

---



## II. TOXICOLOGY AND HEALTH EFFECTS

*In this report, Environment and Human Health, Inc. evaluates the information known about the potential health and environmental risks from exposure to crumb rubber made from recycled tires.*

**H**ealth concerns have been documented in rubber tire fabrication workers that are attributed to exposure to chemicals and dusts. Use of recycled tire shreds or crumbs in athletic fields, gardening and playgrounds involves repeated and direct exposures for both children and adults to tire dust and some chemicals similar to those in tire plants. A comprehensive assessment of the information known about the health risks to the public is necessary to assess safety.

Determination of risks and safety from direct human exposures to mixtures of chemicals and dusts requires a systematic analysis of all data to assure a comprehensive evaluation of the hazard.

### LABORATORY IDENTIFICATION OF COMPOUNDS RELEASED FROM TIRE CRUMBS AND RUBBER MULCH

The Connecticut Agricultural Experiment Station report (See Appendix I), found out-gassing and leaching from synthetic turf rubber crumbs under aqueous ambient temperatures. Several compounds were present, but four compounds gave the highest responses on GC/Mass spectrographic analysis. The four compounds conclusively identified with confirmatory tests were: *benzothiazole*; *butylated hydroxyanisole*; *n-hexadecane*; and *4-(t-octyl) phenol*. Approximately two dozen other chemicals were indicated at lower levels. These chemicals were released in laboratory conditions that closely approximate ambient conditions.

Those chemicals identified with confirmatory analytical studies at the Connecticut Agricultural Experiment Station study have the following reported actions:

- **Benzothiazole:** Skin and eye irritation, harmful if swallowed. There is no available data on cancer, mutagenic toxicity, teratogenic toxicity, or developmental toxicity.
- **Butylated hydroxyanisole:** Recognized carcinogen, suspected endocrine toxicant, gastrointestinal toxicant, immunotoxicant, neurotoxicant, skin and sense-organ toxicant. There is no available data on cancer, mutagenic toxicity, teratogenic toxicity, or developmental toxicity.
- **n-hexadecane:** severe irritant based on human and animal studies. There is no available data on cancer, mutagenic toxicity, teratogenic toxicity, or developmental toxicity.
- **4-(t-octyl) phenol:** corrosive and destructive to mucous membranes. There is no available data on cancer, mutagenic toxicity, teratogenic toxicity, or developmental toxicity.

---

The study also detected metals that were leached from the tire crumbs. Zinc was the predominant metal, but selenium, lead and cadmium were also identified.

The identification of toxic actions is based on research reported in the peer-reviewed literature and official listings, such as the Integrated Risk Information System (IRIS) and Toxic Substance Control Act (TOSCA). Many, if not most, of the compounds present in tire crumbs and shreds have been incompletely tested for human health effects. In some cases, a partial assessment can be based on the estimated actions of a chemical class or on structural activity characteristics.

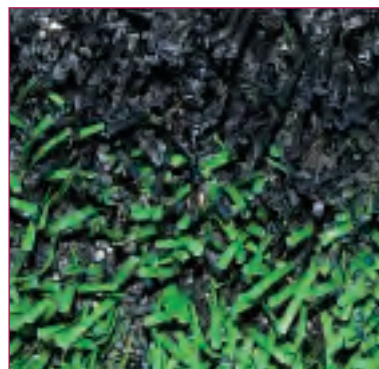
Ascertaining the toxic actions of the chemicals identified in the analytical test is dependent on the levels of research that have been performed and reported in the appropriate literature. A qualitative analysis usually precedes the quantitative analysis to determine potency.


## CANCER

Some of the compounds are identified as known or suspected carcinogens. The following is a discussion of the toxicity and health effects of the agents that have been released from tire crumbs under different conditions. The strongest data available with respect to cancer come from the International Agency for Research on Cancer's study of the rubber industry.<sup>2</sup> Strong and sufficient evidence for cancer in humans was demonstrated in a series of epidemiology studies of rubber fabrication facilities throughout the world. Cancer was also found in some other locations, but the data on exposures were insufficient to attribute a specific work task or exposure to the cancer.

One especially relevant report addressed exposures in a factory in Taiwan that made tire crumbs. In that study, mutagenic actions that were four to five times higher than in controls were shown in extracts of particulate matter collected in the air. These results indicate that the organic-dissolved portion of rubber particles contains various nitre-containing vulcanization stabilizers and accelerators, as well as process degradation products. Benzothiazole and 9-octadecenamide were identified as structures that would be converted to the N-nitrosamines under certain conditions.<sup>3</sup>

An unpublished 2006 Rutgers University study of tire crumbs taken from synthetic turf fields in New York City identified six polycyclic aromatic hydrocarbons (PAHs) at levels that reportedly exceeded the regulatory levels in New York State. These six compounds are highly likely to be carcinogenic to humans. The researchers caution that the availability of the carcinogens in the rubber is not established because solvent extraction was used to release the chemicals from the tire crumbs.





---

The Office of Environmental Health Hazard Assessment (OEHHA) of the California Department of Health prepared a report on potential risks, including carcinogenesis, from the use of recycled tire materials on playgrounds.<sup>4</sup>

A literature review of studies of the release of chemicals from recycled tires in laboratory settings and field studies found 49 chemicals, seven of which were carcinogens.

In a study that modeled gastric digestion 22 chemicals were identified.<sup>5</sup> Hand-to-mouth activity was examined using wipe samples; researchers found four polycyclic aromatic hydrocarbons (PAHs) and one metal, zinc. There also were 46 separate laboratory or field studies that reported either volatile organic compounds (20 studies), semi-volatiles (20 studies), or metals (29 studies). Some mentioned particulate collection.

## ALLERGIC RESPONSES

Allergies are addressed in studies from both California<sup>6</sup> and Norway,<sup>7</sup> indicating a moderate level of health concern. Inadequate data are available to address the concerns about allergic reactions, but it is possible that sensitized individuals will respond to the exposures. With so many children having asthma today, this is a real concern.

Furthermore, the Norway study<sup>8</sup> indicates high levels of latex exposures from the tire crumbs and recommends that such fields not be installed because of the high prevalence in the population of latex sensitivity.

## SKIN, EYE, AND RESPIRATORY IRRITATION

Skin, eye, and respiratory irritation is the most common action identified in the literature for these chemicals.<sup>9</sup> That probably reflects the regulatory requirement for such testing before the chemical can be shipped in commerce. These studies are the most basic of the toxicology testing schemes expected for materials with continuous human exposures. Based on the chemical structures of the aliphatic chemicals present, it is not surprising that they are listed as severe irritants. The irritation potential of aliphatic compounds increases with chain length up to 10 carbons and with increased branching of the molecules.

## THYROID EFFECTS AND NEUROLOGICAL EFFECTS

Other actions reported are thyroid effects, neurological effects, and systemic toxicity related to the liver and the kidneys. There is insufficient exposure information to assess whether these effects would be seen with the releases from ground-up recycled tires used on synthetic turf fields or in gardening mulch.

---

## RELEASE OF METALS TO ENVIRONMENTAL MEDIA

The metals zinc, cadmium, and lead were also identified as contaminants from tire rubber released into ground water.<sup>10</sup> With the exception of zinc, there are insufficient data to assess the health or environmental risks of any of these metals. It appears clear that the zinc levels are high enough to be phytotoxic if they enter the ground water or soil. It is doubtful that there is any human toxicity from zinc at the levels reported, but such a conclusion would have to be tested by more careful study.

## PARTICULATES RELEASED TO THE AIR

Finally, the particulate exposures due to tire dust and chemicals contained in the dust that can be released in the lungs are especially troublesome. Nearly every test adequate to assess the risk that was reported found one or two dozen compounds released from particulates.<sup>11</sup> There are processes in the body that can release the chemicals contained in the rubber particles. Moreover, potent carcinogens are found in the tire dust. Only the assumption of limited exposure could support the conclusions of low cancer risk.

## SUMMARY OF TOXIC ACTIONS

In summary, the toxic actions of concern from the materials that were released from recycled crumb rubber include:


- Severe irritation of the respiratory system
- Severe irritation of the eyes, skin and mucous membranes
- Systemic effects on the liver and kidneys
- Neurotoxic responses
- Allergic reactions
- Cancers
- Developmental effects



## OTHER REPORTS ON RUBBER TIRE CRUMBS WITH ANALYTICAL DATA

A report from the Swedish Chemical Agency (KEMI) lists the materials in tires.<sup>12</sup> Tires contain over 60 different substances—40% is rubber; the rest is carbon black, high aromatic oils, sulfur and various metals. Rubber is elastic polymers. The most common types of synthetic rubber are styrene-butadiene rubber and ethylene propylene rubber. Vulcanizing agents are used in manufacture, and fillers, antioxidants and plasticizers are added for technical properties. A large number of high aromatic oils are added, including polyaromatic hydrocarbons, phthalates that can leach into water, phenols, metals including zinc, and low concentrations of lead.

---



Synthetic turf often contains rubber granules from waste tires, which in turn contain several particularly hazardous substances. Therefore, the Swedish Chemical Agency recommends that rubber granules from waste tires not be used in synthetic turf.



Other reported findings from environmental or laboratory testing, including direct analytical analysis of tire crumbs, are summarized in the California Report (OEHHA)<sup>13</sup> and the Norwegian Public Health Report.<sup>14</sup> These reports document the findings of volatile organic compounds, semi-volatile compounds, PAHs, and metals. These findings are listed in the tables of these reports (see Appendix I).

Both the OEHHA report and the Norwegian study summarized the known non-cancer actions of the volatile, semi-volatile and metal compounds released into the environment by recycled tire crumb rubber and mulch. The listed information included primarily classifications of acute toxicity and irritation. Few of the chemicals have been classified for possible long-term effects and allergies. Although both studies attempted to determine the possible health risks from projected exposures, their evaluations are restricted by an assumption of a single life-time exposure to 10 grams of tire crumbs or less (OEHHA) or estimated daily average exposures from periodic exposures of three to five weekly uses of synthetic turf fields.<sup>15</sup>

EHHI cautions that both of these exposure assumption approaches could underestimate the actual exposures that would occur by orders of magnitude. Even using these assumptions, human health effects were projected for acute and cancer effects of certain of the identified compounds.

The most striking limitation of both the Norwegian and OEHHA studies is the lack of needed data on the actions of some of the more prevalent semi-volatile compounds, such as benzo-thiazole. In fact, these chemicals are not included in the health analysis in either health assessment, which is a serious limitation because the compounds are important components of the chemicals that are released.

### III. DISCUSSION OF RISK ASSESSMENTS

Four assessments that reviewed the information available from reasonably reliable sources are discussed below. The release of materials under ambient conditions was determined. The chemicals of concern were identified and the toxic actions listed. An attempt to determine the exposure potential was made and the human risk assessed. All four studies are limited by the application of the assessments only to the expected environmental and public health impact from crumb rubber at synthetic turf fields and the use of rubber mulch.



## PEDIATRIC STUDY OF TIRE CRUMB USE ON PLAYGROUNDS

*“Case Study of Tire Crumb Use on Playgrounds: Risk Analysis and Communication When Major Clinical Knowledge Gaps Exist”*<sup>16</sup>

The report from the U.S. Environmental Protection Agency notes that children’s exposures may potentially occur by ingestion of tire crumbs or water, inhalation of the dust, or skin contact. Traditional published scientific literature identified one study, Birkholtz et al. (2003),<sup>17</sup> which examined human and ecosystem hazards, and one or two other studies, but could not establish the products’ safety for children. Essentially no specific information was available regarding exposure to crumb rubber constituents from use on a playground. In addition to discussion of potential risks with parents who call with concerns, the authors do advocate for more relevant research.



## CANADIAN EVALUATION OF HAZARD ASSESSMENT OF TIRE CRUMBS FOR USE ON PUBLIC PLAYGROUNDS<sup>18</sup>

A cooperative agreement developed between the Alberta Centre for Injury Control and Research and the Recycling Management Association of Alberta determined the potential exposure of children to surface runoff and puddles. The authors assumed that the potential for oral ingestion is unlikely, that the product is washed and thus free of dust, and that the only exposure pathways are skin contact and ingestion. Both were deemed unlikely and were not measured. The mutagenicity of solvent extracts of the tire crumbs was used to assess the carcinogenic potential. It was concluded that the limited response in the mutagenicity study ruled out the potential for cancer. No quantitative exposure data were collected to support either conclusion.

## NORWEGIAN INSTITUTE OF PUBLIC HEALTH STUDY<sup>19</sup>

This study, discussed previously, used measured air levels of chemicals and an exposure model developed for participants in a building with synthetic turf. Although the study was limited by the absence of necessary toxicity data, it showed a potential for exposures and assessment of the level of risk. The approach used is more relevant for cancer risk assessment than for non-cancer risk assessment. Latex allergy was identified as the major risk. Margins of safety were calculated for each compound identified. The application of averaged exposures probably caused a 10-fold or greater reduction in the actual margin of safety in acute or short-term exposures.

## CALIFORNIA OEHHA RISK ASSESSMENT FOR PLAYGROUND EXPOSURE<sup>20</sup>

This study, described previously, considered single acute exposures by ingestion and chronic hand-to-mouth exposures for 22 chemicals found to be released by tire shreds. The individual

---

non-cancer risk was calculated by comparison to regulatory acute exposure levels. Seven of the 13 metals tested did not have acute exposure levels, so the risk could not be determined. Five of the eight VOCs lacked comparison data and seven of the eight semi-volatiles tested lacked comparison data. Even given this limitation, there were groups of chemicals that exceeded the hazard index of 1. The cancer risk assessment compared the accepted risk level for a single lifetime exposure to recycled rubber crumbs.

## THE FRENCH STUDY

### *“Health Evaluation of the Use of Elastomer Granulates as Filling in Third-Generation Artificial Turf 2007”<sup>21</sup>*

This study was conducted by ALIAPUR, the leading French government body responsible for used tires, along with ADEME, the French Agency for Environment and Energy Management.

“The main goal of the study was to determine the quality of water transferred into the natural environment after passing through the rubber granules and other infill materials from the artificial grass sports fields. In addition, the study obtained a detailed analysis and evaluation of the gas emissions generated by these fields.”



A Health Risk Evaluation (HRE) was performed by the French National Institute for Industrial Environment and Risks (INERIS) “in order to evaluate more precisely, in indoor situations, the health risks linked to the inhalation of the VOC and aldehydes of which these emissions have been quantified by the scientific and technical center of France.”

The study concludes with the statement: “the INERIS stipulates that the health risks associated with the inhalation of VOC and aldehydes emitted by artificial grass fields in outdoor situations give no cause for concern towards human health.”

It is necessary to examine the actual support for this conclusion of “no risk.” The authors base their conclusion on a chamber study in which 2.25 kilograms of used rubber tire crumbs were maintained at a temperature of 23 degrees centigrade (about 70 degrees F) for 28 days. VOC levels of 1,600 grams per cubic meter were found on day one and declined to under 200 grams per cubic meter on day 28. (Dimensions of the quantitative finding are vague in the report). The authors used the 28-day measure in which 112 different compounds were identified. Of the 112 released, the report examined the health risk of only 16 of the chemicals released into the chamber. The authors developed an indoor model to justify the dilution of the actual concentrations found and estimated the risk relative to that of a building materials code.



EHHI concludes that a test on a single sample of 2.25 kilograms of tire crumbs selected after 28 days of “conditioning”—and tested at 70 degrees F in a chamber—could not possibly be representative of the releases that would occur on a hot summer day when a synthetic turf field can reach temperatures of over 130 degrees F.

As well, evaluation of only 16 of 112 compounds released is simply inadequate to conclude that there are “no health risks.” Furthermore, such testing strategies will be of no value in assessing the health risks from “synthetic turf fields” to which several tons of rubber tire granules have been added. This study contains too many flaws, as well as problematic health risk endpoints, to be considered a credible human health evaluation study.

### COMMENT ON THE STUDIES

These four studies and others provide useful information about the scale of the risk, **but none of the studies is sufficiently robust to be used in a public health safety evaluation.**

### POTENTIAL FOR EVALUATION OF THE ACTUAL HEALTH RISK

The available information is sufficient and strong enough to raise plausible questions with respect to acute toxicity for susceptible persons, and for cancer risks. However, the status of the information about human exposures to recycled tire crumb rubber in-fill and gardening mulch is not sufficient to determine the safety of the use of the product in situations that involve continuous episodes of human exposure.

Given the complexity of the exposures, the limited research information on the actual toxic actions of these chemicals, and the limited experience with human exposures at sites other than tire fabrication facilities, identification of maximal safe exposure levels is not scientifically possible. Some researchers have compared projected exposures to background exposures in ambient air,<sup>22</sup> but it is known that many of these compounds, such as the PAHs, are considered health risks in ambient air. There is little other than the Norwegian study<sup>23</sup> to give a scale to the potential exposures. A rough approximation can be obtained from the information in the Connecticut Agricultural Experiment Station study.



Before applying maximal safe exposure assumptions, it is necessary to actually identify the toxic actions of concern. Allergens are one example of exposures that are problematic for susceptible populations.



---

## ESTIMATE OF THE SCALE OF EXPOSURES TO BENZOTHIAZOLE FROM TIRE CRUMB IN-FILL ON A SOCCER FIELD



The exposure potential on a soccer field could be quite large. A square foot of a field with between two and three inches of in-fill would have between five and seven kilograms of tire crumbs, which translates to between 11 and 15 pounds. If the findings from Table 2 in the Connecticut Agricultural Experiment Station study (page 30) are used as a reference, the emissions from the square foot of surface would approach four to six grams on a hot day when the surface approaches 60 degrees C (140 degrees F). Considering the actual size of the soccer fields, that would be substantial release into the ambient air. Actual exposure measurements are needed to determine the potential inhalation risks for players on the field or for spectators and nearby residents.

This same scale of analysis is needed for each of the agents shown to be released and the respirable dusts. If the tire crumbs are carried into a building or an automobile, similar analysis is necessary. EHHI has concluded that the currently available information is sufficient to raise plausible concerns for health risks, but is insufficient to determine how large those risks are.

### PROBLEM STATEMENT

The use of recycled rubber as in-fill on athletic fields, as gardening mulch, or subsurface fill under playground equipment involves direct exposures by children and adults to dusts and chemicals that would be released from the tire crumbs. A review of findings from the currently available reports on health and safety found important gaps in the information needed to determine the public health and environmental risks involved. The following is not fully known for ground-up rubber tire products:

- What are the chemicals actually present in the exposure pathways
- How great is the release of chemicals present in rubber dust under the conditions of use
- What are the toxic actions of the chemicals that are released
- What is the amount of exposure(s) from inhalation, dermal contact or ingestion

The gaps in the available information make it difficult to determine whether the proposed use of recycled tire crumbs in playing fields or playgrounds can be deemed safe.

---

## ADDITIONAL COMMENTS ON THE INADEQUACIES OF PRIOR STUDIES

A program to replace current grass playing fields with synthetic turf fields is underway in Connecticut and other states. The information supporting this effort essentially contains only the health benefits from reduction of injuries due to falls. The potential risk from human and environmental chemical exposures is not known. In its place are general reports with nonspecific data, such as that from the Consumer Product Safety Commission's *Handbook for Public Playground Safety*.<sup>24</sup>

Although chemicals had been shown to be released from recycled tire in-fill, the Consumer Product Safety Commission (CPSC) inferred that "Oral ingestion is deemed to be low in overall hazard because ingestion of the tire crumbs on the ground is not likely and the gastrointestinal system is unlikely to be efficient in extracting toxic chemicals from tire crumbs." The CPSC report continues, "Tire crumb does not contain chemicals with high vapor pressures; thus, exposure via inhalation is deemed inconsequential and the resulting hazard is negligible.... Cancer hazard measured in *in vitro* predictive assays was deemed negative." In a single test, 3/4-inch pieces of tire chips sent to a testing laboratory to be tested with acid (stomach acid) resulted in the following report: "Visual examination of insoluble residue appeared to indicate only fibrous reinforcing strands were dissolved by the hydrochloric acid. The tire rubber did not appear to be affected in any way."



Based on that test, the CPSC concludes, "Therefore if a piece of rubber is swallowed it should not cause any acute or chronic problems." The report then goes on to discuss leaching and other data based on a single test and cites references with limited applicability to the determination of the risk from exposures. **None of the data are at the level needed for public health assessment.**

In contrast to the CPSC report, studies from the Norwegian Institute of Public Health and the Radium Hospital, 2006,<sup>25</sup> cited information showing that dozens of volatile organic compounds off-gas from tire crumb in-fill and are carried in respirable dust particles released from in-fill during playing of sports in an indoor arena. Similarly, the California OEHHA report<sup>26</sup> summarized 46 studies in the scientific literature that identified 49 chemicals released from tire crumbs. Seven of the chemicals leached from tire shreds were carcinogens. OEHHA calculated a cancer risk of 1.2 in 10 million based on a *one-time ingestion* of the tire crumb rubber over a lifetime.

---

OEHHA also conducted a gastric digestion experiment that found 22 chemicals were released. Five of the chemicals released were carcinogens. OEHHA concluded that the risk would be below the one in a million risk level considered to be acceptable. However, the analysis posits that there would only be one single exposure in a lifetime and extends the cancer risk over the lifetime. This is saying that a person would have only one exposure, which in the opinion of EHHI is unlikely.

The frequency of exposures from the use of tire crumbs in playing fields and gardens is not known, but would almost certainly exceed once in a lifetime. Both the Norwegian study and the California report describe attempts to assess the overall risk from the use of tire crumbs on synthetic turf and playgrounds, respectively. In both cases, the lack of reliable exposure measures and the absence of relevant toxicological tests restrict the quantitative determination of the actual health hazards.

A report from Switzerland by Hans J. Kolitzus,<sup>27</sup> cautions that the “the real effect of sports surfaces on sites to the environment cannot be determined using lab tests.” The report seems to caution that although no toxicity has been documented to date, the studies needed to evaluate the risk are not complete. EHHI concludes that neither the Norwegian study nor the OEHHA study is sufficient to determine the health risks to humans.

## OCCUPATIONAL HEALTH DATA FROM THE MANUFACTURE OF TIRE CRUMBS

An occupational study in a Taiwan scrap-tire shredding plant<sup>28</sup> identified volatile organics and particulates in the air that were “frame shift” mutagens. While the report cited epidemiological studies of rubber workers showing acute and chronic respiratory effects, including reduced lung capacity, and increased risk of laryngeal, bladder, lung and skin cancers, no health studies had been done in workers in tire-shredding plants. With the exception of the more volatile solvents, similar types of chemicals are found in shredding facilities and manufacturing plants.



The scrap-tire shredding facility’s assessment listed materials present in the air. The volatile organics found include styrene, benzothiazole, phthalate esters and naphthalene. Airborne particulates in the respirable range constituted amines, aniline, quinoline, amides, and benzothiazole. Mass spectrographic analysis identified eight chemicals in the air, categorized as aromatic, ketone, monomer PAHs and esters. Octane, decane, benzene, toluene ethylbenzene, xylenes and ethyl methyl benzenes were also found. The particulate

---

contained 12 types of chemicals, including three amines, two additives, two amides, two PAHs, two acids and two esters. The results indicated that the organic-dissolved portion of rubber particles included nitre-containing vulcanization stabilizers and accelerators, as well as process degradation products.

EHHI concludes that the chemicals found in the air in tire-shredding facilities should also be considered to be potential contaminants at sites that use crumb rubber in-fill and gardening mulch, but at lower concentrations. The studies cited in the Norwegian and California reports support this conclusion.

## PLAYGROUND SAFETY REPORTS

The OEHHA report<sup>29</sup> also addressed potential risks from the use of recycled tire materials on playgrounds. That study evaluated the release of chemicals that could cause toxicity on dermal contact in children. The report contains a literature review of studies that measured the release of chemicals from recycled tires in laboratory settings and field studies. Of the 49 chemicals listed, seven were carcinogens. Twenty-two chemicals were identified in a study that modeled gastric digestion. As noted earlier, a component of the OEHHA study that looked at hand-to-mouth activity using wipe samples found four PAHs and one metal, zinc. This study identified 46 separate laboratory or field studies that reported VOCs, semi-volatiles, and metals, and also mentioned particulate collection. There were three general groups of substances released: 15 metals, 20 volatile organic compounds, and 14 semi-volatile compounds.



The previously cited study by Birkholz et al.<sup>30</sup> concludes that there is little potential for exposure to cause adverse health effects in children and that no chromosome-damaging chemicals were present with solvent extraction. It does note slight aquatic toxicity. EHHI is concerned about the limited level of the exposure assessment performed in this study and by the sharply different findings from those found in more detailed studies that do identify both the presence of carcinogenic chemicals and mutagenic responses in recycled tire crumbs.

## OTHER HIGHLY RELEVANT RESEARCH

Findings from two studies reported on the internet are important. The first is a report by William Crain and Junfeng Zhang (2007) that found carcinogenic PAHs released from tire crumb in-fill at levels that exceeded New York State Contaminated Soil limits. The findings of that study are totally consistent with the work cited by the Norwegian report, the California OEHHA report and the occupational report from Taiwan.

---

The second study, by Stuart Gaffin at Columbia University's Center for Climate Systems Research,<sup>31</sup> determined that the temperature present on playing field tire crumb in-fill during summer afternoons approached 160 degrees F.



The findings from the study in Norwegian indoor sports facilities show a strong increase in the release of chemicals into the air with increased temperature, although none of the arenas in the study approached temperatures as high as those reported in New York.

In South Korea, the Ministry of Education and Human Resources Development has initiated a study of the safety of synthetic turf fields that have been installed in 605 elementary, middle, and high schools. The study is a response to complaints from teachers of nose and eye irritation and contact dermatitis, and complaints of headaches from both teachers and students.<sup>32</sup>

Other reports in the literature cite current ongoing work to address the public and governmental concerns about potential exposures to recycled tires. One report from Norway<sup>33</sup> concluded that the use of recycled tire in-fill should be discontinued, based on a latex allergy concern.

Although the California report cited an animal study that did not find a positive response in animals, there is concern that types of allergic response cannot be properly tested in animal skin-exposure protocols. It is likely that, when allergens are inhaled by persons sensitized to latex, a systemic rather than contact response will be induced. Higher levels of latex allergy have been found in persons who live near highways. This is because the source of latex is in tires.

EHHI concludes that, given the significance of the potential health concerns, the findings that there are toxic chemicals and particulates present in areas that use recycled tires, the serious gaps in exposure information, and the partial information on the toxic actions of the chemicals released into the environment, *further assessment is absolutely necessary if the public is to be protected.*

Important policy questions raised with respect to tire rubber require analysis of both exposure potential and the toxicity of the mixture of components in air, soil, and dust. The question is thus addressed within the context of the contaminants of concern associated with exposure to the materials released, the health concerns of the communities with potential exposure, and the identification and quantitative assessment of the pathways of completed and potential exposures. The integration of these components constitutes a health hazard assessment on which health recommendations are based.