgras gevaarlijk”

Research needed



Steering committee

- contractors
- rubber recycling industry
- rubber producing industry
- Royal Dutch Football Association (KNVB)
- Dutch Olympic Committee * Sports Federation (NOC*NSF)
- Dutch ministries (VROM, VWS)

➔ *independent research*

Research scope (1)

Research concentrated on:

- environmental risks
- health risks

- recycled tyre rubber granulates

no virgin materials

- infill material in artificial turf football constructions

no other applications (e.g. playgrounds)

- health risks for football player

not for e.g. infill installers



Research scope (2)

Ultimate research goal:

- environmental
 - health
- } standard or directive for all infill materials



Research execution

Independent experts on environment and toxicology:

- Intron (Project Manager)
- Industox (University of Nijmegen)
- National Institute for Public Health and Environment (RIVM)
- Kempeneers Environment and Management
- TNO
- DSM
- ISA Sport

Research content (1)

Research performed in 2 stages

Stage 1:

- literature study
- search for directives for judgement of results
- research on chemical composition of SBR rubber *)
- research on leaching behaviour of SBR rubber *)
- estimation health risks
- estimation environmental risks

*) *SBR rubber = recycled tyre rubber granulates*

Research content (2)

Stage 2:

- literature study continued
- research on leaching behaviour of SBR rubbers extended:
 - ageing due to use;
 - ageing in climatic chamber.
- research on health risks:
 - urine research on PAH exposure;
 - dermal exposure – PAH migration;
 - dermal exposure – local skin effects (literature).



Current status

Stage 1:

- Completed (June 2006)
- Report available via www.intron.nl

Stage 2:

- Running
- Report expected end of November



Results stage 1 (1)



Literature study:

- Overview performed studies on tyres and granulates for summary: see report
- Chemical composition, leaching effects, air and waste water measurements, dermal exposure PAH^{*)}
- No 100% "no risks" conclusion



^{*)} PAH = *Polycyclic Aromatic Hydrocarbon*



Results stage 1 (3)

Search for directives:

- **BSB** = Resolution for Building Materials:
 - for stone-like materials (e.g. asphalt, lava, clay courts)
 - limit values for PAH and leaching of metals
 - minimum application height 20 cm
 - leaching tests: column experiments (NEN 7383/7344)
 - ⇒ water, pH=7, 20°C, 21 days



Results stage 1 (4)

Research on chemical composition/leaching behaviour:

Investigated samples:

- Production: samples taken at 3 granulate producers
- Field: samples taken at 5 football fields < 1 year old



Results stage 1 (5)

Research on chemical composition:

All compounds studied below maximum level of BSB

Results stage 1 (6)

Research on leaching behaviour:

- Leaching of **PAH** very low
- **Zinc (Zn)** concentration

Sample	Production [mg/kg]	Field [mg/kg]
1	4.6	12
2	4.0	41
3	12 ¹⁾	19
4	-	53
5	-	33
mean	6.9	32
BSB	≤ 8.4 mg/kg ²⁾	

1): truck tyre granulates

2): $E_{\max} = 130 \text{ mg/kg}$

Results stage 1 (7)

Evaluation environmental risks:

- Leaching of Zn: research to be extended
 - Field samples with truck tyre granulates
 - Effect of ageing:
 - × fields 3 years old;
 - × samples aged in climatic chamber.



Results stage 1 (8)

Evaluation health risks:

- SBR rubber contains hazardous components, but:
 - Heavy metal concentration meets toys standard
 - Available for football player?
 - Research to be extended:
 - × allergic and irritation effects?
 - × PAH-uptake via skin?
 - ⇒ migration research
 - ⇒ urine research

Urine research

- PAH uptake → 1-hydroxypyrene in urine (marker)
- Football players (non-smoking) on SBR rubber field
 - urine samples during 3 days
 - 2 hours of playing on day 2
 - effect of massage oil



Nitrosamines $R_2N-N=O$

Air measurements 1 field during use:

- Dust particles with PAH and heavy metals
- Volatile aromatic hydrocarbons ("AH")
- Volatile nitrosamines



➔ *Uptake hazardous compounds via respiration?*

Nitrosamines - conclusion

Results air measurements 1 field during use:

- Amount PAH + heavy metals increases during use;
levels lower than health threshold
- No volatile aromatic hydrocarbons found
- Level of nitrosamine (NDEA) *higher* than health threshold

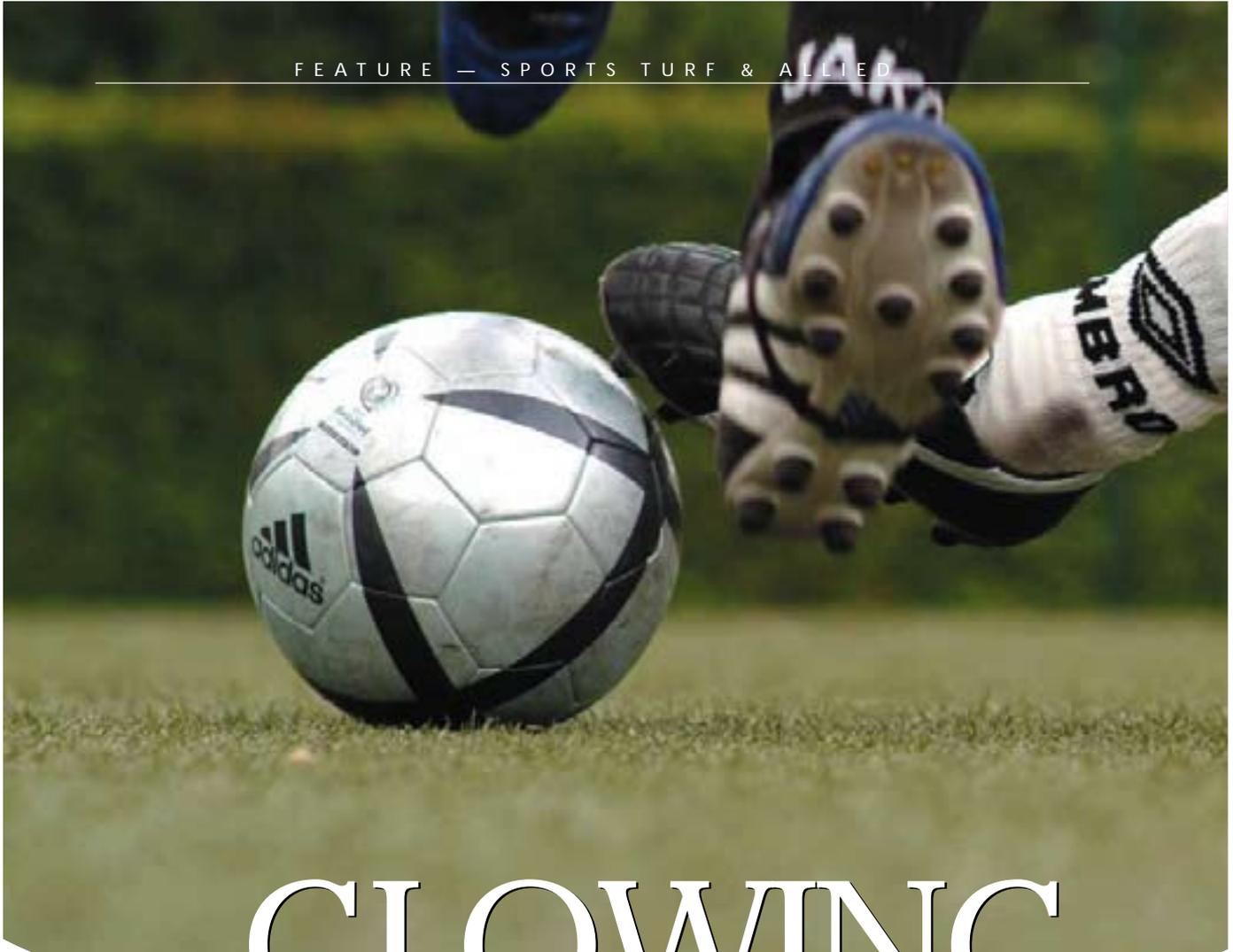
3 times a week – 2 hr football training:

Maximum Exceptable Risk level exceeded after 8 years

➔ *Extended measurements on NDEA*

Section 25:

Stadia Article



GLOWING

In the case of artificial grass surfaces, the infill material contributes to a safer field for the players.

Feature-writer Guy Oldenkotte reports on the latest research results regarding rubber infill materials being used for sports fields.



Third generation artificial grass is widely used at football, rugby and American Football stadia across the globe.

Ever since third-generation artificial grass fields started to grow (no pun intended) in popularity, there has been controversy over the rubber granules used as infill. Doubts about whether the product is environmentally-friendly and player safety issues have all fuelled speculation, forcing several federations to ban the use of this material altogether. However, recent studies have declared the use of rubber granule infill as 'safe'.

Back in the early 1990s, new developments in artificial grass fibre technology and long-pile artificial grass systems, combined with a sand/rubber infill combination, led to a boost in its use, as it suddenly seemed a viable alternative to natural grass. Today, third-generation artificial grass fields are predominantly used for football, rugby and American Football. Key to the success of the granule infill was the use of crushed car tyres.

These tiny little granulate particles were seen as a perfect and cheap solution, which would contribute both to the visual and playing characteristics of a field, as well as to the interaction between the field and the ball or player. By using a waste-product, it was also contributing to the disposal of millions of tonnes of used car tyres, which would otherwise have ended up in a landfill or illegal waste site. Many governments were duly willing to subsidise the re-use of this waste product.

In the European Union (EU) alone, it is estimated that close to three million tonnes of car tyres become redundant every year, while in the United States some 250 million scrap tyres are generated every year. With almost 200 tonnes necessary to generate enough rubber granulate for an average size football field, the increasing popularity of artificial



REPORT

grass fields was considered as being the perfect solution.

But with success also came opposition. Tests at the time showed that, once a field is burning, the rubber granulate could potentially act as an accelerator. Further studies showed that, despite the best efforts of all concerned, the infill material was not completely clear of the metals and chemicals used in the tyre-manufacturing process. It was public knowledge at the time that materials like zinc and Polycyclic Aromatic Hydrocarbons (PAH), could affect the environment, as well as the safety of the players, and so criticism of the product continued to grow.

Price effect

As it became increasingly clear that this product, referred to as SBR, was not the perfect solution, the industry soon came

up with alternatives (please refer to sidebar on p72). Despite efforts to produce a more environmentally-friendly infill material, the price remained the most important factor — since most buyers only look at the price per square metre for their artificial grass systems. An average sized football field requires close to 80 or 90 tonnes of SBR, which currently retails at around twenty eurocent per kilogram. In comparison, the industry's newer TPE or EPDM infill materials sell for prices ranging between one and two euro's per kilogram.

However, what buyers tend to forget is that an artificial grass field requires less EPDM or TPE than SBR due to their contribution to the field characteristics, thanks to the natural softness of the compound used. In addition, it also seems that they forget that in some countries they may have to pay for the removal of SBR once a field is replaced, as

SBR is regarded as a waste product. EPDM and TPE can, however, be re-used in a new field, providing that they have not deteriorated, as they have a shorter lifespan.

Joint Research Project

When the EU advised that it would be banning the use of PAH in car tyres as of 2010, questions were once again raised about rubber granulate. And Scandinavia has already prohibited the use of recycled car tyres in enclosed stadia due to the potential fire hazard. The Italian government followed suit, using the questions being raised in the European parliament to ban the use of crushed car tyres in artificial grass fields until more information was available. This also provided them an excuse for an even bigger concern; the hot temperatures players were complaining about. As recycled car tyres absorb



GLOWING REPORT

The thickness of the infill layer depends on the artificial grass system being used.



Recent research has shown that exposure to SBR poses no ill health effects.

heat, temperatures increased to an uncomfortable degree. The Dutch government also had its doubts, and questions were asked in parliament, with the Dutch artificial grass industry choosing to have its own study conducted.

Artificial grass is regarded as the perfect solution to increase the capacity of sports fields, especially in The Netherlands. And with many football clubs situated in densely populated areas, where cities are increasingly demanding space to be used for city development projects, artificial grass could be the perfect solution.

Banning the use of crushed car tyre infill for use in artificial grass fields would mean that much more expensive alternatives would have to be utilised, making artificial grass fields too expensive and therefore an unattractive option.

In a joint research project, ISA Sport and the research institute, Intron, teamed up with installing companies Arcadis, Grontmij, Heijmans, Van Kessel and Oranjewoud, along with artificial grass manufacturers Desso and Ten Cate Tholon. The Dutch branch of the federation for the rubber industry, VACO, as well as DSM Thermoplastic Elastomers, which produces an alternative infill material, completed the team.

In-depth Research

For almost a year the group studied the consequences of the use of recycled car tyres. In the absence of clear directives, the European guidelines for heavy metal concentration in toys, as well as the Dutch Resolution for Building Materials, were taken as a starting point. Both directives were regarded as the most stringent available in these specific areas. To find out the consequences for the environment, rubber granulate was placed under water and tested over a long period for leaching.

For the test, the research team used a 20cm thick layer, whereas normally the rubber granulate layer would not exceed 3 or 4cm. The results showed that all compounds studied were below the maximum level that was allowed by the Resolution for Building Materials, meaning that the average 3cm thick layer is hardly a danger to the environment at all.

To determine the safety of the player, the test group used the DIN standard for toys. This standard is internationally recognised as being the most stringent on safety for human beings. The research showed that the quantity of each component that could be regarded as 'unsafe'



GLOWING REPORT

The latest infill materials come in a wide palette of colours.

was so low that it would not harm an athlete coming into contact with the material when used in an open field. Here the wind would have access to blow away any possible fumes.

International Consequences

The results of the study have settled arguments in The Netherlands, for now at least. However, what the international community effect will be is not clear yet. In the past, several other research institutes have conducted tests to determine the safety or danger of rubber infill. Their results are, in most cases, only applicable

in the countries that demanded such research, since laws and directives are different in each country. Even within political institutions, like the EU, it is difficult to reach a single directive for all countries participating in this international governing body. And with the price of an artificial grass system still an issue in many countries, the use of crushed tyres as an infill material seems the only option at present. But once the use of PAH has been prohibited in the manufacture of car tyres — as of 2010 — in the EU, this whole argument will no longer be valid.

Variety of infill materials available

The rubber granulate makes the grass fibres stand up-right, making the field look greener and more natural. It also contributes to the playing and safety characteristics of the field, and allows the players' studs to 'sink' into the field. Players will therefore have more grip and stability, and will also have a safer surface. Nowadays, a variety of infill materials are available, as follows:

SBR (Styrene-Butadiene Rubber)

This material is made of crushed car tyres and is therefore very cheap and durable. As it is mainly available in black, it can affect the temperature on the field during the summer. SBR also has the disadvantages that it smells and it is difficult to guarantee a standardised quality over the entire field as up to 35,000 tyres have been crushed to make one single field. To reduce the smell and prevent the SBR contributing to the temperature, the material is also available with a coating.

EPDM (Ethylene Propylene Dien Polymethylene)

This product has been specifically developed for its purpose, which makes EPDM almost eight times more expensive than SBR. By using other material for filling, the industry has tried to make EPDM cheaper, but this had a negative impact on the quality of

the infill, as well as the field. Since it has been produced specifically for its purpose, EPDM is available in a variety of colours, which contributes to the natural look, as well as the temperature on the field. It is also possible to have other materials included in the compound, like anti-statics, UV-stabilisers or flame retardant material. EPDM is not recyclable

TPE (Thermo Plastic Elastomer)

Like EPDM, this infill material is also specifically produced for its purpose and allows other materials to be included. Unlike EPDM, TPE is recyclable, and offers a better contribution to the playing characteristics of the field, like ball bounce and shock absorption. It is available in different colours and can have additives like anti-statics, UV-stabilisers or flame retardants included. Where SBR is very durable, TPE tends to wear faster. Pricewise, TPE is ten times more expensive than SBR.

Other alternatives

Despite the industry's best efforts to produce a more environmentally-friendly infill material, the price remains the most important factor. Several manufacturers are therefore studying alternatives ranging from supplying crushed shoe soles to kokos particles to find a product that brings a contribution to player safety, playing characteristics and price, all while being as environmentally-friendly as possible.