Playground Surfacing

Choosing Safer Materials for Children's Health and the Environment

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Cover photo: A school playground in Westford, Massachusetts, with engineered wood fiber surfacing.

Playground Surfacing:
Choosing Safer Materials for Children's Health and the Environment

Introduction

Playground surfacing helps to protect children as they walk, run, jump, fall, and interact with their surroundings in the course of play. A range of materials are sold as playground surfacing. Some of these materials contain chemicals of concern for human health and the environment. In response to requests from communities, TURI has compiled information on a range of playground surfacing options, with a particular focus on chemicals that may be found in these materials, and how they may affect playground users.

Vulnerable populations, such as pregnant women and children, may be especially sensitive to hazards posed by chemicals found in synthetic playground materials. Children are uniquely vulnerable to the effects of toxic chemicals because their organ systems are developing rapidly and their detoxification mechanisms are immature. Children are also more likely to have hand-to-mouth exposure to environmental contaminants than adults.[1] For these reasons, it is particularly important to make careful choices about children's exposures.

Based on TURI's research on chemical contents of playground surfacing materials, wood products—especially engineered wood fiber (EWF) tested and verified to be free of chromated copper arsenate (CCA)—are safer choices for health and the environment. Synthetic products pose potential chemical hazards that can be avoided by using alternative materials.

Playground Surfacing Materials: Overview

Playground surfacing materials are installed underneath play equipment to cushion falls. They can be made from natural or synthetic materials including sand, pea gravel, wood, and rubber. These materials come in a variety of forms; for example, wood options include wood chips or bark mulch, EWF, or bonded EWF (EWF bound with adhesive). Rubber materials are used in products such as shredded waste tires (also referred to as rubber mulch), rubber tiles and pour-in-place (PIP) surfacing. The U.S. Consumer Product Safety Commission (CPSC) states that grass, dirt, concrete, asphalt, or other hard surfaces are not considered protective surfacing options for playgrounds.[2] Protective fall materials are typically installed on top of a prepared sub-base of gravel, soil, geotextile, or an impervious concrete slab.

Surfacing materials fall into two broad categories: loose-fill surfacing materials and unitary surfacing materials. Table 1 provides an overview of these material categories.

- **Loose-fill surfacing** material consists of loose particles such as sand, pea gravel, EWF, or rubber mulch/shredded tires.[2]
- **Unitary surfacing** materials consist of rubber tiles, rubber mats, or other materials (e.g., rubber granule, plastic, or EWF) held in place with a binder. These materials may be poured in place and cured at the playground site to form a unitary surface.[2] Unitary surfacing installation designs vary between companies, but typically include a base layer beneath a "decorative" top layer of bonded materials. The base layer is usually composed of either

gravel, concrete or asphalt.[3, 4] For PIP and artificial grass installation, a cushioning layer made of either loose or bonded shredded waste tire is usually installed between the base and top layer.

Table 1. Playground surfacing materials: Loose-fill and unitary options

Category	Material
Loose-fill	Engineered wood fibers (EWF)*
	Wood chips or bark mulch
	Sand
	Pea gravel
	Rubber mulch
Unitary	Bonded EWF*
	Pour-in-place (PIP) rubber surfacing*
	Rubber tiles and mats*
	Artificial grass*

* Americans with Disabilities Act (ADA) compliant

Health and Environmental Hazards

Chemicals of concern

Some materials used in playground surfacing contain toxic chemicals, creating potential hazards for manufacturers, installers, playground users, and the environment. This section provides a brief overview of chemical hazards that may be relevant when choosing a playground surfacing material.

Synthetic surfacing materials. A variety of rubbers or plastics can be used in playground surfacing. Loose-fill rubber products are generally made with shredded waste tires. Unitary rubber, including tiles and PIP surfacing, is made with granulated particles processed from materials such as waste tires, thermoplastic elastomer (TPE), or ethylene propylene diene terpolymer rubber (EPDM), and held together with chemical binders and adhesives. An additional material sometimes used is thermoplastic vulcanizate (TPV). In TPV, a vulcanized product such as EPDM is combined or coated with a thermoplastic, such as polypropylene. Chemicals of concern are found in both loose-fill recycled tire rubber and unitary products.[5, 6] Pigments added to tire materials may also be a source of concern.

Tires are primarily composed of styrene butadiene rubber (SBR). They also contain a wide variety of intentionally added chemicals, such as stabilizers, fillers, and vulcanization (curing) agents. Additional substances can adhere to tires during use.[5] Some of these ingredients are chemicals known to be hazardous to human health, such as polyaromatic hydrocarbons (PAHs), volatile organic compounds (VOCs), and heavy metals, such as lead.
A number of PAHs have been identified as known or suspected human carcinogens by the International Agency for Research on Cancer.[7] Many of these PAHs (e.g. benz(a)anthracene, benzo(a)pyrene, benzo(k)fluoranthene, benzo(b)fluoranthene, indeno(1,2,3-c,d)pyrene, chrysene, and dibenz(a,h)anthracene) have been found in waste tire rubber, in the air around the rubber, or in leachate from the rubber according to an EPA literature review.[8] Acute VOC exposure can cause eye, nose, and throat irritation, headaches,

and nausea; longer-term exposure can cause damage to internal organs.[9]

Several VOCs that are known or suspected carcinogens, such as benzene and hexane, have been measured in recycled tire materials.[8] Metals found in recycled tires, such as lead, pose concerns as well. For example, even low levels of lead in a child's blood can result in behavior and learning problems, slowed growth, and anemia.[10] Concerns associated with some other chemicals found in tires (e.g., phthalates) include endocrine disruption.[8]

TPE and EPDM are often marketed as alternatives to recycled tires in unitary surfacing. These materials may potentially pose a lower level of concern than recycled tires, but they can contain hazardous chemicals as well. In addition, both TPE and EPDM can include a variety of polymers and additives. For this reason, it is difficult or impossible to make broad statements about the safety of a given product unless one has access to more detailed information.

TURI reviewed a safety data sheet for a brand of artificial turf infill material made with TPE. The TPE was composed of styrene block copolymer, paraffin oil, calcium carbonate (chalk), carbon black, polyethylene, and unspecified stabilizers and antioxidants.[11] TPE used in playgrounds could have a similar composition, or could contain other chemicals not noted here. In general, EPDM rubber can contain PAHs, VOCs and a range of additives including carbon black, oils, and minerals.[12]

Recycled waste tire material in playgrounds: A study by the Consumer Product Safety Commission (CPSC)

The "Federal Research Action Plan: Crumb Rubber" is a multi-agency study including the CPSC, Environmental Protection Agency and the Centers for Disease Control, created to investigate the potential health and environmental effects of chemicals found in recreational surfacing made from recycled tires. As one element of this study, the CPSC used a combination of focus groups, field observations, and a survey of parents and child-care providers to collect information on children's behavior when playing on loose-fill and unitary surfacing made from recycled tires. The study shows that children frequently pick up or pick at, mouth, chew, or fall on surfaces.[a] The CPSC found that the study findings raise exposure concerns that deserve further investigation. The CPSC offers the following precautions for limiting exposure to materials made from recycled tires.

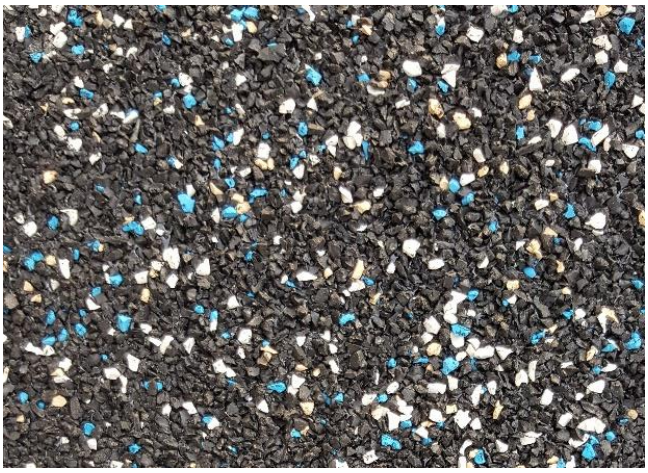
1. "Avoid mouth contact with playground surfacing materials, including mouthing, chewing, or swallowing playground rubber. This may pose a choking hazard, regardless of chemical exposure.
2. Avoid eating food or drinking beverages while directly on playground surfaces, and wash hands before handling food.
3. Limit the time at a playground on extremely hot days.
4. Clean hands and other areas of exposed skin after visiting the playground, and consider changing clothes if evidence of tire materials (e.g., black marks or dust) is visible on fabrics.
5. Clean any toys that were used on a playground after the visit."[b]

[a] Harsanyi, S. 2018. Summary of Playground Surfacing Focus Groups. United States Consumer Product Safety Commission. Retrieved from https://www.cpsc.gov/s3fs-public/Playground_Surfacing_Focus_Group_Report_2018.pdf?

[b] U.S. Consumer Product Safety Commission. 2018. Federal research action plan: crumb rubber. Retrieved from Crumb Rubber Information Center: https://www.cpsc.gov/Safety-Education/Safety-Education-Centers/Crumb-Rubber-Safety-Information-Center

Another synthetic surfacing option on the market is artificial grass, generally composed of plastic grass fibers and nylon or plastic backing atop a polyurethane cushioning layer, fabric liner, and/or shredded waste tires.[13] Many brands use waste tire granules or sand as an infill to hold the artificial grass in place. The chemical constituents of the waste tire materials pose health and environmental concerns. Ingredients found in the fibers and/or cushioning may also be of concern.[14]

Ingredients used in synthetic playground materials vary between brands. It is important for playground decision-makers to be aware of what chemical constituents are present in material options under consideration by asking vendors or manufacturers directly for detailed safety data sheets, test data, and catalogs.



PIP consists of EPDM, TPE, or waste tire granules, held in place with adhesives.

Binders and adhesives. Rubber, artificial grass, and bonded wood unitary surfacing materials contain binder and adhesive chemicals. The binder ingredients used to make and bind unitary rubber tiles, pour-in-place (PIP), and bonded EWF vary depending on brand. Urethanes are typically used to bind rubber and/ or TPE granules together, and to glue rubber tiles or artificial grass pieces together, according to manufacturer safety data sheets reviewed by TURI. Urethanes are made using chemicals in the diisocyanate family, such as methylene diphenyl diisocyanate (MDI). In general, diisocyanates are asthmagens and dermal and lung sensitizers.[15, 16] Hazardous chemicals found in binders mainly pose an occupational inhalation hazard during manufacturing and installation. However, if the cured binder contains any unreacted monomer, this could potentially create exposures for playground users as well.[16]

EWF colored green and bonded together with chemical adhesive.

Sand and pea gravel. Playground sand may contain trace amounts of crystalline silica (quartz) dust. Airborne crystalline silica dust exposure is known to cause pulmonary diseases, including cancer, in an occupational setting.[17] There are several brands of sand on the market that advertise to be free of crystalline silica dust. According to manufacturer safety data sheets. Pea gravel is primarily made from quartz, which does not pose chemical concerns when in stable, solid form.

Wood. Loose-fill wood chips, bark mulch and EWF are all made from raw wood. Wood chips are made from ground fresh trees, and bark mulch is a byproduct of the industrial paper and lumber industries. EWF looks similar to wood chips and is manufactured similarly to bark mulch, but is designed specifically for use as playground safety surface material.[2] Wood products can only be labeled EWF if they meet the specific particle size,

consistency, purity, and drainage standards described in American Society for Testing and Materials (ASTM) 2075: *Standard specification for engineered wood fiber*.[2] EWF is also tested for levels of soluble hazardous elements such as lead, chromium, cadmium, and arsenic.[18]

The CPSC states in the *Public Playground Safety Handbook* that treated wood must not be used in playground surfacing, as it may contain CCA.[2] CCA is an insecticide and wood preservative composed of arsenic, chromium, and copper.[19] The CPSC also states that wood playground surfacing manufacturers must provide test data on material toxicity to ensure that no CCA-treated wood has been mixed in with playground materials. The CPSC suggests avoiding use of any wooden playground surfacing products where the CCA content is unknown. Therefore, it is important for decision-makers to request and review test data before installing.

With regard to chemicals only, the least hazardous choices for playground handlers and users are: loose-fill wood products tested for absence of CCA; pea gravel; and sand tested for absence of crystalline silica dust. A summary of health and environmental hazard information for all materials is presented in Table 4.

A playground in Lowell, MA, with wood chip surfacing.

Environmental concerns

The primary environmental concern associated with playground surfacing is the potential for synthetic surfacing to produce contaminated runoff water. Numerous studies show that metals such as zinc, and toxic chemicals such as PAHs and phthalates, can leach from shredded rubber into natural environments.[8] This means that the leached hazardous substances can be carried into natural systems by stormwater or irrigation runoff. Even small amounts of these toxicants can create negative effects on aquatic life.[5] Any of the synthetic material options can also cause general pollution issues since the synthetic pieces can migrate outside of intended play areas.

Loose synthetic PIP granules can migrate into the environment. These particles were found in an area adjacent to a playground located in Somerville, MA.

Unitary surfacing installation may also lead to loss of water-permeable surface area. Overall, playground surfacing installation designs and material porosity vary between companies, allowing for different drainage capabilities. If the sub-base is an impervious material, such as concrete, or the fall protection material allows for only minimal water filtration to the sub-base, the playground area may disrupt rainwater infiltration. Loss of stormwater filtration through soil leads to lowered water quality and a higher quantity of stormwater runoff into natural water systems, like rivers and wetlands.[20]

As unitary synthetic surfacing begins to age, it may deteriorate and expose the loose-fill cushioning layer underneath. This layer is typically made with shredded waste tires.

TURI consulted Recycle Works Massachusetts on disposal options available for different surfacing materials. End of life disposal options are limited for synthetic materials used on playgrounds. Rubber mulch can only be recycled at specialized facilities for a fee. In general, unitary synthetic products are not recyclable because of their adhesives, and they may not be reused because the materials are usually well worn by the end of their life. Synthetic materials that cannot be recycled or reused are disposed in a landfill for a fee, and do not biodegrade. In contrast, wood materials can be composted onsite, or through a company. Many composting facilities in Massachusetts will pick up or receive these materials for no charge. Used sand and pea gravel may be sifted and reused on other playgrounds, or in different applications, such as landscaping.

Heat hazards

Rubber has a higher potential to cause contact burns as it can heat up and transfer heat quickly to skin.[21] Thermal burns on playgrounds can occasionally result in serious injuries.[22] CPSC reported 29 thermal burns associated with playgrounds (mostly second- and third-degree burns) between 2001 and 2008. Of these, 14 involved playground surfacing.[23]

There are few published studies focused directly on playground surfacing temperatures and burns. However, one study in a hot climate found that unshaded rubber surfacing reached temperatures at or above the CPSC temperature threshold for thermal burn injury.[21]

Dangerously hot temperatures on playgrounds, created by heat absorbing materials, can also create a microscale “heat island."[21] A parents’ group in Massachusetts provided TURI with temperature data. For example, on a day when the air temperature measured 75° F, the parents’ group documented a temperature of 171° F on a PIP playground surface.[24] Research led by the Center for Sports Surface Research at the University of Pennsylvania indicates that all artificial turf reaches higher temperatures than natural grass.[25]

A parents' group in West Tisbury, MA, recorded a PIP surface temperature of 171.1° F with an air temperature of 75° F.

Other potential hazards

Loose-fill materials, in general, have the potential to hide foreign objects, and are more likely to be used by children as "play material" (i.e., throwing or putting in mouth). Wood and pea gravel surfacing have the potential to grow mold, though mold growth can be avoided by ensuring adequate drainage on and around the play area. Drainage planning is recommended for all loose-fill products in order to minimize decomposition, mold growth, and particle migration.[2]

Performance Criteria

Critical fall height ratings

The CPSC requires that playground surfacing materials be tested for critical height, or "an approximation of the fall height below which a life-threatening head injury would not be expected to occur."[2] Because playground materials may degrade or be displaced over time, the CPSC suggests testing the impact performance of playground materials annually. Communities can ask their chosen playground installation company about annual field tests for impact performance. Communities may also choose to install play equipment that requires lower fall height protection.

Loose-fill surfaces have standard fill depths that offer protection for fall injury prevention. Table 2 shows the minimum required depth of each compressed loose-fill material, and the maximum fall height at which injuries will be prevented, according to CPSC. It is important to note that EWF, wood chips, and rubber mulch all offer the same amount of fall protection. Loose-fill material compresses by at least 25% due to use and weathering, which must be taken into account during installation and when planning long-term maintenance.[2] Loose-fill material depths will also decrease over time due to displacement of materials outside of the play area. Critical height depths must be maintained over time by "topping-off" materials in order to preserve performance.

Unitary surface materials have varied quality and shock-absorption properties, and therefore do not have standard fill depths for fall heights.[2] Manufacturers must supply critical fall height test data for all playground surfacing, including specifications for unitary rubber tiles or pour-in-place materials.[2]

Table 2. Minimum surfacing depths for compressed loose-fill materials

Compressed surfacing depth (inches)	Loose-fill material	Maximum protected fall height (feet)
6	Rubber mulch	10
9	Wood chips, EWF	10
9	Bark mulch (non-CCA)	7
9	Pea gravel	5
9	Sand	4

Source: U.S. Consumer Product Safety Commission, 2015

Accessibility

Playground accessibility for persons with disabilities is an important aspect of playground planning. In order for a surfacing material to be labeled as compliant with regulations within the Americans with Disabilities Act (ADA), it must fulfill wheelchair accessibility specifications described in ASTM 1951: *Standard specification for determination of accessibility of surface systems under and around playground equipment*.[2]

EWF and unitary surfacing options are designed to be ADA compliant.[2] The wood pieces in EWF are sized to "knit" together when compacted, causing the pieces to remain in place, creating an even, accessible surface. EWF must be raked to maintain evenness, especially under swings and slides, in order to maintain performance. Provided that they are in good condition, unitary rubber and bonded wood are inherently stable due to the chemical adhesives holding the base cushioning material in place.

Costs

We contacted several suppliers and installers of playground surfacing materials to provide some general, preliminary information on costs associated with material discussed in this fact sheet. Table 3 summarizes these findings. This information is provided for general reference only; costs are likely to be variable, and this overview does not necessarily cover all the factors that may be relevant for an individual community.

Table 3. Cost estimates for initial installation, regular maintenance, and disposal of playground surfacing materials for a 2500 square-foot area[a]

Material	Initial cost	Maintenance activities/cost	Disposal[b]
EWF, woodchips, bark mulch	• Raw materials: $2,600 • Materials and installation with drainage: $7,500	• Raking back into play area, top-off every 3-5 years • Cost of raw materials for 10% top-off: $300	Compost, many companies offer free drop-off or pick up
Sand	• Raw materials: $3,000	• Raking and leveling, top-off every 2-3 years. • Cost of raw materials for 10% top-off: $300	Reused (e.g., surfacing in community areas) or repurposed at a facility
Pea gravel	• Raw materials: $5,000	• Raking back into play area, top-off every 1-2 years • Cost of raw materials for 10% top-off: $500	Reused (e.g., other playgrounds or landscaping)
Artificial grass	• Materials, installation of sub-base, and surfacing materials: $38,000	• Sweeping, blowing or vacuuming, inspection for damage • Patching heavily worn areas	Landfill, recycling or reuse may be possible
Unitary rubber (PIP)	• Materials, excavation, installation of sub-base and PIP materials: $50,000	• Sweeping, blowing or vacuuming, inspection for damage • Patching cracks and heavily worn areas	Landfill drop-off for a fee
Rubber mulch	• Raw materials: $8,000 • Materials and installation: $15,000	• Raking back into play area, top-off every 1-2 years • Cost of raw materials for 10% top-off: $800	Recycled at specialized facilities for a fee

[a] Fill volumes were estimated using minimum fill depths in Table 2. Cost figures were provided by several suppliers in October 2018. Costs are likely to vary by time, location, brand, and functional requirements.

[b] For all options except artificial grass, disposal information was provided by personal correspondence with Recycle Works Massachusetts. TURI did not obtain detailed information on options for disposing of artificial grass.

Questions to Consider when Choosing a Playground Surfacing Material

In researching this topic, TURI found variability in chemical contents, physical characteristics, and/or installation techniques between brands of unitary surfacing products. Below are a number of questions that decision-makers may want to ask manufacturers and vendors in order to gain a more complete understanding of topics such as material contents, installation design, and disposal options.

- What are the chemical constituents of all layers of material?
- What tests have been conducted to check for chemicals in the material?
- What method of disposal is used for the materials when it is time to replace them?
- Are the materials permeable? What are the drainage options for the surfacing?
- What critical fall height protection can be achieved with the material?
- Can the installation company test fall protection performance annually?
- What is the surface temperature of the material located in the sun with air temperature above 80^{o} F?
- What is the lifespan of the materials and cost of maintenance?

Summary

From an environmental and health standpoint, wood products, especially EWF tested and verified free of CCA, are safer choices for playground surfacing material based on chemical content. EWF also offers high fall protection and ADA accessibility when correct material depth and evenness are maintained. Synthetic products, made with or without recycled tires, pose potential chemical hazards that can be avoided by using alternative materials. Table 4 summarizes the overall characteristics for each material reviewed in this document. Playground planners are encouraged to request and carefully review data on contents and toxicity. Planners are also encouraged to read installation instructions from manufacturers on their specific materials in order to make the safest and most informed choices.

Table 4. Summary of health, environmental, and performance criteria

Materials are listed in order of least concern (green) to greatest concern (orange) to playground users based on chemical hazard criteria only. TURI has attempted to identify the key concerns for each material.

Health & Environmental Hazard Criteria					Performance Criteria	
Material (color coding based on chemical hazards)	**Possible chemicals of concern**	**Health effects associated with chemicals of concern**	**Other human health concerns[a]**	**Environmental concerns**	**Fall protection**	**ADA compliant**
EWF, wood chips, bark mulch Tested for absence of CCA	—[e]	—[e]	Mold growth possible[b]	—[e]	High	Yes (EWF only)
Sand Tested for absence of crystalline silica dust	—[e]	—[e]	—[e]	—[e]	Low	No
Pea gravel	—[e]	—[e]	—[e]	—[e]	Low	No
EWF, wood chips, bark mulch Not tested for absence of CCA	Traces of CCA possible.[2]	Arsenic exposure can increase risk of certain types of cancer.[19]	Mold growth possible[b]	Possible runoff contamination	High	Yes (EWF only)
Sand Not tested for absence of crystalline silica dust	Traces of crystalline silica dust.[26]	Inhalation of crystalline silica dust can cause respiratory disease, including lung cancer.[17]	—[e]	—[e]	Low	No
Bonded EWF	Binding substances can contain hazardous chemicals (such as MDI) before they have been cured.[27]	Respiratory issues, skin sensitization, development of asthma and possible carcinogenicity. (Primarily an occupational exposure concern.)[16]	—[e]	Possibility of impervious surface[d]	Depends on installation design	Yes
Artificial grass	PAHs, VOCs, heavy metals, phthalates, and others found in some infills; binding substances can contain hazardous chemicals (such as MDI) before they have been cured; grass blades can pose concerns as well.[5, 6, 8, 11, 12,14]	Carcinogenicity, endocrine disruption, respiratory irritation or skin irritation.[7, 9, 10]	Heat hazard	Possible runoff contamination, migration of synthetic materials offsite	Depends on installation design	Yes
Rubber tiles, PIP	PAHs, VOCs, heavy metals, phthalates; binding substances can contain hazardous chemicals (such as MDI) before they have been cured.[5, 6, 8, 11, 12]	Carcinogenicity, respiratory irritation or skin irritation. (Substances in binder primarily present occupational exposure concerns.)[7, 9, 10]	Heat hazard	Possible runoff contamination, possibility of impervious surface, migration of synthetic materials offsite[d]	Depends on installation design	Yes
Loose-fill rubber	PAHs, VOCs, heavy metals, phthalates, and others.[c, 5, 8]	Carcinogenicity, endocrine disruption, respiratory irritation or skin irritation. (CPSC notes that children frequently pick up or pick at, mouth, chew, or fall on loose-fill surfacing.)[7, 9, 10, 28]	Heat hazard	Possible runoff contamination, migration of synthetic materials offsite	High	No

a. Information on abrasion hazards associated with playground surfacing was not included in this report.
b. Mold growth is unlikely provided that drainage is adequate.
c. Exposure is likely to be greater with loose-fill rubber as children may handle and play with the material.
d. Some installation designs include the addition of an impervious concrete sub-base.
e. TURI did not identify any priority concerns for hazards covered in this report.

Glossary of Acronyms

ADA	Americans with Disabilities Act
ASTM	American Society for Testing and Materials
CCA	Chromated copper arsenate
CPSC	The U.S. Consumer Product Safety Comission
EPA	The U.S. Environmental Protection Agency
EPDM	Ethylene propylene diene terpolymer
EWF	Engineered wood fiber
MDI	Methylene diphenyl diisocyanate
PAH	Polyaromatic hydrocarbon
PIP	Pour-in-place
SRB	Styrene butadiene rubber
TPE	Thermoplastic elastomer
TPV	Thermoplastic vulcanizate
VOC	Volatile organic compound

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Playground Surfacing

Choosing Safer Materials for Children's Health and the Environment

The Toxics Use Reduction Institute is a multi-disciplinary research, education, and policy center established by the Massachusetts Toxics Use Reduction Act of 1989. The Institute sponsors and conducts research, organizes education and training programs, and provides technical support to help Massachusetts companies and communities reduce the use of toxic chemicals.

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