

CHEMICALS IN OUTDOOR ARTIFICIAL TURF: A HEALTH RISK FOR USERS?

June 2009

**Monique Beausoleil
Karine Price
Caroline Muller**

Direction de santé publique de l'Agence de la santé et des services sociaux de Montréal
(Public Health Branch, Montreal Health and Social Services Agency)

Originally published in BISE (le Bulletin d'information en santé environnementale),
Institut national de santé publique du Québec, Volume 19, Number 4, September –
October 2008.

Translated by the National Collaborating Centre for Environmental Health (NCCEH) in partnership with INSPQ through a financial contribution from the Public Health Agency of Canada through the NCCEH. The views expressed herein do not necessarily represent the views of the Agency or the Centre.

Introduction

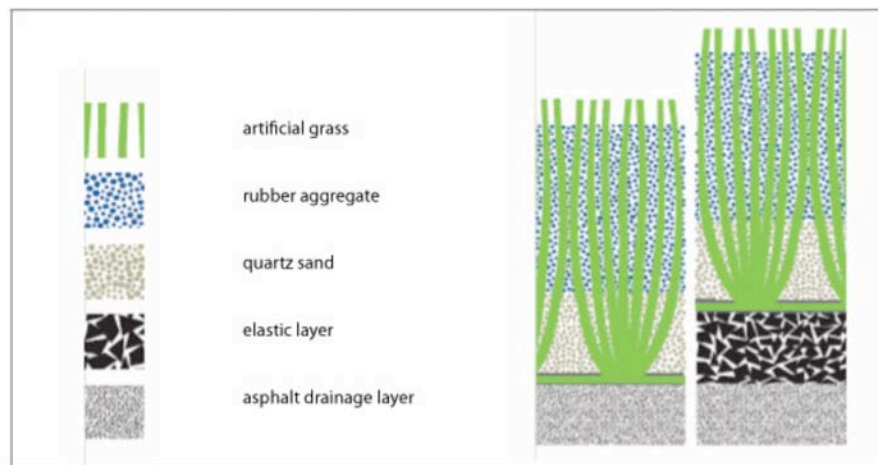
Over the past few years, Quebec has seen the introduction of new sports fields surfaced with artificial turf. This product offers many advantages over natural turf for playing outdoor team sports. It is more durable and allows for more hours of use on a high-quality surface. It is little affected by weather conditions, whereas overused natural turf has large areas of bare ground which become hard and dusty during dry periods or muddy during wet periods, and are therefore not as safe for the players. As a result, artificial turf fields are beneficial in promoting regular physical activity among youth.

However, citizens and organizations in various countries have questioned the safety of certain materials used in the manufacture of these surfaces. To address this issue, many studies have been conducted by a large number of organizations – universities, public health institutes, sports federations, and manufacturers of artificial turf – to assess the potential impact of these materials on players' health and on the environment.

The City of Montreal now has more than thirty sports fields with artificial turf surfaces and is planning to build several more in the coming years. In fall 2007, it asked the Direction de santé publique (Public Health Branch – DSP) of the Agence de la santé et des services sociaux de Montréal (Montreal Health and Social Services Agency) to provide it with an opinion about the risks that the materials used in artificial turf could pose to human health. This evaluation focused solely on the **toxicological risks of the chemicals** contained in or emitted by **artificial turf used for outdoor sports**, although some of the information used came from studies on indoor artificial turf or aggregates used under children's playground modules in parks.

What is artificial turf?

The first artificial turf in Quebec was installed in 1976 at the Centre Claude-Robillard in Montreal for the Olympic Games. It was a first generation turf consisting of a mat of very short synthetic fibres very densely woven into a canvas backing, and a resilient prefabricated cushion to absorb shocks, all sitting on a foundation of granular material, which is generally permeable or well drained. The second generation of artificial turf is composed of a mat of longer, less densely-spaced synthetic fibres woven into a canvas backing and filled with a thin layer of sand. First and second generation artificial turf are now hardly ever used for playing soccer since the advent of third generation surfaces in 1995^{1,2}. Unlike the first and second generations, they offer excellent performance for sports activities and are less abrasive on players when they fall (Figure 1). They are composed of a mat of longer and even less densely-spaced fibres, filled with small rubber granules or a mixture of rubber granules and sand, to a depth of about 4 cm. Aggregates give the turf an appearance and play performance similar to natural grass¹.



Source : <http://www.bag.admin.ch/themen/chemikalien/00228/03458/index.html?lang=fr>

Figure 1. Third generation turf

The fibres in first generation artificial turf may be made of nylon, whereas the fibres in second and third generation turfs are generally made of polyethylene (PE), polypropylene (PP) or polyamide (PA). They are in the form of monofilaments or are fibrillated to simulate natural blades of grass and to provide greater stability to filler aggregates¹.

The materials used as the base for the mat layer are generally polyester or PP, partially reinforced with fibreglass. The inserted fibres are held in place by a second base made of latex or polyurethane (PUR)³.

The main aggregates currently used in the mat layer of third generation turfs are made of rubber derived from recycled tires (SBRr – styrene-butadiene recycled rubber), since these are less expensive than other types of aggregates³. During recycling, the pieces of tire are shredded, the pieces of metal are removed from them using magnets, and the fibre is vacuum extracted. Dirt is removed by washing with water⁴. When only the rubber is left, it is mechanically ground at room temperature or at very low temperature so as to produce “cryogenic granules”, which have the advantage of having a better-defined diameter which limits the production of fine dusts³. The aerodynamic diameter of the granules generally varies from 0.5 to 3 mm over a given artificial turf (Figure 2)⁵.



Source : http://www.nytimes.com/2007/10/28/nvregion/nvregionspecial2/28turfwe.html?_r=1&oref=slogin

Figure 2. Artificial turf material with SBRr granules

Many studies have been conducted to evaluate the chemicals in products from recycled tires and identify potential sources of these chemicals (Table 1). There are also EPDM (ethylene-propylene-diene monomer) aggregates produced from a synthetic rubber formed from ethylene terpolymers, propylene and diene, TPE aggregates formed from thermoplastic elastomer³ and recycled plastic aggregates manufactured from a single alkene monomer⁶.

Table 1. Chemicals detected in products from recycled tires according to the different sources present during the manufacture of tires

POTENTIAL SOURCES	CHEMICAL SUBSTANCES DETECTED
<i>Metals</i>	
Zinc oxide used as a vulcanization activator	zinc
Component of belts and steel bearings	iron, manganese and chromium
Catalyst for rubber synthesis	barium
<i>Volatile organic compounds (VOCs)</i>	
Used in the production of antioxidants	methyl isobutyl ketone (MIBK)
Carbon black used as a raw material	naphthalene
Process oils used as softeners	toluene, benzene, acetone, MIBK
<i>Semi-volatile organic compounds (SVOCs)</i>	
Process oils used as plasticizers and softeners	polycyclic aromatic hydrocarbons (PAH)
Used as vulcanization accelerators and to bind the metal to the rubber	benzothiazoles
Added to tires to inhibit rubber degradation	aniline
Process oils used as softeners or treatment with formaldehyde phenol	phenol
Used to inhibit vulcanization during tire production and decomposition of the end product	diphenylnitrosamine/dimethylnitrosamine

Source: Information from the OEHHA, 2007, collated by TRC, 2008⁷.

Methodology used to assess toxicological risks associated with materials in artificial turfs

The majority (88%) of the approximately thirty artificial turfs in the City of Montreal are third generation, with polyethylene (PE) fibres and SBRr or SBRr/sand aggregates. Therefore, our assessment of health risks for players focused on these materials.

We evaluated data from the scientific literature concerning the health risks of artificial turf materials in three ways.

- First, we identified the measured concentrations of chemicals associated with artificial turf material to compare them with various threshold limit values established to protect the health of the general population (threshold limits for concentrations in materials, concentrations discharged into water by the materials in the laboratory and in the field, concentrations emitted into the air in the laboratory and those measured in outdoor air or indoor air in gymnasiums). These comparisons allow us to assess the risks that these substances could pose to people who engage in sports activities on outdoor artificial turf.
- Second, we reviewed and evaluated the results of toxicological risk analyses for users of artificial turf conducted by various recognized agencies.
- Finally, we reported the findings of the ministries of public health and the environment in several countries regarding the potential health risks of the chemicals associated with artificial turf for users and their recommendations regarding the use of the various materials in the manufacture and installation of artificial turf.

The studies selected are from both North America and Europe. Although none of the chemical analyses reported in these studies was conducted using materials taken in Montreal, we believe their results apply to the artificial turf in the City of Montreal since the base materials are the same, they come from the same major suppliers, and they are often manufactured by the same companies, most of which are based outside Quebec. Despite the variation observed in the concentrations reported by the various studies, our assessment and the toxicological risk assessments carried out by various authors have generally considered the highest concentrations measured.

Results¹

The various studies chosen for our analysis presented or used the concentrations of a number of chemicals associated with artificial turf. Table 2 shows the major categories.

¹ This is a summary of the results taken from our review of the scientific literature. All the data can be seen in our full report at: <http://www.santepub-mtl.qc.ca/Publication/pdfenvironnement/gazonsynthetique.pdf>.

Table 2. Classes of chemicals evaluated

Group	Class	Examples of subclasses or substances
Metals	essential elements	chromium, manganese, zinc
	heavy metals	arsenic, cadmium, lead
	other	barium, iron
Volatile organic compounds	total compounds	total hydrocarbons, TVOC, TSVOC
	aliphatic hydrocarbons	alkanes (butane, propane, pentane), alkenes (butadiene, propylene)
	aromatics	benzene, toluene, ethylbenzene, xylene, alkylbenzene, alkyltoluene
	aldehydes	acetaldehyde, formaldehyde
	ketones	MEK, MIBK,
	alcohols	2-butoxyethanol
	chlorinated hydrocarbons	trichloromethane, trichloroethene
	volatile PAHs	naphthalene, methylnaphthalene
Semi-volatile organic compounds	nitrogenated hydrocarbons	aniline, nitrosamine, benzothiazole
	phthalates	BBP, DBP, DEP, DEHP, DIDP, DINP, DMP, DOP
	phenols	4-t-octylphenol, iso-nonylphenol
	Other	BPC
Polycyclic aromatic hydrocarbons	carcinogenic PAHs	benzo(a)pyrene, benzo(a)anthracene
	non-carcinogenic PAHs	acenaphthene, fluoranthrene, phenanthrene, pyrene

Measured concentrations of chemicals associated with the materials

We selected a number of scientific studies that measured the concentrations of chemicals associated with artificial turf materials in North America and Europe^{2,5,9,10,11,12,13,14,15,16,17,18,19, 20,21,22,23,24,25,26,27,28,29,30,31,32,33,34}. A comparison of the results of these measurements with various limit values established to protect health is provided in Table 3.

Table 3. Summary of the comparison between concentrations of chemicals associated with the materials and the selected limit values

Chemical class	Results
Metals	Analyses of metals identified a slightly more pronounced presence of chromium, cobalt and lead in some materials; however, these metals are not mobilized by rainwater or emitted into the air. In the United States, <u>one</u> measurement of the <u>concentration</u> of lead in the dust from an artificial turf with nylon fibres appeared to be high, while other measurements of the <u>amount</u> of lead on the surfaces of the same type of turf fell within the limit values set by the United States Environmental Protection Agency for indoor surfaces in residences (floors and window sills) inhabited by children ² . Finally, concentrations of zinc measured in all the materials are also higher; this metal can be mobilized in water during experiments in the laboratory, but to a far lesser degree in rainwater on the fields themselves. However, this metal has low toxicity for humans, and the concentrations measured in water are generally below the threshold limit allowed for drinking water in Canada. All risk assessments indicate that toxic metals are not a significant risk to human health, although some warnings have been issued in relation to the potential impact of zinc on the environment.
Volatile organic compounds (total volatile compounds,	Various organic compounds are found in these materials since they are manufactured from petroleum (plastic and rubber). These organic compounds may be mobilized in water in the laboratory using “aggressive” extraction methods, but

² As we will see in Table 4, the U.S. Center for Disease Control and Prevention (CDC) has recommended that the lead in dust from first generation turf be measured only when the nylon fibers are worn and in poor condition and when they contain visible dust. When we visited the only sports field in the City of Montreal that has nylon fibers in its artificial turf, we found that the very short, sand-filled fibers in this third generation turf are in good condition and do not contain visible dust.

aromatic compounds, aldehydes, ketones, chlorine-containing compounds)	very little is mobilized in rain water on the fields themselves. Volatile organic compounds may also be emitted into the air by the various materials; their concentrations, measured in the form of total volatile organic compounds (TVOC) may be sufficiently high in the air in some gymnasiums to cause discomfort and the perception of odours for some people, but they are much too low to have adverse effects on the health of players. Moreover, these levels are frequently observed in indoor air in other environments such as homes, schools and offices. Concentrations measured in outdoor air over fields with artificial turf have been shown to be similar to background levels.
Semi-volatile organic compounds	A number of measurements of various semi-volatile organic compounds (SVOCs) were carried out on materials from artificial turf (phenols, alkylphenols, PCBs, amines, nitrosamines, benzothiazoles, phthalates). The concentrations measured in the materials were generally low; where they were somewhat higher in certain materials (some alkylphenols, aniline and benzothiazoles), the levels measured in the water or indoor air in gymnasiums were very low. Nitrosamines were not detected in outdoor air above artificial turf.
Polycyclic aromatic hydrocarbons	The presence of polycyclic aromatic hydrocarbons (PAHs) in SBRr aggregates is very high due to the use of aromatic petroleum oils as plasticizers and softeners during the manufacture of tires. They are detected in these aggregates but little is found in water when extractions are done in the laboratory, since they are usually not very soluble. The concentrations measured in the air of indoor gyms with SBRr aggregates may exceed average concentrations measured in outdoor air and occasionally approach the maximum concentrations measured in outdoor air in Montreal when air quality is poor. Naphthalene and methyl naphthalene represent over a third of PAHs measured in indoor air because of their higher volatility. However, concentrations of PAHs measured in air above a field surfaced with outdoor artificial turf are similar to the average concentrations measured in outdoor air in Montreal.

Several researchers have raised questions about the possible link between the presence of allergens associated with SBRr aggregates (latex and additives) on the one hand, and respiratory allergic reactions and player contact on the other^{7,14,23,24,25,35,36}. Some data suggest that this link is rather weak: latex allergens are probably destroyed during tire vulcanization; animal tests on sensitivity to SBRr aggregates have come out negative and no increase in cases of latex allergy has been observed in people living near major roads where airborne dust contains rubber from vehicle tire wear. However, the authors point out that we cannot exclude the possibility that people who have already become sensitized through contact with rubber aggregates will develop an allergy or experience allergic symptoms. It should be noted that the population is already in contact with many products made of rubber in their environment (shoe soles, gloves, some types of balloons).

Results of toxicological risk analyses

In the literature we identified seven toxicological risk assessments carried out by recognized organizations that have considered various chemicals, various routes of exposure and toxicological reference values^{14,24,25,37,38,39}. **All these analyses indicate** that exposure to chemicals while engaging in sports activities on artificial turf is low and **that the risks to players' health are not a concern**. Although there are some differences among the approaches to risk assessment used in these studies and the approach generally used in Quebec, we agree with their conclusions, particularly since inhalation exposure data used in these studies are derived from a study conducted indoors in gymnasiums, where exposure levels will be considerably higher compared to players who engage in their sport outdoors. This study also showed that TVOC concentrations measured in indoor air in three gymnasiums in Norway with SBRr aggregates^{2,3} were within the range of concentrations measured in indoor air in various other environments (homes, offices and schools)^{40,41}.

Positions of government agencies

Table 4 shows the positions of various government agencies regarding the toxicological risks associated with artificial turf materials, both in North America and Europe.

Table 4. Positions of various agencies regarding the toxicological risks associated with materials in artificial turf

<p>NORTH AMERICA</p>	<ul style="list-style-type: none"> • The New Jersey Department of Health and Senior Services⁴² recommended the closure of three sports fields because the concentrations of lead found in the nylon fibres in the first generation artificial turf and the dust in <u>one</u> of the fields were considered to be high. • The New York City Department of Health and Mental Hygiene⁴³ considers it to be unlikely that low levels of exposure to the various chemicals measured in artificial turf have any effects on the health of players. The agency tested nylon fibres from a number of artificial turfs, measuring the <i>amount</i> of lead in the dust in µg/sq. ft. rather than the <i>concentration</i> of lead in the dust in µg/g. Since the values found fell within the allowable limits for residential surfaces (floors and window sills) set by the U.S. EPA⁴⁴, it considers that these sports fields can continue to be used by the players in spite of the relatively high concentration of lead measured in the fibres themselves. • The CDC⁴⁵ and its agency the ATSDR consider it appropriate to measure the concentration of lead in the dust from artificial turf with nylon or nylon/PE fibres only where the turf is damaged and contains visible dust, in order to rule out the presence of any (non-essential) lead. • The Connecticut Department of Public Health⁴⁶ believes that based on the data available, the public health risks associated with the chemicals in artificial turf materials appear to be low. It considers sources of exposure not related to artificial turf materials to be more significant than those associated with artificial turf. • The OEHHA²⁵ conducted an assessment of the health risks associated with SBRr aggregates under playground modules and found that the risk levels were below the levels generally considered acceptable. However, this agency has not issued a position regarding the use of SBRr aggregates.
<p>EUROPE</p>	<ul style="list-style-type: none"> • The Norwegian Institute of Public Health and Radium Hospital²⁴ consider that the use of artificial turf (indoors in gymnasiums) with recycled rubber aggregates shows no evidence of posing a major health risk. However, they recommend that SBRr aggregates not be used in new indoor gymnasiums. • The Swiss Confederation's <i>Office fédéral de la santé publique</i> (Federal Bureau of Public Health)²⁶ concluded that the results of studies conducted in Sweden, Norway and Germany showed that playing on artificial turf with SBRr aggregates posed no particular health risks. • Keml¹⁶, an agency of Sweden's Ministry of the Environment, recommended that aggregates from recycled tires not be used in the construction of new artificial turf fields because of the chemicals they contain. However, it considers that the SBRr aggregate in existing fields need not be replaced as long as it remains in good condition because the health and environmental risks associated with these materials are low.

Conclusion

In light of all the information gleaned from the scientific literature, it appears that **the health risks for players who use artificial turf are not significant and that it is completely safe to engage in sports activities on this type of outdoor field.** Although metal analyses have identified the presence of chromium, cobalt and lead in certain materials, these metals are not mobilized by rainwater or emitted into the air. Moreover, although zinc concentrations measured in all the materials were higher, zinc has low toxicity in humans and the concentrations measured in water are generally below the limit value for drinking water in Canada. The concentrations of organic compounds (volatile and semi-volatile compounds and polycyclic

aromatic hydrocarbons) do not exceed the limit values established to protect human health. The various toxicological risk assessments carried out by recognized agencies indicate that health risks for players are not a concern. It should be noted that the small number of countries that have chosen to avoid SBRr aggregates in the construction of new artificial turf fields still believe that the health risks associated with these materials are very low and state that their choice is based solely on environment objectives.

In the course of our review of the scientific literature, we found that surface temperatures and temperatures measured in the ambient air above artificial turf on very hot days could reach significant levels and add to the thermal stress experienced by players engaging in intense sports activities such as soccer. It would be useful to document this problem on the outdoor fields in Montreal, evaluating the thermal loads on players under various conditions as well as carrying out measurements on the materials.

References

1. Gionet, L., 2005. Guide d'aménagement et d'entretien des terrains de soccer extérieurs. Ville de Montréal et Ministère de l'Éducation, du Loisir et du Sport. 77 pages.
2. Moretto, R., 2007. 26 pages, *Environmental and health assessment of the use of elastomer granulates (virgin and from used tyres) as infill in third-generation artificial turf*. ADEME / ALIAPUR / FIELDTURF TARKETT.
www.aliapur.fr/media/files/etudes_documents/Environmental_Study_Report_EN.pdf.
3. Kolitzus, H. J., 2007. Artificial turf surfaces for soccer. 29 pages,
www.iss.de/publications/ArtificialTurf/Study%20KR%206943%20english070511.pdf.
4. Recyc-Québec, 2007. Les pneus hors d'usage - Fiche d'information. Recyc-Québec, <http://www.recyc-quebec.gouv.qc.ca/Upload/Publications/Fiche-pneus.pdf>.
5. Plessner, S. W. et Lund, O. J., 2004. Potential health and environmental effects linked to artificial turf systems - final report. Norwegian Building Research Institute. 16 pages.
6. Mondo, 2008. Une étude sur les risques que pourrait présenter, pour la santé et l'environnement, l'emploi des granules de caoutchouc (pneus recyclés) dans les terrains de gazon synthétique. Mondo. 6 pages.
7. TRC, 2008. A review of the potential health and safety risks from artificial turf fields containing crumb rubber infill. New York City Department of Health and Mental Hygiene,
http://home2.nyc.gov/html/doh/downloads/pdf/eode/turf_report_05-08.pdf.
8. Beausoleil, M., Price, K., et Muller, C., 2008. Gazons synthétiques utilisés pour les sports extérieurs à la ville de Montréal: Revue de la littérature et évaluation des risques toxicologiques. 68 pages.
9. A-Turf inc, 2008. Artificial turf safety. 2 pages,
www.generalmlane.org/district/folders/gmfoundation/turf/turfsafety.pdf.
10. Bresnitz, E. A., 2008. Letter from New Jersey Department of Health and Senior Services to U.S. Consumer Product Safety Commission. New Jersey Department of Health and Senior Services. 2 pages, <http://www.state.nj.us/health/artificialturf/index.shtml>.
11. Bresnitz, E. A., 2008. Letter to the U.S. Consumer Product safety Commission. New Jersey Department of Health and Senior Services,
http://www.state.nj.us/health/artificialturf/documents/cpsc_letter_0608.pdf.
12. EHHI, 2007. Artificial turf - Exposures to ground-up rubber tires - Athletic fields - playgrounds - gardening mulch. Environment and Human Health inc. 36 pages,
http://www.ehhi.org/reports/turf/turf_report07.pdf.
13. Gill, D. et Hainsey, M., 2008. Environmental Intelligence - The truth about lead in artificial turf. Ezine articles, <http://ezinearticles.com/?Environmental-Intelligence---The-Truth-About-Lead-in-Synthetic-Turf&id=1281521>.
14. Hofstra, U., 2007. Environmental and health risks of rubber infill - rubber crumb from car tyres as infill on artificial turf - summary. 7 pages.
15. IBV, 2007. Study of the incidence of recycled rubber from tyres in environment and human health. Instituto de Biomecanica de Valencia.
16. KemI, 2006. Artificial turf from a chemical perspective-a status report. Swedish Chemicals Inspectorate. 27 pages.

17. J.C.Broderick & Associates, 2007. Ambient air sampling for PAH's - Comsewogue High School football field - Port Jeff Station, New York. 4 pages.
18. J.C.Broderick & Associates, 2007. Ambient air sampling for PAH's - Schreiber High School football field - Port Washington, New York. 4 pages.
19. Kopangen, M., 2005. Environmental risk assessment of artificial turf systems. Norwegian Institute for Water Research. 19 pages,
<http://www.iss.de/conferences/Dresden%202006/Technical/NIVA%20Engelsk.pdf>.
20. VROM, 200. Rubber granules as infill material in artificial turf fields. Ministry of Social Housing, Regional Planning and Environmental Administration of The Netherlands,
http://www.ci.wellesley.ma.us/Pages/WellesleyMA_SpragueResources/Debunking%20the%20Myth%20of%20SBR%20Dangers_0420.pdf.
21. New Jersey Department of Health and Senior Services, 2008. New Jersey Investigation of Artificial turf and Human Health Concerns. New Jersey Department of Health and Senior Services. 2 pages,
<http://www.state.nj.us/health/artificialturf/index.shtml>.
22. New York City Department of Health and Mental Hygiene, 2008. Lead Hazard risk assessment of artificial turf playing fields. The City of New York Department of Health and Mental Hygiene,
[http://www.syntheticurfCouncil.org/associations/7632/files/NYC_Lead_Risk_Report_-_4-15-08\[1\].pdf](http://www.syntheticurfCouncil.org/associations/7632/files/NYC_Lead_Risk_Report_-_4-15-08[1].pdf).
23. NILU, 2006. Measurement of air pollution in indoor artificial turf halls. Norwegian Pollution Control Authority.
24. NIPHRH, 2006. Artificial turf pitches - an assessment of the health risks for football players. Norwegian Institute of Public Health and Radium Hospital. 34 pages,
<http://www.iss.de/conferences/Dresden%202006/Technical/FHI%20Engelsk.pdf>.
25. OEHHA, 2007. Evaluation of health effects of recycled waste tires in playground and track products. Office of Environmental Health Hazard Assessment,
www.ciwmb.ca.gov/Publications/Tires/62206013.pdf.
26. Office fédéral de la santé publique de la Confédération suisse, 2006. Fiche d'information: Pelouses synthétiques - Risques sanitaires? 4 pages,
<http://www.bag.admin.ch/themen/chemikalien/00228/03458/index.html?lang=fr>.
27. RAMP, 2007. Artificial turf Chemicals. <http://www.albany.edu/ihe/SyntheticTurfChemicals.htm>.
28. Swedish Chemicals Inspectorate, 2006. Artificial turf from a chemical perspective-a status report. 27 pages.
29. Tencate thiolon, 2008. Technical information manual version 6.0.
30. TSI Testing Services inc pour AstroTurf, 2008. Test report - Parc Ironwood Recreation - Newark, New-Jersey. 2 pages.
31. van Bruggen, M., van Putten, E. M., et Janssen, P. C., 2007. Nitrosamines released from rubber crumb. RIVM (National Institute of public health and the environment, Pays-Bas,
www.parks.sfgov.org/wcm_recpark/SPTF/TurfNitrosamines.pdf.
32. Verna, R., 2006. Is artificial turf a problem? Situation in Italy and prospective of research - [Presentation]. Italian Ministry of Health, http://www.iss-sportsurfacescience.org/downloads/documents/5XVR42HXEI_DRESDA_Roberta_Verna.pdf.
33. Verschoor, A. J., 2007. Leaching of zinc from rubber infill on artificial turf (football pitches) - RIVM report 601774001/2007. Ministry of Housing, Spatial planning and the Environment Hollande,
http://www.parks.sfgov.org/wcm_recpark/SPTF/Verschoor.pdf.

34. Willoughby, B. G., 2006. PAHs and other organics in tyres - origins and potential for release - Background material for the Standards for Artificial Turf Working Group. Consultant in Polymer Chemistry.
35. Anderson, M. E. et coll., 2006. A case study of tire crumb use on playgrounds: risk analysis and communication when major clinical knowledge gaps exist - Commentary. *Environmental Health Perspectives*, 114: 1-3.
36. Iedoux, T., 2007. Preliminary assessment of the toxicity from exposure to crumb rubber: its use playgrounds and artificial turf playing fields. 2 pages, <http://www.asgi.us/whitepaper%20-%20rubber.pdf>.
37. Nilsson, N. H., Feilberg, A., et Pommer, K., 2005. Emissions and evaluation of health effects of PAH's and aromatic amines from tyres. Danish Ministry of the Environment, <http://www.mst.dk/Udgivelser/Publications/2005/05/87-7614-652-9.htm>.
38. INERIS, 2007. Évaluation de risques toxicologiques citée dans Moretto, 2007. www.aliapur.fr/media/files/etudes_documents/Environmental_Study_Report_EN.pdf.
39. Johns, D. M., 2008. Initial evaluation of potential human health risks associated with playing on artificial turf fields on Bainbridge Island. Windward Environmental LLC.
40. WHO 1997. Assessment of exposure to indoor air pollutants, Jantunen, M., Jaakkola, J. J. K., and Krzyzanowski, M., Denmark. 139 pages. ISBN
41. Mosqueron, L. et Nedellec, V., 2001. Inventaire des données françaises sur la qualité de l'air à l'intérieur des bâtiments. Observatoire de la qualité de l'air intérieur. 173 pages.
42. New Jersey Department of Health and Senior Services, 2008. Update: New Jersey Investigation of Artificial Turf and Human Health Concerns - June 2008. New Jersey Department of Health and Senior Services.
43. New York City Department of Health and Mental Hygiene, 2008. Fact sheet on crumb rubber used in artificial turf. Site internet consulté le 10 juillet 2008, <http://www.nyc.gov/html/doh/html/eode/eode-turf.shtml>.
44. U.S.EPA, 2007. Lead; Renovation, Repair, and Painting Program - Federal Register Environmental Document. U.S.Environmental Protection Agency, <http://www.epa.gov/EPA-TOX/2007/June/Day-05/t10797.htm>.
45. CDC, 2008. Potential exposure to lead in artificial turf: public health issues, actions and recommendations. Centers for Disease Control and Prevention et Site consulté le 11 juillet 2008, <http://www2a.cdc.gov/HAN/ArchiveSys/ViewMsgV.asp?AlertNum=00275>.
46. Connecticut Department of Public Health, 2007. Artificial turf fields: health questions. Site consulté le 11 juillet 2008, [http://www.ct.gov/dph/lib/dph/environmental_health/pdf/artificial_turf_\(2\).pdf](http://www.ct.gov/dph/lib/dph/environmental_health/pdf/artificial_turf_(2).pdf).