Attachment 3.

External Peer Review Comments and Responses for the draft research protocol: *Synthetic Turf Fields with Tire Crumb Rubber Infill*.

June 16, 2016

REVIEWER #1

GENERAL IMPRESSIONS AND COMMENTS

The authors of this protocol are to be commended for developing a thorough protocol document under a very restrictive time schedule. They have attempted to design and afford implementation of an investigation that will add substantially to the scientific knowledge of emissions and exposure associated with Synthetic Turf Fields with Crumb Rubber Infill on Playing Fields and Playgrounds.

Criticism of the protocol stems almost completely from the restricted time-scale for the study- a report is due in November 2016 some six month from now. This too-short timeframe results in restrictions on the study that make it far less valuable than it might be with a more realistic schedule. For example, the study will not be statistically representative of the US population due to time and financial constraints. This reduces the generalizability of the study, but leaves in place the data-gathering nature and informational content. However, it begs a representative study drawing upon the results of this one to be done at a future date. Further many samples, in particular biological samples, will be archived as there simply is not enough time to collect and analyze all of the samples in time for the report.

Response: We acknowledge and appreciate the concerns regarding the impact of time and funding constraints on research design decisions. A representative sampling design would be a preferable approach for the tire crumb rubber characterization portion of the study; however, given the large number of fields across the United States developing a sampling frame, selecting a sample, performing recruiting, and completing sampling and analysis is well beyond the scope of the time and resources available. Given past experience regarding the difficulty in obtaining research participation agreement, it is also not clear whether a representative sampling approach would yield an adequate response rate for a representative design. Our research design will provide important information to fill gaps on chemicals present in tire crumb rubber and key exposure parameters, and is intended to examine potential differences based between unused and field-applied materials, and between indoor and outdoor fields that likely experience different weathering patterns. The exposure

characterization portion of the research is defined as a pilot-scale study. It will be aimed at providing limited exposure information while also examining methods and approaches for personal exposure characterization for field activity scenarios and expanding the numbers and types of chemicals measured in personal exposure assessment. It is also aimed at attempting to better characterize relevant activity patterns and improve our ability to estimate dermal and ingestion exposures, along with inhalation exposures. Delaying analysis of biomarker samples is intentional and intended to allow a determination of the most relevant chemicals for measurement.

An additional concern is the arbitrary nature of the sample sizes selected for the various components of the study. The authors have done an excellent job of assessing the power of the study to distinguish between different regions, etc., but the analysis was clearly *post-hoc* with the actual sample size selected based on what could be done with the time and fiscal restraints.

Response: We acknowledge the constrained sample sizes, however, the sample size determination was not post-hoc. An original estimate of research capabilities based on time/resource constraints was for a total of only 20 fields. After performing power calculations and recognizing the need for more power, we doubled the number of fields from 20 to 40, reduced the number of field characteristics strata from 3 to 2, and added the collection of samples from tire recycling facilities.

All in all, this study is about as well designed as it could be within the restraints. I have addressed specific issues in my responses to the Charge Questions below.

CHARGE QUESTIONS

The purpose of this peer review is to seek constructive comments to improve the technical content in the draft protocol.

1. **Do the research objectives clearly address the important need for,**
    a. **reducing uncertainties regarding characterization of chemical constituents of tire crumb rubbers used on natural turf fields? Please explain.**

The Research Objectives as outlined in the several Specific Aims, will provide substantial new information on chemical constituents of tire crumb rubbers as used in artificial turf fields and other recreational applications. The protocol calls for a literature search to evaluate what is currently extant with respect to such data but, more importantly, calls for an analysis of a number of samples drawn to be at least somewhat representative, if not fully statistically so, of sources present in the "real world." Such samples will be analyzed for VOCs, SVOCs, and metals, as well as microbial contamination. This will improve understanding and characterization of potential emissions, and exposures (See below) experienced by individuals using such recreational facilities. Data gathered in this component will

improve the quantitative distribution of emission characteristics. While this may not reduce uncertainties, it will more fully characterize variances. Further, it may characterize uncertainties more clearly. With regard to reducing uncertainties, one will need to wait for the results to assess this component as studies to date are merely anecdotal and may not have experienced the full range of emission characteristics. Modeling uncertainty differs substantially from modeling variability and the data collected here may allow assessment of both.

Response: We agree with the reviewer that this research study will allow for a more fully characterized variability of tire crumb rubber chemical constituents as well as improved understanding regarding potential for exposures. The results will need to be carefully examined regarding their potential for reducing uncertainties. We do anticipate reducing uncertainties regarding what chemicals people might be exposed to through their use of synthetic turf fields.

b. to better characterize exposure factors and exposure for people using synthetic turf fields? Please explain.

The protocol Aims suggest a substantially improved understanding of the factors influencing exposure and a better estimate of the variability in such exposure should be an outcome of the protocol. However, most of this information will be collected via questionnaire response and association with videography. True exposure, at least that measured by biological sampling, will not be completed in time for the report due in November 2016, some six months from now. This reduces the utility of the calculated exposure factors as the "Exposure" measure actually being used is quite weak.

Response: The decision to delay analysis of biological samples is intentional. We believe that the tire crumb rubber characterization and exposure characterization measurements and analyses need to be completed prior to analyzing biological samples. It will be important to apply biological specimen analysis for chemicals that have a high likelihood of demonstrating exposure to tire crumb rubber constituents and not simply reflect exposures to chemicals from other sources in people's lives. At this time, we do not know what the most relevant analyses might be for the synthetic turf field exposure scenarios. We will first identify relevant chemicals for biological specimen analysis through the tire crumb rubber and exposure characterization portions of the research.

The authors assess the statistical power of their study, but it is really a post-hoc analysis. They use two measures, one with low variability and one with high variability to assess the power of this study to distinguish between groups- in particular groups in various regions of the country. They are commended for doing such analysis, but the real "sample size" is determined by the amount of time they have to

complete their data collection and analysis and the funding level of the study. Indeed, as they report on Page 15:

> "Although the potential difference in chemical concentrations between and among fields in different U.S. regions is of interest, this study is likely to be underpowered for assessing those differences"

For the high-variability BaP case, they do not reach 80% power unless the groups differ by a factor of two. I doubt that would have decided on such a large difference given a less restrictive set of study parameters. The low variability case- lead exposure, which has sufficient power to distinguish a 20% differences, is more realistic with regard to an expected study design.

Given these problems, the authors have reduced expectations for the study and suggest that it is really a pilot-level investigation. This reviewer concurs with that assessment.

Response: The number of fields for inclusion in the tire crumb rubber characterization study is constrained by time and cost factors. However, the sample size selection was not post-hoc. The number of fields (40) was decided based on an evaluation of the minimum number of fields after examining the power to detect differences for high and low variability chemicals. There is very little existing information to guide strata sample size determinations. Observing differences of a factor of two for chemicals like BaP between unused material and aged material, or between indoor and outdoor facility material may or may not prove to be unlikely. For example, Zhang et al. 2008 saw a decrease in BaP from 8.6 ng/g in tire crumb rubber two months after installation to 0.8 ng/g nineteen months later at one field. In addition, the plan includes a tire recycling facility sampling component which adds samples that address unaged materials. We do consider the exposure characterization portion of the study to be a pilot study that will help us better understand how to design and conduct a larger-scale exposure study in the future, if warranted.

2. Will the research protocol likely result in meeting the research objectives? Why or why not?

Research objectives will be partially met using the protocol as presented here. However, the convenience sample selected for analysis has significant shortcomings. Using convenience sample, due to short time scale for the study, gives results that are not generalizable to a larger population, as recognized by the authors in the quote above. As stated under Charge question #1, the authors perform statistical power calculations for a low variability compound (lead) and a high variability compound (BaP) showing that they have good power to detect 20% difference in group for the former but only for 100% difference for the latter. However, in both cases, they do not account for the non-random convenience sample. Hence, generalizability is sacrificed in order to speed the process and reduce the budget. One is

free to speculate the utility of such a study design. That is not to say that no useful information will be obtained. On the contrary, the data obtained in this investigation will increase knowledge of the general subject several-fold. However, this study cannot be touted as the definitive investigation, but rather serves as a pilot-level investigation that would afford a better design of a more statistically robust investigation. If one views the Objectives is this fashion, the study is adequate and sufficient. If one views it as the definitive investigation of this problem, the protocol is incomplete.

Response: We appreciate the reviewer's input on our ability to interpret and apply the research results. We agree that the sample design will not allow for generalization of results to the universe of synthetic turf fields in the United States. Also, we agree that a definitive investigation cannot be completed in the available time frame. However, the research will provide valuable information to better understand and identify the important potential chemical and microbiological exposures, will test and apply multiple methodologies for measuring tire crumb rubber constituents and exposures and human activity factors, and will set the stage for designing and implementing future human exposure studies, if feasible. The research will also improve our ability to model potential exposures and to evaluate potential exposures in the context of toxicity and risk.

3. **Are the proposed approaches and methods valid and consistent with the current state-of-the-science? Are there other approaches or methods that should be considered? Please explain.**

My concern about choosing a convenience sample has been addressed above.

There are both targeted and untargeted compounds of interest. For the metal analysis, the authors propose the use of ICP-MS. This analytical method is generally considered the method of choice for this set of contaminants. Further, it represents an efficient use of sample extracts as multiple metals can be determined in the same analytical run.

For the large number of VOCs and SVOC in untargeted analyses, the authors propose using scanning over a range of 50-550 amu and matching spectra with a large-scale (~33,000) library of compounds looking for statistical matches, e.g., > 90% statistical likelihood. This method of identification should be looked upon as semi-quantitative rather than quantitative but is likely to produce useful data for future studies.

I also express some concern about the targeted analysis. Although not completely clear from the protocol as presented, it would appear that literally hundreds of compound are targeted. The likelihood of ideal chromatographic separation coupled with appropriate ion identification in a single MS or MS/MS methods seems unlikely. Co-elution, similar mass fragments for similar compounds, etc., call

into question the targeted analysis quantification. Analysis in SIM mode is also very time consuming, especially for similar compounds, while TIC may not offer sufficient sensitivity for quantification. Alternatively, multiple method could be employed, but such would require levels of post-analysis data handling that are daunting to say the least.

Response: Given the relatively unknown potential for multiple tire crumb rubber chemical constituents to be identified across many possible organic compounds, we have elected to apply two strategies for analysis. We have included many compounds (e.g. PAHs, phthalates, benzothiazole, 2-mercaptobenzothiazole) that have been identified in previous research or are of potential concern; we will perform fully quantitative targeted analysis for these chemicals. However, given the large range of other chemicals potentially used in tire rubber manufacturing, we will also apply suspect screening analysis through analysis of chemical standards for many other compounds (which may also allow semi-quantitative reporting) that will provide chromatographic retention and mass spectra confirmation of suspect compounds. We will also conduct a subset of non-targeted analysis which will allow us to generate exact chemical formulas, retention indices, and mass spectra that can be further evaluated if/as needed based on criteria such as relative abundance. Through this process, we expect to identify key chemicals of interest for exposure and toxicological assessment. The reviewer raises important concerns and considerations in chromatographic analysis and evaluation of mass spectra. Our laboratories have been engaged for several years in capacity building for suspect screening and non-targeted analysis approaches for large numbers of chemicals in environmental media using high resolution and high sensitivity chromatography and mass spectrometry. We will apply GC/MS methods, including TOFMS for VOCs and we will apply both GC/MS/MS and LC/TOFMS methods for SVOCs to be able to identify a wide range of chemicals with different chemical/physical properties. We will apply appropriate QA and QC measures and will properly qualify our findings when chromatographic separation and spectra uniqueness impact identification and quantification.

4. **Are the proposed target analytes appropriate for characterizing tire crumb rubber material and potential exposures? Are there others that should be considered? Please explain.**

Without doing a literature review equivalent to what the authors are proposing for Phase I of their work, I cannot be fully sure, but it does appear that they have identified the main metals, VOCs, and SVOCs likely to be contained in and emitted from tire crumb rubber. Further, their proposed untargeted analysis may (it is not certain) lead to identifying new and important compounds of interest, although such may only be identified in semi-quantitative terms. However, this is likely to be sufficient to aid in the design of the next investigation.

Response: We appreciate the reviewer's comment and agree that the chemical identification component of the research will improve the ability to plan and implement future exposure and toxicological investigations.

5. **Will the study design and sampling plan produce data and information that will be useful and defensible? Are there any suggestions or modifications that would strengthen the usability and defensibility of the data? Please explain.**

The data collected will be useful, if not completely defensible in light of statistical problems and concerns about analytical methods discussed above.

For example, on Page 34, the authors state explicitly:

> "It is important to communicate to the public and other stakeholders that the study activities that can be completed in 2016 are not designed to and will not be sufficient by themselves to directly answer the public's question about safety, but will implement research necessary to achieve that goal in the longer term."

and:

> "The requirement to complete work under the Federal Research Action Plan in 2016 and research funding limitations place important constraints on the research that are reflected in design choices. For example, the tire crumb rubber characterization study is limited to 40 fields and 9 recycling facilities, with modest power for detecting difference between strata. A representative sampling design was considered, but the time and costs required to develop and implement a study based on a national sampling frame of synthetic turf fields are well beyond the scope of time and funds available"

Response: Please see earlier responses regarding research constraints, sample sizes, and generalizability.

Further, the protocol as presented is not yet complete. There are several examples of incomplete specification of parameters. For example, on Page 43 the authors state:

> "NOTE: Preliminary experiments are underway to determine material amount, time, and flow parameters for the dynamic chamber emission experiments."

and a bit further down:

> "(e.g. 25 °C and 50% relative humidity (RH); 60 □C and X% RH"

indicating that the choice of relative humidity was still being determined. Essentially, one is being asked to review a somewhat incomplete protocol. All of this stems from the compressed schedule of protocol

production, review, and implementation. I am sure the authors themselves feel uncomfortable bringing forward a documents not yet fully complete.

Another, perhaps more serious example occurs on Page 57:

> "At the time of research protocol preparation, no method has been selected for collection of dust samples at synthetic turf fields for metal and SVOC analysis. Method development will be performed for the dust collection method(s), conditional to gaining access to one or more synthetic turf fields for methods testing and evaluation."

In this case, the authors have yet to determine an appropriate method for collecting certain samples deemed important in the study. While I am fully confident that these researchers have adequate training and experience to select an appropriate method, the fact that the protocol is being reviewed without such a method in place is troubling.

Response: We appreciate the reviewer's concerns regarding the completeness of the protocol. Ideally, we would perform method development and evaluation in advance of completing a research protocol. The aggressive timeline has us working on multiple fronts to prepare for the research. This includes developing appropriate conditions for dynamic chamber emissions testing for VOCs and SVOCs, and further development of methods for exposure characterization, especially field dust sample collection. These activities are ongoing, concurrent with protocol development. We will have approved SOPs for all methods prior to implementation.

It is mentioned that biological samples, e.g., blood and urine, are to be taken in this investigation. I believe this to be a critical aspect of the study since this is the principal way, outside of modeling, actual exposure would be determined. However, according to my reading of the protocol, such biological samples will be archived for later analysis due to both cost and time constraints. This is a significant flaw and shortcoming. While understandable in light of the November 2016 proposed date for the draft final report, the fact that exposure measurements will thus be reduced to questionnaire and videographic data analysis, would lead to a study of far less value that might otherwise be if biological samples were also analyzed.

Response: Please see the earlier explanation regarding the intentional purpose of holding the biological samples in storage until we identify chemicals of interest for biomonitoring. We will revise the protocol to include further explanation of this reasoning and approach.

6. Has the final use of the data and information been adequately considered in the design and planning of the research? Please explain.

Much of my discussion of the significant shortcomings of this protocol has been directed toward this question and I will not repeat such here. However, I will point out the discussion presented by the authors on Page 63:

> "Much of the data being collected under this research protocol is intended to be used in exposure screening and exposure modeling efforts. However, there will not be sufficient time to complete these analyses in time for inclusion in a 2016 draft status report."

It would seem that the authors themselves feel that the timing constraints placed on this study preclude execution of work of the quality that they would choose to put forward as scientists. The statement focuses on the use of data collected in this investigation as tools in exposure screening- questionnaires, semi-quantitative data analysis- and the implementation of modeling tools in an effort to estimate, at least stochastically (SHEDS), the exposure experienced by individuals exposed to tire crumb emissions. However, the last sentence above calls all of this into question. If there is not sufficient time to complete analyses of questionnaire data, emission characteristics, potential exposures through the air and direct contact, and biological measures of exposure associated with real-life activity on fields using these materials prior to the report deadline, one must ask if the study is of sufficient utility to be carried out. A system of financially constrained and data-poor results, rushed to completion is likely to produce results that are not sufficient to answer the real questions at hand. I think the authors acknowledge this in the comment on Page 63 quoted above. If a study requires 18 months to complete in a scientifically defensible way, forcing it to be completed in 9 months, does not make it more efficient; it makes it far less useful.

Response: We acknowledge that the timeline will likely not allow completion of all of the work of interest in 2016, including biomonitoring analysis, exposure screening, and exposure modeling. By the end of 2016 we will prepare a status report of information and results produced to that time, and will identify the additional work that will be needed.

REVIEWER #2

1. **Do the research objectives clearly address the important need for,**
    a. **reducing uncertainties regarding characterization of chemical constituents of tire crumb rubbers used on natural turf fields? Please explain.**

Answer: Yes the proposed studies do certainly have the important possibility of reducing uncertainties regarding the chemicals present in crumb rubber turf fields. While this is an important goal, in fact the proposed studies may actually over-do somewhat. If a chemical is not present in the crumb rubber there should not be a need to monitor it in air, dust, or on players' surfaces or blood or urine. I assume that some care will be taken to not monitor for chemicals that are not present in the product. But this is a very comprehensive and well-planned evaluation of what is there and how it gets into people.

Response: We agree with the reviewer that the tire crumb rubber characterization should inform what chemicals are measured in the exposure characterization. To the extent that tire crumb rubber results are available prior to analysis of exposure characterization samples, we can refine target analyte lists to focus on the most relevant chemicals.

There is one possible issue that is not addressed, which is whether there is a possible bias in the sample collection because of the voluntary nature of collecting samples. This is especially an important concern when obtaining the new samples from the recycling facilities, as these facilities will have every reason to want to not have the study find results that would compromise use of crumb rubber. It would be vastly preferable to have trained individuals not employed by these companies collect the samples so that there could not be allegations of cover-up and to be sure that the samples represent the real product.

Response: We agree with the reviewer, and we have decided that we will use only research study personnel (staff or contractors) to collect samples from recycling facilities. We will not rely on recycling companies to provide samples. The decision will be reflected in revised protocol language.

    b. **to better characterize exposure factors and exposure for people using synthetic turf fields? Please explain.**

Answer: Yes, the proposed studies will go a long way to determine and document the exposure of people using synthetic turf fields. Again the studies are exhaustive and comprehensive. The systematic sampling of indoor as well as outdoor crumb rubber fields is a great strength. I have only one concern, which is that none of the analyses are directed at possible exposure of very small children who do play on crumb rubber playgrounds.

Response: The reviewer is correct. The research described in this protocol is focused on synthetic turf fields and their users. The Consumer Product Safety Commission is developing additional research that will be focused on young children and playgrounds with recycled tire mulch or molded mat products.

The air sampling is proposed to heights of 1 meter, appropriate for adults but not for toddlers and small children. This are almost certainly the group most at risk due to their size, height, tendency to sit on the turf and their hand-to-mouth activity. While infant playgrounds are not the major user of crumb rubber, it is likely a very important exposure that is greater than that of older children and adults.

Response: We believe that air sampling at 1 meter heights is appropriate for synthetic turf field measurements since it is relevant for the youngest children likely to be engaged in active play on synthetic turf fields. We agree that different measurement heights might need to be considered for playground situations, but playgrounds will not be monitored in this specific piece of research. The Consumer Product Safety Commission is developing additional research that will be focused on young children and playgrounds with recycled tire mulch or molded mat products.

The video recording proposal is good and should give an indication of the variety of actions on crumb rubber fields. There is a danger here however, in that the greatest exposure is going to come from more extreme athletic events, not just routine play. It is going to be important to capture these extreme situations not just on video but also when obtaining samples. This concern is only partially addressed.

Response: One of the challenges for the research is that, a-priori, we may not fully understand which activities are likely to lead to the highest contacts with, and exposures to synthetic turf fields and constituents. In our proposed extant video examination, we will try to capture a range of activities that we think may put people into higher exposure scenarios. Likewise, for the exposure measurement study and videotaping we will attempt to include higher exposure scenarios, and the measurements are likely to focus on practice sessions that have repetitive drills. However, we acknowledge that this is a pilot effort that will inform improved future data collections.

2. Will the research protocol likely result in meeting the research objectives? Why or why not?

Answer: Yes, with only the reservations expressed above. There is also the issue of exposure specifically from skin abrasions which is not specifically addressed. I'm not sure how one would design a study to address that, but it is an important issue.

Response: We appreciate the concern about increased exposure potential through abraded skin. For the current activities, we cannot implement that type of analysis in the current timeframe. However,

if our dermal sampling is successful, it may be possible to estimate the potentially increased dermal exposure through abraded skin areas for different sized abrasions.

The proposal is for a very comprehensive (and expressive!) determination of the presence of toxic chemicals, their migration into air, their uptake by inhalation, ingestion and dermal absorption. If anything I think that most of the objectives could be met with a less extensive study, even though I applaud the comprehensiveness proposed. For example, is it really necessary to collect both dust samples and PM10? The dust exposure will be captured by the wipes on the skin of players, and the PM10 samples should capture what players would be inhaling.

Response: We believe that characterizing field dust is an important element of the research, since dust is involved with inhalation, dermal, and ingestion exposures. For dermal exposures, it will be helpful to examine the relationship between potentially available dust/residues through surface wipe measurements, and the amounts measured on people's skin. If we can successfully collect bulk dust from fields, it may allow some characterization of particle size distributions relevant for all exposure routes and may allow assessment of particle fraction attributable to tire rubber.

The plan to hold the human samples for analysis later only if and when there is evidence of exposure to specific chemicals is reasonable, but this will have to be carefully explained to subjects who may not like donating multiple blood and urine samples that are likely never to be analyzed.

Response: We appreciate this reviewer recommendation. We will need to develop communication approaches to help convey this to the research participants.

3. **Are the proposed approaches and methods valid and consistent with the current state-of-the-science? Are there other approaches or methods that should be considered? Please explain.**

Answer: Yes the proposed approaches and methods are totally state-of-the-art. The only addition that I can think would be valuable would be to obtain some air sampling at heights much closer to the ground in regard to small children.

Response: We reviewed the information from the 2010 Connecticut research studies that provided some evidence for differences in chemical and particle concentrations close to the ground vs. higher above the fields. Our capacity to make measurements at multiple heights on fields would be challenged given the time and resources available to us. Given the available information and resources, we have selected using a 1-meter height that is relevant for young field users engaged in

active play, and a compromise for older field users where a 1.5-meter height might be more appropriate.

But the methods are outstanding. A very positive feature of the proposed methods is that for study of the bacterial community composition and antibiotic resistant genes. This is a very important and previously understudied issue, and the methods proposed are really great.

4. **Are the proposed target analytes appropriate for characterizing tire crumb rubber material and potential exposures? Are there others that should be considered? Please explain.**

Answer: If anything the list of analytes is too complete. There is no point analyzing things not present in the crumb rubber samples obtained from the recycling facilities, although there may be some value in measurement of VOCs that may be coming from the plastic "grass" rather than the crumb rubber. But a very intensive analysis of the crumb rubber coming from the recycling facility should be done, and that is proposed. Those result should then determine the analysis in the rest of the study.

Response: We appreciate the reviewer's thoughts on the breadth of analysis. One of the data gaps, and one of the concerns expressed by a number of people is that previous studies have not consistently attempted to measure the very wide range of chemicals potentially present in tire crumb rubber in a comprehensive way, along with measurements that provide insight on potential exposures (e.g., through emissions testing and bioaccessibility measurements). We have decided to apply a range of analytical methods to more completely and comprehensively examine potential chemical constituents in the rubber material, and through testing that may provide more insight on the potential for exposure. This will allow for more focus evaluation of relevant constituents with more confidence that key constituents are not missed. Our extensive chemical list was primarily based on reports from previous research as well as chemicals that may be used in rubber and tire manufacturing. While many of the chemicals may prove not to be measureable at detectable levels, we will try to address this data gap and concern as comprehensively as possible. With limited time and resources, the research focus is on assessing recycled crumb rubber material. We do not plan on analyzing the synthetic grass blade material at this time. If blade materials are collected as a byproduct of tire crumb rubber sample collection, the blade material may be stored for possible future analysis.

5. **Will the study design and sampling plan produce data and information that will be useful and defensible? Are there any suggestions or modifications that would strengthen the usability and defensibility of the data? Please explain.**

Answer: Yes, the data and information coming from this study will be of enormous use, and with the high quality laboratory analysis will be defensible provided the results are presented in a way that does not go beyond the specific information collected. The document is very good in describing the limitations, as for example not dealing with the effects of heat beyond the effect of heat on release of VOCs. This is important concern, especially for young children. The study also clearly acknowledges that it does not address ecological risk or leachate from the crumb rubber, or exposure from other components of the crumb rubber mats. The sample size is limited, which will limit the statistical analysis. It will be very important to acknowledge these limitations in the communication of results.

Response: We thank the reviewer for this response, and we agree that limitations resulting from modest sample sizes and not having representative samples will be very important to communicate with research results.

6. Has the final use of the data and information been adequately considered in the design and planning of the research? Please explain.

Answer: It is almost impossible to evaluate the dissemination plan until one knows what the data shows. In spite of the comprehensive nature of the study it will be underpowered in terms of sample numbers, as clearly acknowledged in the document. Almost certainly it will not be possible to make flat statements implying that use of crumb rubber fields is either "safe" or "unsafe", and it would be extremely unwise to do so either way. I suspect the results will show that while there are toxic chemicals in crumb rubber, the exposure to individuals playing on such fields is limited but still there is some exposure. I am especially concerned about the issue with very small children, which is simply not addressed systematically in this proposal.

The way these results are presented with regard to cancer and non-cancer risks will be tricky, since certainly PAHs and some metals are carcinogenic, and all of the chemicals have non-cancer health effects. This discussion will have to be nuanced, discussing levels of exposure but not denying the known risks of these chemicals. Results also will need to be presented in relation to exposures occurring on natural grass fields. It is reassuring that the document makes that the study activities "will not be sufficient by themselves to directly answer the public's question about safety, but will implement research necessary to achieve that goal in the longer term." This is precisely the appropriate tone on which to communicate the results to the public.

Response: We appreciate the reviewer's thoughts on interpretation of results from the research. We agree that this research will not directly answer the question about "safe" or "unsafe". It will provide information to better understand the most relevant chemicals, exposures to those chemicals, and

toxicity information available for those chemicals. Future efforts may be able to apply the results for exposure and risk screening. Also, this research may provide information needed to design large scale exposure and/or epidemiological assessments should those be warranted.

The reviewer is correct that the study is not directly aimed at assessing exposures for very young children. We believe that the research being developed by the Consumer Product Safety Commission for improved understanding of exposures at playgrounds will most directly address this issue. However, the information produced under this research protocol should provide some information that can be used to assess exposures to younger children in different scenarios, including fields and playgrounds.

REVIEWER #3

Summary

The proposed project will enhance the data and information available about adult and children exposures to chemical and microbial contaminants arising from playing and practicing on artificial turf fields, particularly from crumb rubber infill. While the proposed timeline will present a challenge, and resulted in limiting some aspects of the study such as the site selection and postponing the biomarker measurement, valid data will be obtained from the proposed work.

There are multiple strengths to the study. These include: the use of extant video posted on YouTubes that document adult and children playing on artificial turf presents an interesting opportunity if a proper selection protocol can be developed and human subject consent obtained; the number of chemical analytes to be determined in both total and bioaccessible extracts; the measurements of microbial contamination on fields; and the extensive exposure characterizations planned.

Several areas though can be improved. These include: additional details should be provided on how the data will be used for risk assessment and management; how aging of the fields affects exposure needs greater consideration; and measurement of lead in the turf material itself should be done as it is a potential important source of lead exposure.

Response: The results from this research will not directly answer the question about "safe" or "unsafe". However, it shouldprovide information to better understand the most relevant chemicals, exposures to those chemicals, and toxicity information available for those chemicals. Future efforts may be able to apply the results for exposure and risk screening. Also, this research should provide information needed to design large scale exposure and/or epidemiological assessments should those be warranted.

A key component to this research is to better understand how the potential for exposure to tire crumb rubber chemical constituents may change due to material aging and use. We have included unused/used and indoor/outdoor design components to address this research question. We also anticipate analyzing materials that have been present on fields for different amounts of time; however, this may be complicated by the maintenance practice of period tire crumb rubber refreshment or replacement. Questionnaires will be used to provide information for material age assessment.

With limited time and resources, the research focus is on assessing recycled crumb rubber material. We do not plan on analyzing the synthetic grass blade material at this time. If blade materials are collected as a byproduct of tire crumb rubber sample collection, the blade material may be stored for

possible future analysis. This has been added to the research protocol and to the facility participation agreement form.

It is suggested that an advisory board that includes members who are trusted by the wide range of groups interested in this issue be formed to advance risk communication by facilitating the acceptance of reports issued and helping communities understand whether artificial turf is a safe alternative for their athletic fields. Overall, the proposed work will expand the knowledge of the contaminants that are present in the crumb rubber infill used in artificial turf fields and what the associated exposures to adults and children using those fields.

Response: We acknowledge that the reviewer has provided a good recommendation for the creation of an advisory board for facilitating research and risk communication. This recommendation will not be addressed as part of the research protocol but will be followed up separately for discussion in the participating organizations.

1. **Do the research objectives clearly address the important need for,**
   a. **reducing uncertainties regarding characterization of chemical constituents of tire crumb rubbers used on natural turf fields? Please explain.**

1a. Crumb rubber contains a number of potentially hazardous substances and as detailed in the document's introduction there is insufficient data and studies to fully characterize what is in the tire crumb rubber used as infill for artificial turf fields. A major component of the proposed research objectives will be the collection of crumb rubber from manufacturers (new material) and from in-use fields from different regions of the US. These samples will be analyzed for a wide range of chemical constituents (see response to question 4 about species to be analyzed) that are of potential public health concern. The proposed targeted analyses are comprehensive and will be supplemented by an exploratory analysis to identify additional organic compounds (volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs)) present in the crumb rubber. The results obtained will considerably add to the data base of the levels of the chemical constituents present within crumb rubber that is used on artificial turf fields thereby reducing the uncertainty in the characterization of the crumb rubber infill. As noted in the Draft document on Page 11, paragraph 2 though, due to time constraints, a convenience sample will be collected, the design used in most if not all previous studies on the issue, and the data available will not be suitable for nationwide generalizations. The results from a convenience sample though can provide insight into the compounds and levels present in the crumb rubber used as infill for artificial turf and when combined with existing data, guide whether a larger, probabilistic sample based study should be conducted and for what chemical species.

b. to better characterize exposure factors and exposure for people using synthetic turf fields? Please explain.

1b. The activities, duration and frequency of use of artificial turf fields leading to children and adults multi-route exposures to contaminants present in the crumb rubber has not been well characterized. The proposed study will compile relevant exposure factors through the use of questionnaires, videotaping of participants where questionnaires were administered, and review of extant, publically-available video YouTubes of children and adults playing and practicing on artificial turf fields. The questionnaires are designed to understand multiple exposure routes – inhalation, dermal and inadvertent ingestion. Plans were also outlined to collect samples for biomarker measurements from adults and children after using the artificial turf fields. The samples will be archived for future analyses due to the project's proposed timeline. The questionnaires are designed to understand the field utilization at the facility level and for individuals. The facility questionnaires focus on facilities currently having artificial turf fields with crumb rubber infill. Queries include identifying the types of activities supported/occurring at a facility, by whom (age stratified – my understanding of question 11 on page 100/101) and the frequency/extent of use. Information will be collected for indoor and outdoor fields relative to their field type and the maintenance done, which can affect exposure. (Note: Please verify that the choices for question A16 are correct, that the frequency of refill/refresh of the crumb does not happen more frequently than yearly.)

Response: We have modified the questionnaire to ask two distinct questions. One question asks about whether the field has had complete tire crumb rubber replacement, and if so, the frequency. The second question asks about refreshment/additions, and now includes frequency response categories of 3 and 6 months, which we think are appropriate based on outreach contacts to field managers.

The use of extant YouTubes to gather activity pattern data is an interesting approach, though has a number of human subject concerns. More thought and justification is needed for the criteria used in deciding which YouTubes to incorporate in the study to make sure that they portray common activities. YouTubes may be posted by people for selected activities rather than routine use so may present a skewed view of activities. There was a discussion of evaluating the highest contact activities (e.g. a soccer goalie), which is appropriate considering the proposed scope, though those selections need to be remembered when conducting the risk assessment.

Response: We are asking the IRB explicitly about human subjects considerations and the requirements that would be necessary to use extant videos in this research activity. We will not use extant videos unless and until we have IRB and EPA Human Subject Research Review Official approvals. Regarding the criteria for selection of videos, we are concerned about being too explicit in selection criteria at

this time since we will not have a good understanding of the type of extant videos available for scenarios of interest until we actually spend time searching and viewing. As the reviewer notes, we are interested in videos for people and activities related to what are likely to be higher contact rate scenarios. We will provide some additional text to the research protocol, but it may not be as specific as the reviewer would like to see. We would like some flexibility that our initial assessments will help further elucidate relevant selection criteria.

Only facilities currently having artificial turf fields are eligible for the study. Consideration should be given to administering the relevant portions of the questionnaire at facilities with natural grass fields, particularly those that may have had artificial turf fields but removed them. This could help verify that there are no major activities/use differences between artificial turf and natural grass fields so that the data being collected can be used in estimating what the exposures would be when a field is converted to artificial turf.

Response: While there is merit is considering exposures to natural grass fields, this study is limited to synthetic turf fields based on the goals of the current study. Because of time and resource constraints, we have chosen to focus data collection efforts on synthetic turf fields and their users at this time. We do not think we could conduct the research for synthetic and natural fields and users with enough numbers to support examinations of significant differences.

2. Will the research protocol likely result in meeting the research objectives? Why or why not?

The results of the proposed work will expand the information available on the potential exposure to chemical and microbial contaminants from crumb rubber infill and artificial turf fields and activity patterns data that can lead to exposures of potentially hazardous constituents during the use of artificial turf fields. The literature review will provide the current scope of available information on this issue.

Insufficient discussion is provided to assess whether item 3 of the research goals (Page vii and 7) "Conducting an initial evaluation of potential cancer and non-cancer toxicity of key chemical constituents" will be accomplished. Presumably, the data gathered could be used to provide an exposure estimate based on concentration distribution measured for each constituent multiplied by an inhalation, ingestion and dermal exposure contact rate. The exposure estimate can then be compared to IRIS and Hazard Quotients for each species. However, details of how this assessment is to be done are not provided. A full risk assessment would benefit from future work that would include a probabilistic sample design and biomarker work that validated exposure estimates.

Response: During the 2016 research time frame we plan to perform the necessary measurements to identify relevant chemicals, generate activity information for improved multi-route exposure assessment, and obtain toxicity information for relevant chemicals. However, the time available following completion of those activities will not leave us with sufficient time in 2016 to perform exposure and risk screening with the careful attention and reviews they will require. In our 2016 status report, we will report on the results developed through that point in time, and identify recommended next steps and future work.

One consideration that is alluded to (e.g. Page 15 where weather is discussed and >2 year old are specified), but not adequately described is how aging affects the contaminant composition of bioavailability of the crumb rubber infill and artificial turf fields. (Page 15 states that the study is likely to be underpowered to assess regional differences.) Understanding changes in chemical composition as a function of aging is an important part of a complete characterization of the constituents of crumb rubber in fields. Reference is made to having fields that are >2 years old and presumable the actual age of the fields would be known from the questionnaire. Aging may affect the release of chemicals and may be affected by temperature and solar radiation. Thus, there could be differences across the US of how aging affects the availability of contaminants. As noted in the document, the number of samples being collected will not be sufficient to understand the role of aging, temperature and solar radiation on the composition of material, nor the variability in the composition of the starting material. The data from the indoor may be more comparable across the different regions than the outdoor results since indoor materials are subject to a narrower temperature range and are sheltered from solar radiation.

Response: One of the key data gaps is how the aging of tire crumb rubber materials affects the presence of and the potential for exposure to tire crumb rubber constituents. Existing data are limited. For example, Zhang et al. (2008) described large decreases in PAH content in tire crumb material approximately 20 months after installation, but this information is available for only one field. There is also uncertainty as to whether mechanical and meteorological weathering cause the tire crumb material to break down, and potentially increase the available of smaller particles for exposure. We do not have sufficient time for conducting longitudinal studies starting with new fields. Our design will attempt to provide valuable data to assess time and weathering impacts. By studying unused material from recycling centers, and material that has been on the field for at least two years, we will get some insight as to whether the Zhang et al. result of organic chemical decreases is common among outdoor and indoor fields. We will also attempt to characterize particle size for materials collected. We anticipate that we will collect samples from field materials that have a range of ages, and to the extent feasible, we will assess whether there may be trends in chemical content and particle size

distribution with age. This is complicated, however, because additional new tire crumb rubber is often periodically added to fields. We will collect information about field installation dates and information about dates of new material addition to help interpret our results. We expect there to be substantial differences in weathering conditions for outdoor and indoor facilities (due to differences in sunlight and ozone exposure). There may also be differences in weathering conditions on a regional geographic basis. However, it is not clear that our sample sizes will be large enough to support assessments of differences for outdoor fields on a regional basis.

One aspect of exposure that is not considered is that crumb rubber often sticks to clothing due to static charge. Thus, crumb rubber particles would be brought home on clothing where it is laundered, potentially exposing individuals not playing on the fields. The additions of a few questions to the current questionnaire could help assess the scope of this issue.

Response: The take-home aspect of tire crumb rubber from synthetic turf fields has not been well characterized. We have questions in the questionnaire about tire crumb rubber take home frequency, and based on the reviewer's comments we have added questions about where in the home the tire crumb rubber ends up to see if we can distinguish between potentially higher or lower exposed people using this approach. However, we have not been able to develop meaningful questions that would provide objective questionnaire data on the amount of material brought home. If the chemical measurement results in this research provide more information about the relevance of take-home exposures, future studies may be necessary to objectively measure amounts and to assess mitigation measures people can follow to reduce take-home pathways.

I do have a concern about the inclusion of military facilities in the limited number of fields to be sampled. While it is important to protect our military personnel, before including those fields it is important to document that the source of the field and crumb rubber and the maintenance of artificial turf fields at military facilities are the same as that used and followed by community and recreational facilities in the civilian sector. This is necessary for the results to be relevant to (and accepted by) the general population.

Response: We will collect information about the field installation company, but that might not yield information on the tire crumb rubber suppliers. Some of the information developed through outreach communications indicates that there are only a modest number of suppliers of tire crumb rubber used in synthetic fields, and this might suggest that material used on military installations is unlikely to be different than for civilian installations. The exposure characterization research component will not

include people using fields at military installations and will thus reflect exposures at fields used in other settings.

There was a discussion of the human subject concerns relative to avoiding coercion by commanding officers when recruiting military personnel to participate in this study. While what was describe follows human subject guidelines, the practicality of doing so within the structure of the military is a challenge and the efforts required may not be warranted unless there is a major concern that the exposures are particularly high for military personnel so knowledge of potential exposure for that group would be a real benefit to them.

Response: We will not ask military personnel or their families to participate in the exposure characterization portion of the study.

3. **Are the proposed approaches and methods valid and consistent with the current state-of-the-science? Are there other approaches or methods that should be considered? Please explain.**

The approach being taken and methods describe are valid and consistent with the state of the science. The protocols include looking at materials from different sources and examining two different temperatures, 25˚C for typical conditions and 60˚C for maximum temperature for emission considerations, with studies in dynamic chamber to assess emissions. A wide range of metals and chemicals are to be analyzed using ICP-MS, GC-MS and HPLC-MS, which is valid and appropriate. The microbial analysis using 16S ribosomal RNA PCR techniques is appropriate. The microbial analyses, while documenting the presence of specific species, do not indicate the viability of those species. If microbes with potential hazards are found to be present their viability should also be demonstrated. The incorporation of bioaccessibility of metals and SVOCs, rather than total digested levels, is an appropriate approach to estimate the potential risk. Different exaction fluid compositions have been reported in the literature to assess bioaccessibility. The fluids proposed are similar to those used in other studies.

The incorporation of videography in exposure characterization in addition to questionnaires is a state of the science approach. The use of computer interview forms and geo-locating facilities should improve the accuracy of the information being obtained. The evaluation of extant videos is a novel approach if the selection of the videos can be done to assure that they are representative of actual artificial turf field use and IRB human subject consent can be obtained. Standard methods will be used for air and wipe samples for inhalation and dermal exposure characterization. The utility of the silicone wristbands mentioned on page 18 is not developed enough to understand how the chamber experiments will be

extrapolated for facility and personal monitoring, though this only appears to be in a very limited number (≤5) of experiments.

Response: We will include more information on the exploratory nature of the proposed wristband assessment in the protocol. There is interest in how the wristbands might be used in future exposure measurement studies for synthetic field users. As a first step towards determining feasibility, it is important to understand how to measure the relevant chemicals in wristbands and to assess the sorption of chemicals when exposed to tire crumb rubber materials. The exploratory tests are intended to provide the initial assessment and demonstration, which can then inform decisions about using the wristbands in future exposure studies.

4. **Are the proposed target analytes appropriate for characterizing tire crumb rubber material and potential exposures? Are there others that should be considered? Please explain.**

The list of metals includes those likely to be of interest and amenable to ICP-MS analysis. Both total digestion and bioaccessible extracts are to be evaluated. Similarly an extensive list of both VOCs and SVOCs are provided, which include the species previously reported to be in crumb rubber (aromatic VOCs, PAHs, Phthalates, and agents used in rubber processing/additive to tires). Some compounds listed are of general environmental interest though less likely to be from the crumb rubber, such as chlorinated hydrocarbons. Utilization of GC/MS and HPLC/MS are appropriate for both the targeted and exploratory VOC and SVOC analyses. Inclusion of microbial analysis has not been done in as many studies as the chemical analysis and is an interesting addition. The list appears to be complete. The analyses of the biomarker samples will add to the cost, time and effort to the project and as indicated will not be completed prior to the initial time period. If this is the case, it may be possible to select which biomarkers to measure based on what metals, VOCs and SVOCs are identified on different fields so that a more targeted approach can be used to reduce the cost of the analyses.

Response: Regarding the biomarker analysis, we agree with the reviewer. The decision to delay analysis of biological samples is intentional. We believe that the tire crumb rubber characterization and exposure characterization measurements and analyses need to be completed prior to analyzing biological samples. It will be important to apply biological specimen analysis for chemicals that have a high likelihood of demonstrating exposure to tire crumb rubber constituents and not simply reflect exposures to chemicals from other sources in people's lives. At this time, we do not know what the most relevant chemicals might be for the synthetic turf field exposure scenarios. We will first identify relevant chemicals for biomonitoring analysis through the tire crumb rubber and exposure characterization portions of the research. We may identify the need to develop or assess analysis

methods not currently used as part of the routine CDC biomonitoring analysis program prior to analyzing the biological samples.

5. **Will the study design and sampling plan produce data and information that will be useful and defensible? Are there any suggestions or modifications that would strengthen the usability and defensibility of the data? Please explain.**

It is expected that the study plan will produce data and information that are useful within the many constraints provided in the plan that include a limited number of sites and conditions that can be sampled and the time frame that the work needs to be completed within. It will be important to complete the biomarker analyses in a timely fashion. While the focus of the study is on the crumb rubber infill, one of the main exposures of concern from artificial turf fields is exposure to lead which can come from the turf material rather than the infill, particularly if lead based dyes or paints are used to provide different colors. Measuring the heavy metal levels, particularly lead, on composite samples of turf material should be considered to verify that they are at low concentrations. The metals can become released as the turf materials age. This will increase metal exposures to all users of the field through inadvertent ingestion from contact with hands and clothing.

Response: With limited time and resources, the research focus is on assessing recycled crumb rubber material. We do not plan on analyzing the synthetic grass blade material at this time. If blade materials are collected as a byproduct of tire crumb rubber sample collection, the blade material may be stored for possible future analysis.

6. **Has the final use of the data and information been adequately considered in the design and planning of the research? Please explain.**

The data use and analysis has been adequately considered within the design and planning, though as mentioned above more details on risk assessment should be provided. The limitation of the study design and timeline are described in the report.

Response: The results from this research will not directly answer the question about "safe" or "unsafe". It should provide information to better understand the most relevant chemicals, exposures to those chemicals, and toxicity information available for those chemicals. The scope of the current protocol does not include exposure screening or risk screening due to the short timeline for completing the work. Future efforts may be able to apply the results for exposure and risk screening. This research should also provide information needed to design large scale exposure and/or epidemiological assessments should those be warranted.

One issue that should be expanded is the outreach to stakeholders. This project is being undertaken in part due to health concerns expressed by communities for which artificial turf fields have been or are planned to be installed. Forming an advisory board that include members who are trusted by the wide range of groups interested in this issue could serve a forum for obtaining input, feedback and improving risk communication with the various groups. They could help in presenting results and assuring the readability of the language, thereby enhancing the acceptance of reports issued and future findings by the federal agencies relative the safety or hazards of artificial turf fields. This would help communities to make an informed choice when selecting field materials.

Response: We acknowledge that the reviewer has provided a good recommendation for the creation of an advisory board for facilitating research and risk communication. This recommendation will not be addressed as part of the research protocol but will be followed up separately in discussion by the participating organizations.