January 3, 2008

**Topic # 13: TOXINS IN SYNTHETIC TURF**

**Prepared and Presented By:** Jim Fox

**Approved by the Director:**

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**Proposed Action:** Discussion

**Summary**
Synthetic turf offers numerous advantages over natural playfield surfaces. It requires no mowing, watering, fertilizers or herbicides, and allows the field to be used a greater number of hours during the year. However, some reports of chemical analysis of artificial turf have shown that it is composed of a number of hazardous substances that could be detrimental to the environment and on people using the field if the substances were released through leaching or outgassing.

**Staff Recommendation**
Staff recommends that the RCO investigate ways that the Recreation and Conservation Funding Board (RCFB) could provide assistance and incentives to applicants to foster use of construction materials and practices that reduce potential negative environmental and public health impacts.

**Background**
At the request of a member of the RCFB, staff looked into concerns that have been raised over the use of synthetic turf in playfields, including investigation into the use of Polybrominated Diphenyl Ether (PBDE) flame retardants.

Synthetic turf offers numerous advantages over natural turf. It requires no mowing, watering, fertilizers or herbicides, and allows the field to be used a greater number of hours during the year. Although the initial costs are higher, reduced long-term maintenance and increased playing time make artificial turf generally more cost effective in the long run. A comparative analysis of synthetic versus natural turf is attached to this memo.

The new generation of synthetic turf is typically composed of thousands of tiny rubber granules, about the size of grains of rice, made from ground up recycled rubber tires.

The synthetic grass blades are made of polyethylene or polypropylene. Research on the environmental and public health hazards of rubber tires has lead to a concern about their use for this purpose. Numerous research papers and newspaper articles have addressed these concerns, and a bill was recently introduced into the New York legislature that would prevent further installation of synthetic or artificial turf until a "complete study of the potential adverse environmental and public health impacts" of the material is undertaken[1].

Hazardous substances identified in artificial turf include polycyclic aromatic hydrocarbons, phthalates, and heavy metals (zinc, lead, arsenic, chromium, cadmium)[2]. However, there is insufficient data to assess the extent that these substances leach into water or are released through outgassing in hot weather, and whether they can be absorbed into the bodies of athletes through inhalation, ingestion or skin contact. A paper entitled *Hazardous Chemicals in Synthetic Turf: A Research Review* is attached to this memo.

Staff was unable to find a reference citing PBDE flame retardants as a component of synthetic turf, although turf manufacturers claim that the turf is fire resistant. PBDEs are used in a wide variety of products such as computer casings, fabrics, carpet pads, and furniture cushions. Research has shown that these chemicals can leach into the environment and accumulate in animal tissues. Research has also shown that PBDEs have significant public health impacts. A study conducted by the Washington Departments of Health and Ecology is attached to this memo.

As a result of the environmental and public health concerns regarding PBDEs, legislation was passed in the 2007 session of the Washington State Legislature that phases out two of most toxic forms, deca- and penta-BDE.

**Analysis**

Materials and construction practices funded through RCFB grants are subject to current environmental regulations. However, often there is a choice of materials and construction practices that are more environmentally friendly and offer fewer public health risks. It is beyond the scope of the RCFB to dictate standards or to serve as an environmental hearing body. However, there may be ways through evaluation criteria, funding incentives, and technical assistance that the RCFB can foster more sound practices. Examples include green construction practices, low water use landscaping, salmon friendly trail stream crossings, and campground siting.

**Next Steps**

[1] *NY Assemblymember Englebright's Bill Would Require Study Health Impacts of Artificial Turf*. National Caucus of Environmental Legislators, Nov. 5, 2007.
[2] *Synthetic Turf Chemicals.* RAMP, 2007.

If the RCFB would like to pursue this issue, staff will investigate ways that the Board can provide incentives and assistance to applicants in order to foster use of materials and practices that reduce potential negative environmental and public health impacts, with a briefing to the Board next fall or winter.

# Natural and Synthetic Turf:

# A Comparative Analysis


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# Artificial and Natural Turf:
# A Comparative Analysis

## EXECUTIVE SUMMARY

The San Francisco Recreation and Park Department is embarking on a program to increase the quality and the capacity of the athletic fields of San Francisco. ,  One element of this program is the building of several new soccer fields with the latest generation of synthetic turf.

The focus of this document is to compare the relative costs and benefits of synthetic and natural turf on soccer fields. The advantages of synthetic turf for soccer fields are well known and include the following: reduced maintenance costs, significant increases in playing time, and a superior playing surface. A thorough, balanced analysis comparing synthetic and natural will focus on these issues: their relative installation costs, the expected life span of the fields, their relative annual maintenance costs, their respective capacities for amount of play, their relative safety, and their relative impacts on the environment.

Synthetic fields require a large initial investment, but they also yield significant annual savings in maintenance costs. The cost of installing a synthetic turf soccer field is considerable. The price is about $800,000 per pitch.  The cost of installing a natural turf field varies, but a reasonable estimate is about $260,000.  The annual maintenance cost for a synthetic turf field is about $6,000, while that for a natural turf field is about $42,000.  A synthetic field costs about $540,000 more to install, but realizes savings of operating expenses of about $36,000 per year.

Any calculation of when a synthetic field will have "paid for itself" must factor-in the increase (anywhere between 50% and 100%) in playable hours that synthetic fields facilitate.  A 50% increase in playable hours would provide a recovery of initial costs in 10 years, while an increase of 100% would have costs recovered in 7 _  years.

The life span of synthetic fields is somewhere between 10 and 15 years.  When they do need to be "re-installed" at that time, the cost would about half of the initial cost because the foundation, base, and drainage system would be re-used.

In addition to increasing playable hours, synthetic soccer fields have several other benefits over natural turf fields.  They provide a superior, flat, level playing surface. They are safer on which to play.  And they promote several environmental benefits.

Clearly, the San Francisco Recreation and Park Department should continue to install more synthetic turf soccer fields.  The citizens of San Francisco deserve more and better recreational opportunities of the sort these fields would provide.

## BACKGROUND

The San Francisco Recreation and Park Department is in the preliminary stages of embarking on a comprehensive program of increasing the quality and the capacity of the athletic fields of San Francisco. One way to do this is to construct soccer fields using synthetic turf. In 2003, the Department constructed two new soccer fields with the latest generation of synthetic turf. The preliminary results have been overwhelmingly positive and the Department has several proposals for more such projects.

This new type of synthetic turf has several advantages over natural turf:

(1) The new synthetic fields have significantly reduced operating costs because they require much less labor and materials to maintain. Irrigating, fertilizing, and mowing, that are required on natural turf, are not necessary on synthetic turf.

(2) The new synthetic fields increase by 50% to 100% the amount of play possible on fields. These new synthetic fields do not have to be shut down for periods of maintenance and rehabilitation and they rarely have to be closed because of rainy weather. Furthermore, unlike their natural turf counterparts, they do not require the imposition of a ceiling on the amount of play allowed in order to protect the quality of the field.

(3) The new synthetic fields have a superior quality playing-surface. The flatness and uniformity of the new synthetic fields produces venues that provide better and safer recreational opportunities for soccer and other ground sports.

Given their advantages of superior playing surface, increased capacity for play, and reduced maintenance costs, it is understandable why there is a move toward the new synthetic turf for soccer fields. But because these new fields are expensive to install (approaching $1 million per soccer pitch), budget constraints limit the number of such fields that may actually be built.

A comprehensive evaluation of the relative costs and benefits of having synthetic-turf soccer fields requires compiling more detailed information in several areas:

- The relative installation costs for building a new synthetic field vs. a natural-turf field
- The realistic life-span of new synthetic-turf soccer fields
- The relative annual costs of maintaining a synthetic field vs. a natural-turf field
- The amount of increased capacity for play possible with synthetic fields
- The relative safety benefits of synthetic field vs. a natural-turf field, and
- The relative environmental factors of synthetic vs. natural turf.

Such a comprehensive cost-benefit analysis will provide the basis for developing a realistic plan to plan to build more synthetic soccer fields at SFRPD facilities. The purpose of this document is to outline some of the relative costs and benefits of natural and synthetic turf on soccer fields.

# INTRODUCTION

Throughout this document, there are repeated references to "synthetic turf fields". In all cases this refers to the newest generation of such products. It by no means refers to material like the original synthetic turf, AstroTurf. Whereas AstroTurf was hard and abrasive, the newest material is soft and spongy. The newest generation of synthetic turf places a fine-textured canopy of polyethylene fibers (the synthetic blades of grass) over a base of well-drained aggregate. The fibers are then top-dressed with a layer of small granules of crushed rubber, or a combination of crushed rubber and sand. There are a number of distinct proprietary brands of new synthetic turf on the market: Sprinturf, SmartGrass, Sporturf, and others. However, the name brand of the industry leader for this new type of synthetic grass is Field Turf. Field Turf has a longer track record and has been installed in more locations than any of its competitors. In fact, in some circles, the term "Field Turf" has come to be used as a nickname for this whole new generation of synthetic turf. This document will avoid reference to any of these proprietary brands and will instead use the generic term "synthetic turf" to refer to this newest generation of material.

# INSTALLATION COSTS

**Key Variables for Natural Turf Installations**

Any fair cost comparison for installing a synthetic field and a natural field must take into account several key variables of a natural-turf field: (1) type of field preparation, (2) type of drainage system, (3) the nature of irrigation system work and (4) size of field.

***(1) Field Preparation Type***

Natural field installations are done using one of these distinct models of field preparation:

- "Native Soil" – the existing soil is roto-tilled and graded. This model is cheaper to install, but ultimately suffers from poor drainage and compaction and consequently less play, more damage, and reduced turf vigor.
- "Sand-Based" – a 10" to 12" layer of sand with drainage system is installed over the native soil. Sand-based fields can be played on sooner after it rains, but they do not wear as well as soil-based natural fields.
- "Native Soil with Amendments" -- the native soil is roto-tilled, amendments (such as organic matter or other material) are added, the area is roto-tilled again, and then graded. This type of renovation is a reasonable compromise: the soil drains better than the "Native Soil" Model (although not as well as a sand –based field) and wears better than a sand-based field.

To summarize, the Native Soil Field has poor drainage and quickly becomes compacted, while the Sand-based Field doesn't wear as well as the Amended Soil Field. Consequently, for the purposes of this comparison, we are specifying that the natural field renovation in our comparison be the "Native Soil with Amendments" Model.

***(2) Drainage System***

Most of the athletic fields in San Francisco are built on heavy, clay soil. Most have very poor drainage, have not been amended in any thorough and systematic way, and have no sub-surface drainage systems. Any serious natural-turf field construction or renovation in San Francisco should include a sub-surface drainage system, in order to maximize the amount and quality of field play.

***(3) Irrigation System***
Many of the irrigation systems on our athletic fields are over fifty years old and do not provide for the uniform, thorough irrigation of our athletic fields. Almost all need at least some modification, some need extensive rehabilitation, and some need complete replacement. Our comparison includes calculations for each of these levels of irrigation work.
***(4) Size of Field***
The focus of our inquiry is on construction of soccer fields. The standard size of SFRPD soccer fields is 200' x 300' = 60,000. A full-size regulation field is 330' x 210' = 69,300 sq. ft. A serious natural-field construction must include a reasonable perimeter and an area for "moving the field" (to minimize wearing out the middle and the goal mouths). Consequently, a reasonable size for an area to contain a natural-turf soccer field is about 360' x 250' = 90,000 sq. ft.
**(5) Adding Amendments**
To be effective, amendments of organic matter and sand should be applied at a rate of at least four inches over the entire surface and then incorporated uniformly by roto-tiling. Four inches thick translates to over 1100 cu. yds.
**(6) *Sod vs. Seed***
The most durable grass for soccer fields in San Francisco is hybrid Bermuda grass. Hybrid Bermuda cannot be grown from seed, but is available in sod (produced from stolons). Accordingly, our natural turf construction model assumes sod installation.

## Natural Turf Installation Costs

# Summary of Costs for Building a Natural Turf Athletic Field

| TASKS | Irrigation Model | | |
|---|---|---|---|
| | **Irrigation Modification** | **Irrigation Rehab.** | **Irrigation Installation** |
| | **(Minor Irrigation Work)** | **(Significant Irrigation Work)** | **(New Irrigation)** |
| | | | |
| Planning | $20 k | $20 k | $20 k |
| Excavation | $20 k | $20 k | $20 k |
| Amending | $80 k | $80 k | $80 k |
| Drainage | $40 k | $40 k | $40 k |
| Irrigation | $10 k | $50 k | $90 k |
| Grading | $10 k | $10 k | $10 k |
| Sod Installation | $40 k | $40 k | $40 k |
| | | | |
| **TOTALS** | **$220 k** | **$260 k** | **$300 k** |

In summary, the costs for building a good natural turf athletic field is somewhere between $220,000 and $300,000, depending primarily whether it is an upgrade of an existing field or new construction. The average construction cost is about $260,000 for a natural-turf field.

### Synthetic Turf Installation Costs

A synthetic field installation includes installation of the sub-surface drainage system, the rock-and-gravel foundation, the carpet of synthetic fibers, and the in-fill of crushed rubber or crushed rubber and sand. A synthetic soccer field needn't be constructed over as an area as big as a natural turf one, because it doesn't have to be moved. It need only be about 350' x 230' or about 80,000 sq. ft.

The total cost for synthetic turf, properly installed, is about $10/sq.ft, or roughly $800,000. This indeed is roughly what the Department paid for each of the synthetic soccer fields (at Franklin Sq. and at Youngblood Coleman Plgd.).

## Maintenance Costs

### Natural Turf Maintenance

There is a range of costs for maintaining a natural-turf field, depending on the amount of play, the condition of the field, the staffing level, etc. A reasonable estimate for Gardener labor costs is about 1/3 Full Time Equivalent, or about $20,000 including fringes and overhead. Gardener tasks include litter removal, irrigating, fertilizing, mowing, aerating, over-seeding, filling holes, and conducting safety-inspections. The Heavy Equipment Operation provides truck drivers to deliver soil and sand and to drive the big, "gang mowers" and provides operating engineers to load bulk materials and to roto-till and top-dress, all at an average annual cost of $4,000 per pitch. The Field Marking Crew paints each soccer pitch at least 20 times a year for an annual cost of $3,000. The average annualized cost for plumbers to repair, modify, and overhaul irrigation systems is $2,000. Materials and supplies needed for each field include water, fertilizer, seed, sand, soil, sod, and paint, totaling about $10,000 annually. The annualized cost of equipment, primarily trucksters and mowers, is about $3000.

**Annual Maintenance Costs for Natural-Turf Soccer Field**

| Expense Items | Expenses | Total Costs |
|---|---|---|
| Gardener Labor | $20,000 | |
| Heavy Equipment Labor | $ 4,000 | |
| Field Marking Labor | $ 3,000 | |
| Plumber Labor | $ 2,000 | |
| Labor Total | $29,000 | $29,000 |
| Material and Supplies Total | $ 10,000 | $ 10,000 |
| Equipment (Annualized) Total | $ 3,000 | $ 3,000 |
| **Grand TOTAL** | | $42,000 |

The total maintenance cost for a natural-turf soccer field is about $42,000.

## Synthetic Turf Maintenance Costs

The new synthetic fields have significantly reduced operating costs because they require much less labor and materials to maintain. A number of operations, such as irrigating, fertilizing, field marking, and mowing, that are required on natural turf, are not necessary on synthetic turf. The regular gardener maintenance (1/15 FTE) tasks that are required include removing litter, inspecting the field, grooming the synthetic turf with a tow-behind sweeper, and occasionally adjusting the grade by adding the "synthetic soil" to low spots.

### Annual Maintenance Costs for Synthetic-Turf Soccer Field

| Expense Items | Total Costs |
|---|---|
| Gardener Labor | $4000 |
| Repairs and Materials, as needed | $2000 |
| **TOTAL** | $6000 |

The total maintenance cost for a synthetic-turf soccer field is about $6,000.

### Summary of Field Costs

| Type of Turf | Installation Costs | Annual Maintenance Costs |
|---|---|---|
| | | |
| Natural | $260,000 | $42,000 |
| Synthetic | $800.000 | $ 6,000 |
| Difference | $540,000 more initially for synthetic | $36,000 more annually for natural turf |

Synthetic fields require a large initial investment, but they also yield significant annual savings in maintenance costs. Based only on the figures above and **thinking only of the number of fields** it would be about 15 years before the total costs (installation costs plus the cumulative maintenance costs) of the natural turf field would begin to exceed those of synthetic turf. However, this is somewhat misleading because it doesn't take into account that **synthetic fields virtually double the events (whether practice sessions or game) that can be staged on the field annually.**

## Number of Hours of Play

Synthetic fields virtually double the number of hours a field can be used. They don't require a two-month rehabilitation closure or a one-day-a-week maintenance closure. With lights, events can go from 8 A.M. until 10 P.M. And synthetic fields are open many more days in rainy weather than their natural-field counterparts. Consequently, approximately twice as many events can be held on a synthetic field. **Cost per field event held is a much better indicator of relative value than just cost per field. Factoring this doubling of field events into the equation, in effect, cuts in half the time necessary to reach the break-even point. In short, because of the dramatic increase in playable hours, synthetic fields pay for themselves in eight to ten years!**

# Life Span of the Fields

### Life Span of Synthetic Fields

The industry leader for synthetic fields, Field Turf, guarantees their fields for eight years. Therefor, it is reasonable to assume that the fields will last in the range of 10 to 15 years. At the end of its life span, a new synthetic field would cost significantly less than the original because the basic design, foundation, and drainage would already be provided

### Life Span of Natural Fields

The life span of a natural-turf field varies greatly, depending on the amount of use, turf practices, staffing levels, etc. Given the existing pressure to over-use our soccer fields, it is difficult to keep them at a high level of quality. It is reasonable to assume that such highly used fields will need a major overhaul every ten years or so. This would obviously not be a total replacement, but instead a rehabilitation of the soil profile, the grade, the turf, and the irrigation system.

# Safety of Play

The latest generation of synthetic turf, such as Field Turf, is safer than natural turf. It is flat, even, and soft, and it doesn't have gopher holes, bumps, or muddy patches. The new synthetic turf also doesn't have some of the disadvantages of the older AstroTurf, which was abrasive and prone to injuries from twisted knees and ankles. There are rigorous scientific studies (available on request) that document statistically that synthetic turf is safer to play on than natural turf.

# Environmental Issues

Several environmental issues are a part of the discussion of synthetic vs. natural turf soccer fields. On balance, there are environmental advantages to using synthetic turf. Use of synthetic turf reduces the use of herbicides, chemical fertilizers, and paint. Fertilizers are increasingly being targeted as a source of ground water contamination. Having synthetic fields also reduces the use of gas-powered equipment, especially mowers, thereby cutting back on emissions of air pollutants. On the other hand, there have been questions raised about possible toxins in the materials used in synthetic fields. At this point there is no documentation to substantiate these charges. The only significant environmental drawback to synthetic fields is that their components do not biodegrade and will therefor end up in a landfill.

# Conclusion

The numerous benefits of synthetic soccer fields far outweigh the high cost of their installation. Clearly, the San Francisco Recreation and Park Department should continue to install more synthetic turf soccer fields. The citizens of San Francisco deserve more and better recreational opportunities of the sort these fields would provide.

Rachel's Democracy & Health News #937, December 13, 2007

# HAZARDOUS CHEMICALS IN SYNTHETIC TURF: A RESEARCH REVIEW

[Rachel's Introduction: Across the country, schools, parks, and private sports organizations are installing the "new generation" synthetic turf. It is springier than the old AstroTurf and feels more like natural grass. But it is made from used tires, which contain toxic chemicals.]

By William Crain and Junfeng (Jim) Zhang

Across the country, schools, parks, and private sports organizations are installing the "new generation" synthetic turf. It is springier than the old AstroTurf and feels more like natural grass. However, the new turf is being installed before there has been thorough research on its potential health risks. Fortunately, increasing numbers of research agencies are conducting studies. But as we shall see, the studies are often limited and reach premature conclusions about the turf's safety.

Presence of Hazardous Chemicals

Of special concern are the small rubber granules that rest between the turf's plastic blades of grass. These granules, which are the size of grains of rice or smaller (0.5 to 3 mm), contribute to the turf's resiliency. The granules are typically made from large quantities of recycled rubber tires; between 25,000 and 40,000 scrap tires are used to produce the granules for a standard soccer field.[1]

Although the tiny granules (sometimes called the "infill") lie between the plastic blades of grass, they also are common on the surface, so children and athletes come into frequent contact with them. In fact, many players have told us that the granules get into their shoes and wind up in their homes. When we learned that the granules are so accessible to park users, we decided to test samples of the granules to see if contained toxic chemicals found in scrap tires. Specifically, we wondered if they contained any of 15 polycyclic aromatic hydrocarbons (PAHs) on the U.S. Environmental Protection Agency priority pollutant list or heavy metals that also can have toxic effects.

Our first preliminary study[2] analyzed two samples of granules from a New York City Park. The analyses revealed six PAHs at concentrations sufficiently high that the New York State Department of Environmental Conservation (DEC) would have required their removal if the PAHs had been in contaminated soil sites. The six PAHs were: benzo(a) anthracene, chrysene, benzo(b)fluoranthene, benzo(a)pyrene, benzo(k) fluoranthene, and dibenzo(a,h)anthracene. All six are likely to be carcinogenic to humans.[3]

We also conducted follow-up analyses of granules from two other New York City Parks, gathering two samples from one park and one sample from the other park. We detected three of the same PAHs at elevated levels in at least one of the samples. A particularly hazardous PAH -- dibenzo(a,h) anthracene -- exceeded the DEC soil standard in all three samples.[4] The results of our studies generally conform to those of the Norwegian Building Research Institute.[5]

We also found that the granules contained worrisome levels of zinc and lead.[2] These metals also been detected in research by others, including the Norwegian Building Research Institute[5] and the Rochesterians Against the Misuse of Pesticides (RAMP).[6] Zinc isn't necessarily harmful. In fact, we need some zinc, and it is included in multivitamin pills. But excessive zinc produces problems such as stomach cramps and anemia in humans.[7]

Although the detected levels of lead have generally been below contaminated site soil standards set by the New York Department of Environmental Conservation (DEC), many health scientists warn against adding any lead at all to the environment, for even small amounts can contribute to neurocognitive problems in children.[8]

These preliminary studies only indicated that toxicants are present in the rubber granules. The more critical question concerns the bioavailability of the toxicants: Can they leach into the surrounding environment and harm human and non-human organisms? Can they be absorbed into the bodies of children and athletes who use the turf fields?

Leaching into Water and Soil

Numerous studies have demonstrated that chemicals in whole tires, tire shreds, and recycled tire crumbs can leach into water and soil.[9-12] In addition, many of these studies have demonstrated that the chemicals harm or kill aquatic life, including algae, minnows, trout, and frogs.[13] The chemicals also can stunt the growth of land plants.[13] Researchers have been slower to identify precisely which chemicals in the rubber produce the toxic effects, but researchers generally believe that the culprits include metals such as zinc.[9, 13] One investigation implicated PAHs in the death of trout where rubber tires had been placed in water.[14]

Two studies specifically asked what happens when synthetic turf granules are placed in water, and both studies found that considerable zinc was released.[10,11] In a widely cited report funded by a Candadian tire recycling agency, Birkholz and his colleagues[15] discovered that ground-up rubber from a flat playground surface killed aquatic life. Birkholz emphasized that that rubber material was less toxic if it had been on the playground for more than three months, but the effects of ageing merit further study; zinc might actually be released in greater quantities after a few years, as the rubber degrades.[10]

Noting that most of the research on damage to non-human organisms has been conducted in the laboratory, a report by California's Office of Environmental Health Hazard Assessment (OEHHA) concludes that there is little risk in real-life, outdoor conditions. Specifically, the OEHHA concludes that "during rain events" the recycled tire material in play areas is unlikely to leach toxic chemicals in high enough concentrations to harm aquatic life.[16] But the OEHHA's conclusion is speculative; it only cites one study that supports its view. What's more, the study it cites only examined how water quality was affected by a tire trench -- not the tiny rubber particles in synthetic turf that move about and can potentially flow into streams and bodies of water. A study by FieldTurf Tarkett (Nanterre, France) and French research agencies also questions the potential harm of leaching, but FieldTurf Tarkett is the world's largest manufacturer of synthetic turf, so it's difficult to assess its findings.[17] A recent Dutch investigation reaches the more sober conclusion that "the leaching of zinc is a major concern."[18]

Toxic chemicals in rubber material might also leach into human drinking water. So far, the research on this possibility is sparse. The OEHHA report observes evidence of increased quantities of toxic chemicals in groundwater, but the report emphasizes that the contaminants hadn't spread more than a few meters from the rubber sites.[19]

We will now turn to the possibility that the toxicants in recycled rubber can be absorbed by children and athletes from play on synthetic turf surfaces.

Inhalation

In their widely cited report, Birkholz et al. maintained that inhalation in not "a plausible route of exposure because no volatile compounds would be expected to remain in the shredded, solid material."[20] But as Brown[21] observes, this speculation has turned out to be incorrect. The Connecticut Agricultural Experiment Station recently found that at 60 deg. C (140 deg. F) -- a temperature that synthetic turf reaches in the summer -- the rubber granules off-gassed several hazardous volatile organic compounds (VOCs) into the air.[11] Three chemicals -- benzothiazole, n-hexadecane, and 4-(t-octyl) phenol -- are irritants to humans; a fourth chemical, butylated hydroxyanisole, has many toxic effects and may be carcinogenic to humans.[22] In addition, in 2006 the Norwegian Institute of Public Health and Radium Hospital observed that several VOCs were released from rubber granules in an indoor facility.[23] Others, including RAMP, also have detected VOCS.[5,6] Although the Norwegian Institute -- as well as the FieldTurf/French agencies [17] -- play down the possibility that the chemicals would remain in the air sufficiently long to cause harm, more research on this question is needed. Research also is needed on the extent to which rubber granules produce particulate matter that aggravates asthma.[21]

Ingestion

Because children's bodies are still developing, they are especially vulnerable to the damaging effects of toxic exposures. Infants and toddlers are also uniquely susceptible to exposure through ingestion because they like to put objects into their mouths.[24] When parents watch games from the sidelines, they frequently let their young children crawl about on the turf nearby, and the children might pick up and swallow the rubber granules. Infants and toddlers also might ingest the granules that wind up in their homes after the games.

Birkholz et al.[15] evaluated the possibility that the ingested crumb material from flat rubber playground surfaces produces cancer. Based on the results of in vitro genotoxicity assays, Birkholz et al. concluded that the risk is negligible; substances extracted from shredded rubber did not damage DNA or chromosomes. However, the investigators did not specify the potentially harmful chemicals they tested. In addition, the fact that the research was funded by the tire recycling industry raises questions in the minds of many.

OEHHA, whose research was commissioned by the State of California, examined the extent to which metals, PAHs, and VOCs might be absorbed through the digestive system. Simulating the environment of the human stomach, the researchers concluded that risks to human health are de minimis.[25] But as Brown[26] notes, the researchers explored only the acute effect of a single ingestion. The researchers acknowledged that if a child ingested some chemicals repeatedly, the results might be different. Their data suggest that the ingestion of several metals, including lead, is of particular concern.

Moreover, the OEHHA investigators only simulated the stomach environment. There is a need to simulate the digestive process more completely -- to include the enzymatic actions of saliva and intestinal fluid as well.

Skin Contact

The results from studies of skin contact are ambiguous. In their main study of dermal exposure, the OEHHA researchers[27] found that one PAH, chrysene, can be absorbed from a playground rubber surface onto a polyester wipe. The authors then estimated that if children engaged in considerable hand contact with the rubber over several years -- and sometimes put their hands in their mouths -- the children would experience an increased cancer risk. This conclusion is based on a fair amount of speculation, but it alerts us to a danger.

In a 2005 study in Denmark, Nilsson et al. placed synthetic perspiration on a tractor tire for one hour but failed to find that any PAHs gravitated to the liquid.[28] However, this study, like the OEHHA research on dermal exposure, examined relatively large rubber surfaces (a playground surface and a tire). The results derived from this approach can be misleading when the actual dermal contact occurs with the tiny rubber granules in synthetic turf. Tiny particles have proportionately larger surface areas. Consequently, toxic chemicals contained in the small granules may be more readily absorbed through ingestion or skin contact.

A recent Netherlands study[10] examined the urine of football players after they had "intensive skin contact with rubber crumb on an artificial field pitch." The urine tests did not "unambiguously" indicate that PAHs had entered the athletes' bodies. Although this is important information, similar research needs to be repeated under a variety of playing conditions and include children.

In Korea, teachers have noticed nose and eye irritation among school children playing on artificial turf surfaces.[29] Others have called for research how dermal contact with rubber infill might cause allergic reactions.[10]

Conclusion

Hazardous chemicals are clearly present in synthetic turf rubber granules that are made from recycled tires. Some metals in the granules, including zinc, leach into water and, if they behave like the metals in other rubber tire material, they can kill aquatic life. However, it is not yet clear whether this leaching presents a health risk to humans and other species in ordinary life conditions. It also is unclear whether the various toxic chemicals in the rubber granules can be absorbed into the bodies of children and athletes through inhalation, ingestion, or skin contact. Much more research is needed. Although some reports have concluded that the risks are minimal, such conclusions are premature.

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[2] Crain, W., and J. Zhang. Hazardous Chemicals in Synthetic Turf. Rachel's Democracy and Health News, #873, Sept. 21, 2006.

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WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

Washington State Department of
Health

# Washington State Polybrominated Diphenyl Ether (PBDE) Chemical Action Plan:

## *Final Plan*

January 19, 2006

Department of Ecology Publication No. 05-07-048

Department of Health Publication No. 334-079

# Executive Summary

This is the final version of the Chemical Action Plan (CAP) for a class of flame retardants called polybrominated diphenyl ethers, or PBDEs. It is the second CAP done as part of the Department of Ecology (Ecology)'s *Proposed Strategy to Continually Reduce Persistent, Bioaccumulative Toxins (PBTs) in Washington State* (issued December, 2000). Ecology is also finalizing a rule (Chapter 173-333 WAC, Persistent Bioaccumulative Toxins Regulation) to guide the development of CAPs. This CAP is consistent with both the *Strategy* and the PBT rule. The first CAP, for mercury, was completed in January 2003.

In January 2004, Governor Locke directed Ecology, in consultation with the Department of Health (DOH), to investigate and recommend options to reduce the threat of PBDEs in the environment. The final result is this PBDE CAP, which has been developed through a multi-program, multi-agency effort, with external stakeholders involved at each step. External advisory committees included representatives from such varied interests as business and consumer and environmental protection.

When Governor Locke directed Ecology and DOH to focus on these chemicals, we knew very little about them. What was known was that PBDEs were showing up in people and in the environment in increasing amounts, and those levels were significantly higher in North America than elsewhere. PBDEs are a source of growing interest and concern around the world. New studies and information continue to appear on an almost weekly basis.

This document builds on the *Interim PBDE CAP* which was released in December, 2004. Based on the available information at that time, Ecology and DOH believed that a ban on products containing PBDEs was warranted. However, further study of how a ban could be structured was needed, including research on chemical alternatives for PBDEs and on costs and benefits. This research, and a thorough review of the most current scientific information about the environmental and human health risks of PBDEs, was considered in the development of this plan. In addition, Ecology and DOH kept a close watch on the experiences of other states and Europe where policies to reduce PBDEs have been crafted.

A great deal has been learned, and there is still a great deal more to understand. At each step of the way, Ecology and DOH have struggled with limited data and limited access to data, and the uncertainty that comes with a new field of study (emerging information). We know that:

- There is already a reservoir of PBDEs in humans and in the environment. In 2001 alone, almost 70,000 metric tons of PBDEs were produced globally, almost half of which was used in products sold in the U. S. and Canada.

- The various commercial grades of PBDEs have been used in a wide variety of products, from carpet pads to TV plastic. The production of two PBDEs, Penta-BDE and Octa-BDE, has been phased out in the U.S. and in most international markets as well. And the use of Deca-BDE is anticipated to increase.

- Current research indicates that the most likely pathways of exposure for people are through indoor dust and various foods.

- PBDEs have been found in fish, polar bears, grizzly bears and Puget Sound orcas.

- PBDEs initially drew attention because they were found in women's breast milk and the levels in breast milk were rising quickly. While levels of PBDEs found in breast milk in the U.S. are not yet at a level of concern, levels in U.S. women are 10 to 100 times that found in women in Europe.

- There are potentially serious health and environmental consequences as the amounts of PBDEs increase, such as neurotoxicity (i.e. effects to neurological development from exposures to unborn and newborn infants), leading to impacts on behavior, learning and memory. Other health effects may include bone malformations, reproductive impacts, and liver disorders.

- Deca-BDE is likely to breakdown in the environment to more toxic and bioaccumulative forms of PBDEs.

- Banning these substances, as long as a safer alternative exists, can avoid negative health effects from PBDEs for people, and to the environment in Washington.

Unfortunately, there is a lot we do not know. We lack adequate toxicity information on the alternatives to Deca-BDE. This is likely due to the fact that, under current U.S. chemical policies, toxicity studies on these chemicals are not required or are not published. We don't know the rate of breakdown of PBDEs in the environment, or exactly what congeners are produced as a result of breakdown of PBDEs. (However, in the laboratory, deca-BDE has broken down to penta- and octa-BDE, so there is concern that other breakdown products may be more toxic than the parent compounds.) We don't know exactly how PBDEs move from products into our bodies and the environment, or how much Deca-BDE breakdown products will contribute to levels in our bodies and the environment. We don't know how PBDEs impact other species such as fish, orcas or bears. And we don't know how much more PBDE could be produced and sold as manufacturers try to comply with future fire protection rules from the Consumer Product Safety Commission.

The recommendations in this Chemical Action Plan were developed after a thorough consideration of what is known and what is not known. We believe these recommendations represent prudent policy, and that the suggested actions are commensurate with the risk involved, both to human health and the environment as well as to Washington businesses. What we want to avoid is adopting a policy that allows the continued build-up of PBDEs in our bodies and in the environment as we try to resolve the unknowns.

## PBDE basics

PBDEs are members of a broad class of brominated chemicals used as flame retardants. Flame retardants like PBDEs are added to products so that they will not catch on fire or burn so easily if exposed to flame or high heat. In the event of a fire involving these products, PBDEs slow ignition and the rate of fire growth. The result is that people have more time to extinguish or escape the fire. PBDEs have been added to plastics, upholstery fabrics and foams in such common products as computers, TVs, furniture and carpet pads.

There are three main types of PBDEs used in consumer products: Penta-BDE, Octa-BDE and Deca-BDE. Each has different uses and different toxicity. In 2001, the total PBDE volume worldwide was estimated at over 67,000 metric tons, including 56,100 metric tons of Deca-BDE. Manufacturers of Penta- and Octa-BDE in the U.S. agreed to voluntarily stop producing these two forms of PBDEs at the end of 2004. With the discontinuation of Penta- and Octa-BDE, Deca-BDE will account for 100 percent of PBDE usage.

The highest levels of PBDEs in people have been found in the U.S. and in Canada, which are the largest producers and consumers of products with PBDE flame retardants. Levels of total measured PBDEs in human tissues in the U.S. are 10 to 100 times higher than reported for Europe and Japan. While these numbers are significant, it is important to understand that the mere presence of chemicals does not necessarily represent a health risk. Although PBDEs are present in people and many foods, these levels have not yet reached those shown to be toxic in lab animals and do not pose an immediate health threat. If PBDE levels continue to rise, however, real health risks can be expected, particularly for our children. This is especially significant given the existing large volume of PBDEs already in the environment and the possibility of the increasing use of them in products.

## New work completed since December, 2004

With production of Penta- and Octa-BDE discontinued, Deca-BDE became the focus of Ecology and DOH's PBDE work. Since the release of the *Interim PBDE CAP*, DOH and Ecology focused on three key areas related to the need for action on Deca-BDE. As a result, three new chapters have been added to the Plan: 1) a review of studies on the degradation of Deca-BDE (Chapter IV); 2) an alternatives assessment (Chapter V); and 3) a cost-benefit analysis (Chapter VI). The additional information discussed in these chapters provided the framework for assessing whether or not to ban Deca-BDE from commerce in Washington State.

### Degradation

Even at the time the *Interim PBDE CAP* was published, Ecology and DOH's research indicated that while Deca-BDE in its original form is considered relatively safe, it is likely to degrade into more toxic forms. A more in-depth review (presented in Chapter IV) continues to reinforce this assumption. The degradation of Deca-BDE is central to Ecology and DOH's concern about the human health and environmental safety of this flame retardant. Laboratory studies indicate that the breakdown of Deca-BDE takes place through exposure to sunlight and through biological activity. Therefore, the Deca-BDE that is already in the environment is likely to be a long-term source of the more toxic forms of PBDEs long into the future.

**Deca-BDE Alternatives Assessment**

DOH conducted an extensive survey of the available literature to determine if safer, effective alternatives to Deca-BDE exist for use in electronic enclosures. It is important to note that "safer" relates to impacts on human health and the environment, not the ability of the alternative to work as a flame retardant. **The alternatives assessment considered only those chemicals already proven to meet fire protection standards.**

DOH limited its focus to electronic enclosures because the black plastic used to enclose the rear of TVs accounts for somewhere between 45 and 80% of Deca-BDE commercial use. DOH considered only those alternatives previously shown to work in the same plastics and products as Deca-BDE while providing adequate fire protection. As with so much of the PBDE work, the undertaking was hampered by both limited and emerging information. There is a general lack of toxicity and other testing information on many of the alternatives. While companies are often willing to share their data, much of it has never been published. However, there was sufficient data collected to conclude that promising alternatives exist, ones which are already in use and meet fire protection standards, and we want to continue this research.

**Cost Benefit Analysis**

Ecology conducted a Cost Benefit Analysis (CBA) of a statewide ban on Deca-BDE in electronic enclosures in order to weigh the benefits to human health and the environment against the costs to business.

Information on costs was hindered by difficulties getting information from businesses about their Deca-BDE use. Many businesses were reluctant to share cost data with us, possibly because the state could not provide confidentiality for this information. When it became apparent that critical data would not be available, Ecology developed an alternative model which we believe might be successfully used to compare costs to benefits. However, this model hinges on the identification of at least one safer, effective alternative to Deca-BDE, which has not yet been identified. In addition, there is considerable uncertainty in the data needed to quantify health benefits. Ecology is therefore unable to determine whether benefits exceed costs (or vice versa). Consequently, Ecology has concluded that the cost benefit analysis has limited utility at this time to inform decisions on phasing-out uses of deca-BDE.

# Recommendations

Recommendations for reducing PBDEs in the environment and for protecting human health are detailed in the body of this plan. Many of the policy options that were considered are also presented, and the rationale for the policies recommended is provided. Key recommendations are summarized as follows:

- The Washington State Legislature should prohibit the manufacture, distribution (but not transshipment) or sale of new products containing Penta-BDE and Octa-BDE in Washington state. The ban may include an exemption for new products that contain recycled material from products that contained Penta-BDE and Octa-BDE, pending further review.

- The Washington State Legislature should ban Deca-BDE provided that safer, effective, affordable alternatives are found or upon additional evidence of Deca-BDE harm.

- If safer alternatives are not identified, Ecology and DOH should work with stakeholders to explore incentives to encourage manufacturers to develop safer, effective alternatives as well as product redesign changes that eliminate the need for PBDEs.

- Ecology should establish appropriate disposal and recycling practices for products containing PBDE flame retardants.

- Ecology and DOH should work with other states and interested parties in a dialogue toward improving U.S. chemical policy. Current U.S. chemical policy, based upon the Toxic Substances Control Act (TSCA), has resulted in only minimal testing of many chemicals currently in use. The lack of adequate testing data on promising alternatives to Deca-BDE already in use exemplifies the need to improve TSCA and/or its implementation.

- The state's purchase of products containing PBDEs should be restricted in appropriate contracts, consistent with Executive Order 04-01.

- DOH should continue to develop methods and materials for educating the public on how to minimize exposure to PBDEs. This will include information on the benefits of breastfeeding and advice about eating fish as part of a healthy diet.

- To ensure that workers in certain industries are not exposed to unacceptable levels of PBDEs, DOH and the state Department of Labor and Industries should continue to investigate the feasibility of implementing a workplace exposure study in collaboration with the federal Center for Disease Control and Prevention.

Note: A number of the recommendations presented in the *Interim CAP* are underway, and some have been completed. For example, the state Department of Labor and Industries has already begun providing information to employees on how to minimize PBDE exposures. And DOH has created brochures and a website to educate the public on reducing exposure to PBDEs.