Memorandum

To: *Report Responder for the CPSC*

From: *Laura C. Green, Ph.D., D.A.B.T.*

Date: *June 29, 2015*

Subject: *Comment on CPSC Report #20150608-22F81-2147431268*
Assessment of the risk of cancer posed by rubber mulch used in playgrounds

As a toxicologist, I have been asked by Rubberecycle (a company that manufactures, among other products, rubber mulch for playgrounds) to comment on CPSC Report #20150608-22F81-2147431268. This CPSC Report provides the following comment and request made by Dr. Debra Lay, Principal of the Jonesport Elementary School, in Jonesport Maine:

> *There have been a few reports lately about rubber mulch causing cancer in children. We have rubber mulch on our playground and we are interested in getting accurate information in order to make an informed decision on whether we should remove this substance. Please advise.*

As explained below, I have examined the relevant evidence, and have found that rubber mulch is neither known nor reasonably expected to cause cancer, and is otherwise safe for use in playgrounds. I know of no reason that this mulch should be removed from the playground at Jonesport Elementary School.

Reports of cancer in soccer players and other athletes who play on synthetic turf fields

To begin, I note that there are no reports that rubber mulch causes cancer (either in children or others). I believe that Principal Lay may be referring instead to news reports of a *possibly* elevated incidence of cancer among soccer players who play (at least some of their games) on synthetic turf fields, some of which are "infilled" with crumb rubber.

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In particular, in May of last year, a Seattle, Washington TV station broadcast a story, "Toxic Turf? UW coach draws connection between turf and cancer." The TV story noted:

> *University of Washington assistant soccer coach Amy Griffin sees a troubling connection between the turf and cancer among soccer players. Griffin [said] . . . that 13 players from the state of Washington were all diagnosed with rare types of cancer. Of those 13, 11 were goalkeepers. Griffin can't say why goalkeepers are getting cancer but she wonders if it could be caused by the crumb rubber, a kind of filler in turf fields. . . . 'Everyone says it's just a coincidence and kind of walks away, but the ratio of goalkeepers to field players is 15 to 1, 16 to 2, and I know plenty of goalkeepers that have cancers and I don't know many field players,' Griffin said . . .*

Other news reports followed, with additional cancers reported; but, to my knowledge, no systematic or scientific study of these cases has been performed or published.

For example, in February of this year, the nonprofit group, Environment and Human Health, Inc. (EHHI; at http://www.ehhi.org/turf/cancer_cases_grow_0115.shtml), reported:

> ***Cancer cases among student athletes playing on synthetic turf continue to grow***
>
> *Amy Griffin, Assistant Women's Soccer Coach at the University of Washington, has been keeping a list of athletes who have developed cancer after playing on turf fields containing waste tires.*
>
> *So far she has identified 126 athletes, 109 of which are soccer players, 10 were football players, and six were field hockey and lacrosse players, who have developed different forms of cancer.*
>
> *The reported cancers are:*
> *51 lymphomas*
> *19 leukemias*
> *10 Brain*
> *9 Testicular*

9 Sarcoma
6 Thyroid

The rest are rare forms of cancer.

It is important to note the predominance of lymphomas and leukemias. 1,3 butadiene is connected to lymphoma and benzene is connected to leukemia. Both of these chemicals are present in rubber tires.

What is *not* known regarding these cancers in soccer players

As noted above, these cancer-cases have not been reported on in any scientific journal, and no details have been reported – we do not even know if the reports are completely accurate. We do not know, for example, the ages, sexes, or races of any of the cases, nor do we know the specific forms of leukemia, lymphoma, or other cancer-type for any individual soccer-player. Nor do we have any idea the extent to which any of these athletes have played on fields containing "waste tires", nor how "waste tires" is here defined.

Lacking this information, it is not possible to determine whether these cases constitute an actual cluster — that is, whether, as a group (and exactly what group is being examined is unclear), they have experienced a significantly larger incidence of cancer-cases than would be expected, based on rates in the general population. EHHI notes a "predominance of lymphomas and leukemias," but these are among the most common types of cancer that develop in children and adolescents (Ward *et al*., 2014), and so are not necessarily noteworthy.

Moreover, although cancers in young people (I am assuming, but do not know, that most of these 126 cases are in relatively young athletes) are not common, in 2014 in the U.S., almost 16,000 children and adolescents (from 0 to 19 years of age) were expected to have been diagnosed with some form of cancer (Ward *et al*., 2014). Thus, learning about many cancer diagnoses in adolescents (again, I am assuming that most of these cases are among adolescents) would be entirely expected.

Suppose that these 126 cases do represent a cluster — that there are indeed significantly more cases of cancer among soccer players and other young athletes than one would "expect." Does this mean that the cluster has an identifiable cause? In fact, no. As explained below, a great

many cancer clusters have been evaluated in great detail, and for almost none has a cause ever been found.

Results of prior investigations of cancer clusters

For several reasons, unusual coincidences of cancers among groups of younger people are noteworthy, and many of these have been extensively investigated. However, exhaustive study of such clusters in young people has never established an environmental or other exogenous cause: these clusters appear to be due instead to randomness (Caldwell, 1990; Gawande, 1999; Trumbo, 2000; Connecticut Department of Health, 2012).

Here, for example, is what noted epidemiologist Glynn Caldwell (1990) wrote toward the end of his long career:

> *Beginning in 1961, the Centers for Disease Control investigated 108 cancer clusters and reported the findings in Epidemic Aid Reports. The clusters studied were of leukemia (38%), leukemia and lymphoma (30%), leukemia and other cancer combinations (13%), and all other cancer or combinations (19%). These clusters occurred in 29 states and five foreign countries . . . Eight different data collection methods were used, often in combinations, and four types of laboratory methods on four different specimen types. Although 14 different categories of associations were reported, no clear cause was found for any cluster.*

A priori, then, an apparent association between playing soccer (or other sports) on synthetic turf fields and risk of leukemia and lymphoma may be reported, but that does not mean that the association is causal, as opposed to coincidental.

Of course, some clusters of cancer in communities *are* due to shared environmental and carcinogenic exposures, so one cannot and should not over-generalize.

For example, clusters of skin cancer (and other diseases) have been repeatedly reported among groups of people who drink water that has been (naturally) contaminated with high concentrations of arsenic, and this is because such exposures are genuinely carcinogenic (IARC, 1980). Similarly, clusters of lung cancer and of mesothelioma occur in communities plagued by

naturally large amounts of erionite (a mineral similar to asbestos) in local rocks and soils, and, again, these associations are known to be causal (IARC, 1987).

Importantly, however, no community-based cluster of any of the cancers *at issue here* has been found to have an identifiable, external, chemical cause.

Another reason to doubt an external, chemical cause for adolescent cancers is this: the type of leukemia prevalent in childhood (namely, acute lymphocytic leukemia, or ALL), lymphomas, and brain tumors are *not known to be caused by cigarette smoking* (IARC, 2004). Of course, cigarette smoke is the most chemically complex and important cause of cancers of several tissues and organs (not only the lung) in the U.S. (Surgeon General's Report, 2014; IARC, 2004). Since chronic exposure to such a potent mixture of carcinogenic chemicals does not cause the cancers at issue, then on what reliable basis could it be suggested that the much smaller doses of some of the same chemicals (potentially) emanating from rubber particles could cause these cancers? I can think of none.

Some salient features of lymphomas, leukemias, and other cancers that occur in adolescents

As noted above, EHHI reports that of the 126 cases of cancer in athletes, 51 are cases of lymphoma. Lymphomas are not uncommon cancers: in 2014, more than 760,000 Americans were diagnosed with a form of lymphoma (Leukemia & Lymphoma Society, 2015). Indeed, among adolescents who develop cancer, lymphomas are *the most common type* (IARC, 2008). Interestingly, dogs are also prone to developing lymphoma, with some breeds more likely to develop this cancer than other breeds (Teske, 1994).

I would note that there are many different types of lymphomas, and these vary substantially with regard to their prevalence, genetic pre-dispositions, other risk-factors, and clinical courses (Swerdlow *et al*., 2008; Morton *et al*., 2014). (This is one reason that the lack of detail about these cases in athletes makes causal interpretations impossible). As suggested by the patterns of lymphomas in dog-breeds, and in some human families, some lymphoma-types have a strong genetic component (Bassig *et al*., 2015); while others appear to be due to the significant alterations in the immune systems of people (i) infected with H.I.V., (ii) afflicted with various autoimmune diseases, or (iii) on immunosuppressant drug-therapies (Cáceres *et al*., 2010; Liang *et al*., 2014). Although many hypotheses have been raised and investigated, to date, no community-based exposures have been established to cause lymphoma (IARC, 2008).

Leukemias also vary according to type, prevalence, etiologies, and clinical courses (Jandl, 1996). Although not specified by EHHI, as noted above, I suspect that most of the leukemias in the soccer players (at least, in the younger players) are the type known as acute lymphocytic leukemia (ALL). This is important because ALL — as opposed to a major leukemia-type in adults, namely acute myelogenous leukemia (AML) — is *not* known to be caused by overexposures to chemicals, such as benzene, nor by chronic exposure to the chemicals present in cigarette smoke (IARC, 2004).

More generally, no type of cancer in adolescents is known to be caused by overexposure to chemicals. Instead, many of these cancer-cases are known or believed to occur spontaneously, or to be caused by factors common to us all (Lynch, 2010; Matés *et al*., 2012; Tomasetti *et al*., 2013; Tomasetti and Vogelstein, 2015). Some cases of cancers in adolescents appear to be due to infections with viruses such as Epstein-Barr virus (EBV); and some are apparently due to inherited genetic mutations (IARC, 2008).

EHHI's causal hypothesis with regard to crumb rubber (and rubber mulch) and cancer

Turning back to EHHI's apparent hypothesis with regard to rubber and cancer, I begin by noting that tires are industrial products made with various potentially hazardous chemicals; and that although tires *per se* are essentially inert, crumbled or shredded tires can release small amounts of various chemicals. In particular, synthetic rubber products tend to have a distinctive smell, caused primarily by release of trace amounts of volatile amines and organic sulfur compounds (Ambelong, 1963). These compounds are more odorous than they are toxic, and they are certainly not known or reasonably expected to pose a risk of cancer, regardless of the level of exposure.

EHHI suggests, however, that two other chemicals (i) emanate at significant concentrations from rubber and (ii) might pose a significant risk of cancer.

As quoted above, EHHI writes:

> *It is important to note the predominance of lymphomas and leukemias. 1,3 butadiene is connected to lymphoma and benzene is connected to leukemia. Both of these chemicals are present in rubber tires.*

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These statements are misleading in several ways. First, there is nothing surprising about a "predominance of lymphomas and leukemias" among young people: as noted above, these are the most common cancers in adolescents. Indeed, it would be striking if these cancer types were *not* prevalent in any random group of adolescents with cancer.

Second, the implication that crumb rubber (and/or rubber mulch) is a significant source of people's exposures to the chemicals 1,3-butadiene and benzene is simply incorrect. It is true that 1,3-butadiene is *used* to make synthetic rubber (for tires and other products), but it is also essentially all *used up* in this process, in that it reacts with another chemical, styrene, to form a stable polymer, styrene-butadiene rubber. This stable polymer is no more a significant source of exposure to 1,3-butadiene than, say, a thoroughly baked cake is a significant source of exposure to raw eggs.

Nor would tires be expected to contain anything more than perhaps trace amounts of benzene. While it is the case that some tire building-machine operations rely on solvents that do contain small amounts (less than 1%) of benzene, there is neither evidence nor reason to maintain that tires would absorb, retain, and then release any significant amounts of benzene.

It is not surprising, then, that studies of ambient air in contact with crumb rubber in-filled synthetic turf fields have reported either (i) no detectable concentrations of 1,3-butadiene or benzene, or (ii) only the very low-level concentrations found in air throughout suburban and urban environments (Dye *et al*., 2006; Norwegian Pollution Control Authority, 2006; Moretto, 2007; Denly *et al*., 2008; Lim and Walker, 2009; Li *et al*., 2010; Schilirò *et al*., 2012). As noted by researchers Schilirò *et al*. (2012), for example, "On the basis of environmental monitoring, artificial turf football fields present no more exposure risks than the rest of the city." Their conclusions were based on measurements in ambient air of benzene and the related compounds, toluene and xylenes, as well as on measurements of inhalable particles (in the size ranges of PM_{10} and $PM_{2.5}$) and of polycyclic aromatic hydrocarbons (PAHs).

Third, as just suggested, all of us are exposed to very small amounts of both 1,3-butadiene and benzene via ordinary outdoor (and indoor) air, every day. This is because both chemicals are present in the exhaust from automobiles and from several other common sources. However, the evidence that benzene can cause leukemia (and again, only AML, and not ALL of childhood, and not lymphoma) does not come from these common, low-level, environmental exposures, but instead from massive exposures experienced by workers inside poorly ventilated factories,

prior to the institution of modern industrial hygiene (Graham *et al*., 1988). It is entirely misleading to conflate these genuinely dangerous, historical, occupational settings with any outdoor environments, even on heavily trafficked roads, for example, let alone on playing fields or on playgrounds surfaced with rubber mulch.

Finally, although EHHI claims that 1,3-butadiene "is connected to lymphoma," in fact it, like benzene, is known to cause leukemia (AML) and not lymphoma; and, again, it is known to do so in over-exposed factory workers (Delzell *et al*., 1996), but not known to do so in the public at large, which routinely experiences vastly smaller, environmental exposures.

Theoretical risks of cancer from crumb rubber in-filled synthetic turf fields

Because some potentially carcinogenic chemicals are present in crumb rubber (as they are in ordinary dirt and other media), several studies have sought to estimate the degree of theoretical health-risk associated with these chemicals. Although these studies have focused primarily on crumb rubber, they are relevant for rubber mulch as well.

For example, Van Rooij and Jongeneelen (2010) studied young-adult male soccer players following intensive contact with crumb rubber-infilled synthetic turf. The researchers sought to determine whether this contact would lead to increased exposures to polycyclic aromatic hydrocarbons (PAHs). The researchers found that it did not. They concluded, "If there is any exposure, then the uptake is very limited and within the range of uptake of PAH from environmental sources and/or diet." This was the case despite the fact that the athletes "had black residue of crumb dust on knees, hand palms and elbows . . . [confirming] that skin contact had occurred to dust of the tire crumb rubber."

A recently published study from New Jersey's state medical school (The Robert Wood Johnson Medical School) provides additional information. In particular, Pavilonis and colleagues (2014) subjected samples of both new and turf field-aged crumb rubber to extractions with solutions of synthetic sweat, synthetic lung fluid, and synthetic digestive fluid. They analyzed the types and amounts of chemicals that appeared in these synthetic biofluids, and then assessed whether children's and adults' exposures to these chemicals would be risky. Their data indicated that health risks to children and adults from extensive contact with crumb rubber ranged from none to negligible. Small amounts of potentially carcinogenic metals were detected in the crumb rubber-extracts, but the theoretical lifetime risks associated with these

were all less than one in one million, and, *per* the authors, "therefore risk was considered negligible."

Earlier scientific studies and health risk-assessments have reported similar results. For example, in 2003, Birkholz and colleagues published their study, "Toxicological evaluation for the hazard assessment of tire crumb for use in public playgrounds." Aggressive extraction of crumb rubber and testing of that extract revealed no significant toxic or mutagenic activity. (Mutagenic activity is an *in vitro* surrogate for ability to initiate cancer). Based on these and other results, the authors wrote, "We conclude that the use of tire crumb in playgrounds results in minimal hazard to children and the receiving environment."

In 2006, the Norwegian Institute of Public Health published their report, "Artificial turf pitches – an assessment of the health risks for football players." These researchers focused on indoor fields, because this is the setting in which air emissions would be much more concentrated, relative to outdoor fields. The investigators reported:

> *Worst case calculations based on air measurements carried out by NILU [Norwegian Institute for Air Research] and exposure values from the Norwegian Institute of Public Health indicate that training in sports halls does not cause any increased risk of leukaemia as a result of benzene exposure or any elevated risk as a result of exposure to polycyclic aromatic hydrocarbons.*
>
> *On the basis of the exposures which have been calculated in connection with the use of indoor halls with artificial turf in which recycled rubber granulate is used, there is no evidence to indicate that the use of such halls causes an elevated health risk. . . . It has been concluded that exposure to benzene and PAHs in the quantities in which they have been measured in the halls will not cause any increased risk of cancer in people using the halls.*

In 2007, the Dutch researcher Hoftstra published his report, "Environmental and Health Risks of Rubber Infill. Rubber Crumb from Car Tyres as Infill on Artificial Turf." His analysis was based on an extensive review of prior studies, as well as on the generation of new test data from fresh and weathered samples of rubber infill. Hofstra wrote:

> *Based on the available literature on exposure to rubber crumb by swallowing, inhalation and skin contact and our experimental investigations on skin contact*

> *we conclude that there is not a significant health risk due to the presence of rubber infill for football players on artificial turf pitch with rubber infill from used car tyres.*

Finally, the Connecticut Department of Public Health (CT DPH) has published three peer-reviewed studies of synthetic turf fields (Ginsberg *et al*., 2011a and 2011b; Simcox *et al*., 2011), and recently (January 20, 2015) issued a memorandum to local health departments and districts in the State. In this, CT DPH (2015) affirms its "position that outdoor artificial turf fields do not represent an elevated health risk." The Department notes:

> *. . . CT DPH finds no scientific support for a finding of elevated cancer risk from inhalation or ingestion of chemicals derived from recycled tires used on artificial turf fields. . . . federal and state authorities have taken seriously the concerns that artificial turf fields may present a health risk due to contaminants in recycled rubber. The best way to investigate these concerns is via an exposure investigation. Studies conducted in Connecticut and elsewhere have shown a very low exposure potential, less than from typical outdoor sources of air pollution. The current news reports of a list of soccer players with cancer does not constitute a correlation or causality and thus raises a concern that currently lacks scientific support. Thus, the CT DPH position expressed in 2011 at the conclusion of the Connecticut study, that outdoor artificial turf fields do not represent an elevated health risk, remains unchanged.*

Data from a recent, unpublished study by EHHI at Yale University

Earlier this month, EHHI (at http://www.ehhi.org/turf/new_study_jun2015.shtml posted this press release:

> ***New Study – Many carcinogens found in Yale analysis of crumb rubber infill and playground mulch surfacing***
>
> *North Haven, Conn., June 11, 2015—Environment and Human Health, Inc. (EHHI), an organization of physicians and public health professionals, is releasing its study done at Yale University showing that the analysis found 96 chemicals in the rubber tire infill used in synthetic turf and*

> *rubber tire mulch used as surfacing in toddler playgrounds.*
>
> *Of the 96 chemicals detected – a little under a half have had NO toxicity assessments done on them for their health effects - therefore nothing is known about them. The other half have had SOME toxicity testing done on them - but even many of those chemicals had incomplete toxicity testing and therefore all health effects are not fully known. Of the half that have had toxicity assessments, 20% are probable carcinogens. . . .*

Comments on the EHHI/Yale study

For many reasons, the EHHI/Yale study does not demonstrate that rubber mulch or crumb rubber pose a significant risk of cancer (or other diseases).

First, the study has not been published (or released in any complete form) nor, to my knowledge, has it been peer reviewed. In fact, contrary to the press release, the study does not appear to have been written up in even an unpublished manuscript. At my request, Nancy Alderman of EHHI was kind enough to supply me with a summary of some of the methods and a spreadsheet of the results to date: I have attached these materials to this memorandum.

Second, as far as I can tell, the summary results presented are entirely non-quantitative: there is no indication of the concentrations of any of the detected chemicals, let alone is there any attempt to assess levels of exposure or doses potentially received by children or others playing on or near rubber mulch or crumb rubber. Accordingly, there is no way to judge *the degree to which* any such exposures might be risky. Since all of us eat, drink, breathe, and otherwise contact at least trace levels of many carcinogens daily, it is crucial to be quantitative when assessing cancer-risks (and then acting wisely upon those assessments). Absent at least semi-quantitative estimates of risk, informed judgments simply cannot be made.

Third, according to the summary of the study-methods, the chemicals were detected in methylene chloride extracts of a mixture of ground and unground crumb rubber or rubber mulch — but methylene chloride extraction is not a relevant or reliable means of assessing how rubber mulch in playgrounds might become solubilized or otherwise release chemicals that could then be absorbed across a child's skin, for example, or across a child's digestive tract (were he or she to ingest some rubber). For purposes of human health risk assessment, instead

of using a non-biological solvent such as methylene chloride, one should use simulated sweat or simulated gastric fluid, as was used in the published, peer-reviewed study by Pavilonis *et al*., 2014, for example, cited above.

Fourth, EHHI reports that eight of the chemicals detected in the methylene chloride extracts of at least one of the nine samples of mulch are "probable carcinogens" (there were another five samples of "infill" that are not considered here) — but none of these eight chemicals is so categorized by authoritative bodies, such as the International Agency for Research on Cancer (IARC), the U.S. National Toxicology Program (NTP), or the U.S. Environmental Protection Agency (EPA). Moreover, not one of the putative "probable carcinogens" is consistently detected in the samples of mulch.

For example, EHHI lists pyrene (detected in seven of the nine samples) as a carcinogen, but no rodent bioassays of pyrene are in fact positive; and, *per* U.S. EPA, "Overall, the database for pyrene is substantial, and the weight of evidence suggests that this PAH is not carcinogenic" (EPA-635-R-08-012A). Not surprisingly, then, neither IARC nor NTP lists pyrene as either a known or a probable human carcinogen (See http://www.cancer.org/cancer/cancercauses/othercarcinogens/generalinformationaboutcarcinogens/known-and-probable-human-carcinogens# for complete lists of carcinogens compiled by IARC and NTP).

Similarly, EHHI lists heptadecane (detected in one of the samples) as a carcinogen, but no rodent bioassays indicate that heptadecane is carcinogenic, and it is not listed as a carcinogen by either IARC or NTP. EHHI lists phthalamide as a carcinogen, but the NTP bioassays for phthalamide yielded negative results in male and female rats and mice, and it is not listed as a carcinogen by either IARC or NTP.

And EHHI lists 9,10-dimethylanthracene, fluoranthene, phenanthrene, 4-(1,1,3,3-tetramethylbutyl)-phenol, and 1-methylpyrene as carcinogens; but, again not one of these five chemicals is listed as a carcinogen by either IARC or NTP.

Finally, I would note that the chemicals butadiene and benzene were *not* detected in this EHHI/Yale study. Recall that these two chemicals are indeed established causes of cancer in humans, and that EHHI had hypothesized that both are present — and presumably bioavailable — at significant concentrations in crumb rubber and rubber mulch. I would add that the elevated temperatures used to dry and to analyze the samples would likely have obscured the

presence of either compound, but it remains the case that the causal hypothesis raised by EHHI has yet to be supported by actual data or other reliable evidence.

Overall, then, the evidence on crumb rubber and rubber mulch does not suggest, let alone demonstrate, that rubber mulch poses a significant risk to the health of children or others. As such, I believe that Principal Lay can rest assured that the mulch in her playground has not put her students at risk of developing cancer.

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