FINAL REPORT

July 14, 2011

An Evaluation of Potential Exposures to Lead and Other Metals as the Result of Aerosolized Particulate Matter from Artificial Turf Playing Fields

Submitted to:

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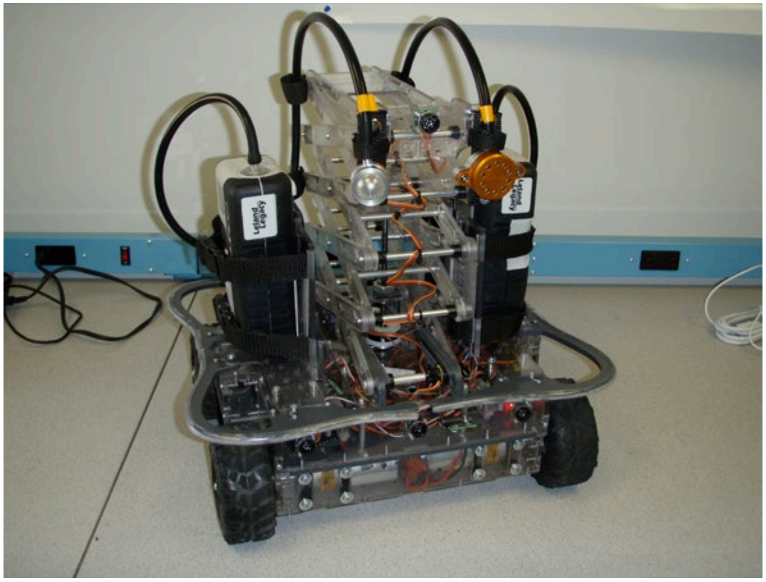
Introduction

In the middle 1960's Monsanto created the first artificial grass, playing surface (Chemgrass) for play areas and athletic fields. Over the years, what later came to be known as AstroTurf and other similar products have become widely accepted and used by communities, schools and stadiums. Recently, controversy has arisen as to the safety of artificial turf playing fields (Claudio, 2008). One particular question of major interest arises with regard to the presence of lead and other metals including chromium, arsenic, and cadmium, which may be present either in the synthetic blades or grass or in the rubber particles used as infill. Since all of these metals are toxic if significant amounts enter the body, the question that needs to be addressed is that while it is known that these metals are present in many of these artificial turf materials, is there a risk of the material entering a person playing on the fields body in such a quantity as to pose a health hazard

The primary routes through which materials such as metals can enter the body are through inhalation, ingestion, and direct trans-dermal absorption. Because of the physical structure of these artificial turf materials and the metals involved, inhalation appears as the most likely candidate as the route of exposure. There is however, a real question as to whether lead or the other metals are present in a form that can result in the formation of respirable or inhalable particulate matter and the more important question is if it is present, is it present at such a level as represent a real health hazard. In order to answer these questions we have conducted a pilot study to assess the potential for exposure to lead, chromium, arsenic and cadmium as a respirable/ inhalable aerosol from playing on artificial turf. The nature of the use of these playing fields is such that the usefulness and representativeness of a static sample is questionable. The reason for this can be appreciated by anyone who has watched athletes run on artificial turf and observed their feet. What can be seen are small black puffs of the material used to provide stabilization to the blades of turf grass, known as infill. While larger particles are visible, smaller potentially respirable particles are also being kicked up from the turf that is not readily apparent. There can be little doubt that with the constant activity inherently present on an artificial turf field during a game, it is likely to result in the suspension and/or resuspension of particulate matter present in the artificial turf. Research has shown that even limited activity on carpeted surfaces can result in multiple orders of magnitude of increases in respirable/inhalable particulate matter (Shalat, et al. 2007, 2011). It is therefore desirable to sample in a non-static fashion for any potential particulate matter that is released from the surface. Unfortunately, it is not really practical to put sampling pumps on athletes during strenuous exercise; however, an alternative is available by using a robotic sampler recently developed at EOHSI.



Methods

The PIPER Mk IV is an autonomous, fullly programmable robotic sampler that has been designed and constructed to have the flexibility to sample both indoor and outdoor locations and can be equipped with a variety of instrumentation. The PIPER Mk IV sampling system consists of the robot and a laptop computer that the operator uses to control the robot. PIPER weighs 10 kg and is 41 cm wide, 35 cm long and 25 cm in height. It can carry up to two personal exposure instruments and can sample room air at any height from 20 to 100 cm using its telescoping tower. PIPER has a central processor on board which controls avoidance maneuvering through the use of active infrared and sonar sensing modules. The processor also receives and executes behavioral programming transmitted via a wireless link from the control program on the laptop. The laptop contains the main PIPER software program and provides the software platform for control of PIPER's operation. The PIPER Mk IV platform can support up to two sampling devices simul-taneously. The devices are attached to PIPER via adjustable nylon webbing, which allow a variety of shapes and sizes of samplers and personal air sampling pumps to be accomodated. A range of size selective particulate and bioaerosol samplers can be accomodated by the use of snap on attachments that can allow quick changes for evaluating different size and types of particle fractions.

The PIPER sampler can be programmed to sample from a designated area. This is accomplished through a data port, which allows PIPER to be connected to a laptop computer in the field. Once programmed PIPER can operate continuously for up to 2.5 hours. It can run at speeds up to 3.7 ft per second, which is approximately 2.5 miles per hour. During the course of operation the sampling head can either be set at a fixed height or programmed to sample at varying heights across its full range of 20 to 100cm.

Environmental Sampling

The New Jersey Department of Environmental Protection provided investigators with a list of contacts for potential fields that had been generated by New Jersey Department of Health and Senior Services to be tested. In addition, it would have been desirable to have fields for artificial turf materials spanning a range of ages since installation - new, 3 to 5 years old, older than 5 years. The goal was to recruit a sample of a total of 12 to 15 fields. This would have provided a detailed picture as to whether any product produces significantly more or less particulate metal exposure than another and whether aging of the product effects the levels of metal particulate. Unfortunately becaues of a variety of circumstances, that will be discussed in more detail below only five fields were actually sampled. The protocol that was carried out for the 5 sampled fields follows.

Stationary samplers were located on the midfield, sideline of each field. Simultaneous sampling was carried out with stationary and PIPER samplers. Initial sampling was carried out for the wipe sample of each field followed by the air sampling. Wipe samples were taken by means of a polyester filter pad fixed (See Figure – Right) to the bottom of PIPER. The size of the wipe area of the pad was 14 cm x 14 cm. In the case of field 1 PIPER was driven along a 100 yd length of the field and all subsequent fields across 50 yd length.

Air sampling was carried out with the PIPER Mk IV, at a height of 22cm. PIPER was programmed to run in a rectangular patterns across the central part of the field, since the middle of most playing fields often receives the greatest wear. This sampling consisted of one 30 minute sampling period with a direct particle reading instrument, followed by a 120 minute sampling by filter using a Leland Legacy Pump and an SKC 100 µm (inhalable particles) at 10 L/min. Additionally, a 12 year old boy was recruited to simultaneously collect a personal breathing zone sample. The boy was allowed to carry out his activity on one end of the field while PIPER sampled at the other end. The boy was instructed to jog, run and dribble and kick a soccer ball as if he were in soccer practice. The duration of testing with the player was for one hour with a 5 minute break half way through the testing for a water break.

Metals Analysis

The samples were digested using a microwave sample digester CEM Mars 2000. The samples were digested in concentrated nitric acid and diluted to a final acid concentration of approximately 5%. Filter samples were analyzed by inductively coupled plasma mass spectrometry on a Thermo-elemental X5 instrument. All the standard solutions were prepared in 5% HNO_3. The sample masses were scanned for key analytes including As, Cd, Cr and Pb as specified by NJ DEP. A detailed description of the sample collection and analysis is provided in the attached QAPP (Appendix 1). The results of the metals analysis are attached in Appendix 2.

Results

In 2009 we were provided with a list of 7 schools and town recreational field locations with artificial turf fields. These locations had self-identified as having artificial turf fields and were concerned about possible health risks. Of these 7 fields, 2 fields consented to be tested. We made approximately 10 further contacts and were able to sample 2 additional recreation fields during 2009. In Spring 2010 we contacted an additional 23 superintendents in Middlesex County and 17 in Somerset County. Contacts consisted of written correspondence, followed up by at least one telephone call. As a result, one additional field was recruited. Thus, out of almost fifty potential fields, only 5 schools consented to have their fields tested. For more than half the contacts there was no response to the written contacts, nor response to repeated voice mail messages. There were three primary reasons for those who we were able to make contact with declining to participate in this project. The most common reason for not participating was the concern that if anything was uncovered it could lead to potential litigation. The next most common concern was that it might lead to the need to replace the field. The last reason, only cited by one community, was concern that testing the field could void the warranty from the manufacturer.

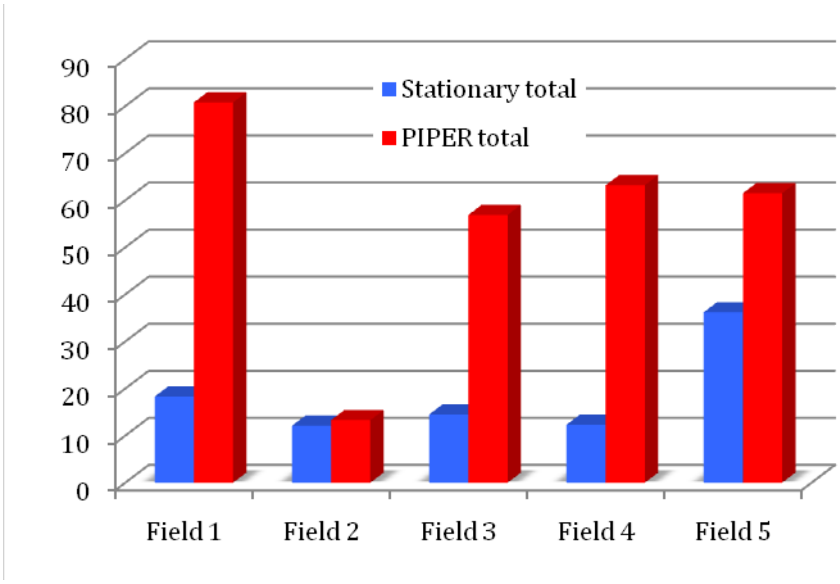
There were five fields that were tested and detailed characteristics are presented in Table 1. The complete results of the metals analysis are available in Appendix 1. Temperatures were measured at air sampling height above turf. With the exception of field 1 all were relatively new fields.

Table 1: Characteristics of sampled artificial turf fields.

Field	**Age of Field (yrs)**	**Season**	**Temperature $^{\circ}$F**	**Rel. Humidity**	**Wipe Samples Pb (ng/ft^2)**
1	8	Summer	88.5	43%	10,330
2	1	Summer	81.3	61%	20
3	3	Summer	80.2	64%	100
4	3	Summer	80.4	68%	100
5	3	Summer	104.5	43%	20

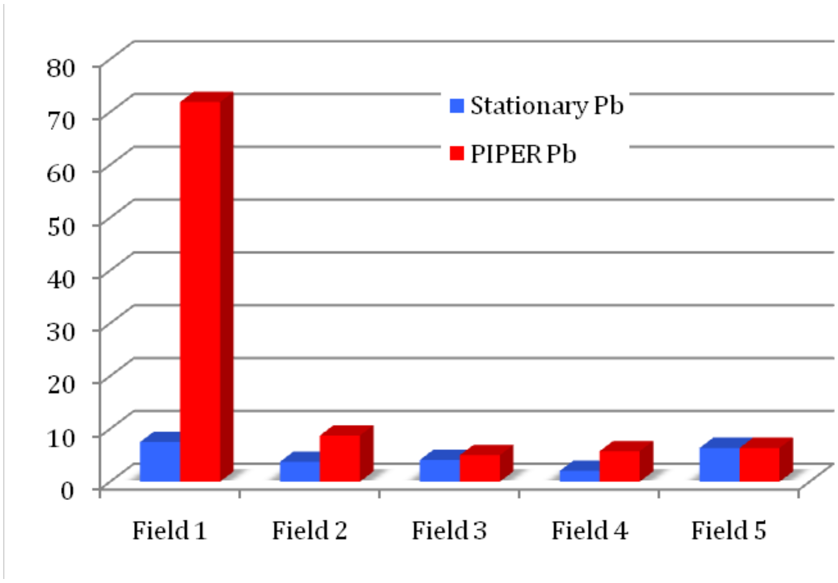
Mean sampling duration was 115 minutes for both stationary and PIPER samples. The mean level of inhalable particulate (PM_{100}) from stationary measurements ranged from 12.3 - 36.2 $\mu g/m^3$. For PIPER samples the mean particulate level was 13.3 – 80.3 $\mu g/m^3$ for the latter. A comparison of the observed measurements: for inhalable particulate (PM_{100}), are presented for each of the five fields in Figure 1.

Figure 1: Comparison of total inhalable particulate as sampled by stationary versus PIPER sampling (µg/m3).



All air samples were subsequently analyzed for the presence of metals. Among the metals with known human toxicity that were observed to be present in air samples above the limit-of-detection (LOD) were arsenic, cadmium, chromium, and lead. A complete listing of the results of the metals analysis of air sampling is presented in Appendix 2.

Figure 2: Comparison of total inhalable lead particulate as sampled by stationary versus PIPER sampling (ng/m^3).



In addition to the stationary and PIPER sampling, we were able to carry out personal sampling on a 12 year-old child while he carried out activities that would normally occur during soccer practice on a turf field. This was carried out only on Field 4. A comparison of the measurements for total inhalable PM for stationary, PIPER and personal sampling are presented in Figure 3. A similar comparison is presented in Figure 4 for measurements of inhalable lead particulate. The child was a 12 year old boy, 152.5 cm in height and who weighed 43 kg.

Figure 3: Comparison of PM_{100} measurements from stationary, PIPER and child soccer player ($\mu g/m^3$).

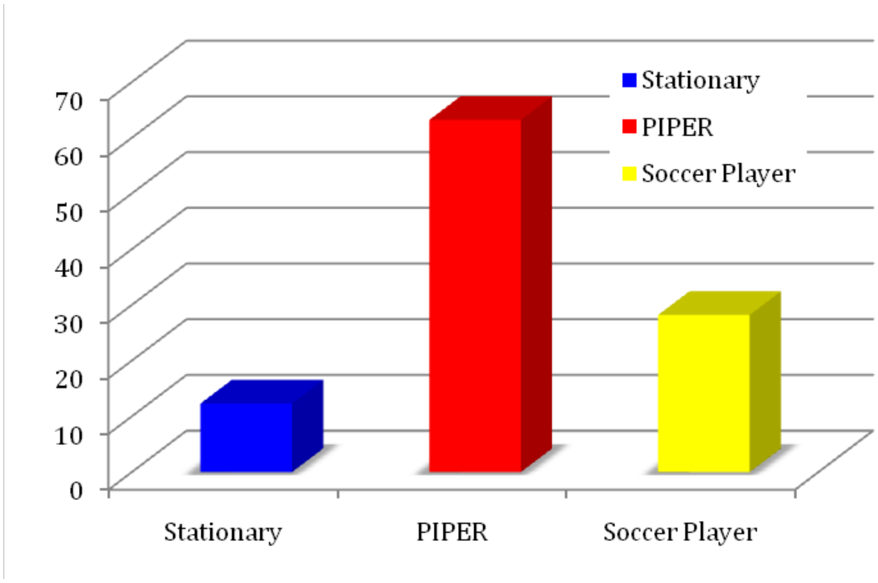
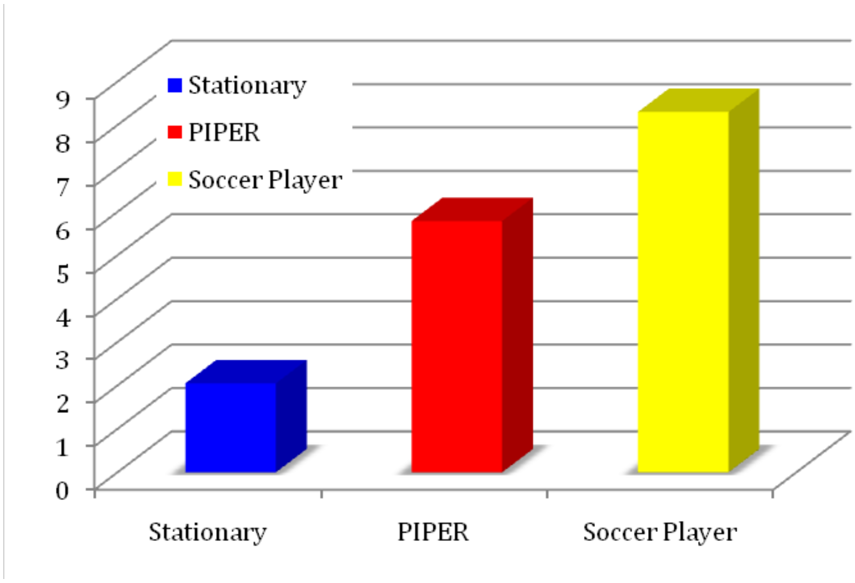


Figure 4: Comparison of Pb levels in inhalable particulate matter on Field 4 (ng/m^3).



Discussion

The findings of this study, although limited in scope, raise some concerns with regard to potential hazards that may exist for individuals and in particular children who engage in sports activities on artificial turf fields. In fact, only one of the 5 fields tested had elevated levels of lead observable in surface wipes - Field 1 at 10.33 $\mu g/ft^2$, while all other fields were at or below 0.1 $\mu g/ft^2$. For air samples, as can be seen from examining Figure 1, *Pb* samples that are collected using PIPER are higher than stationary sampling. In fact the mean ratio of PM as measured on the PIPER sampler relative to general area stationary sampling on the five turf fields is 2.8 (linearized S.E. 0.72), with a range of 1.1 to 5.2. While the relative humidity did not appear to be a major factor, the presence of dew that was observed at the start of sampling on field 2 is likely to be a factor in the absence of elevated levels being observed relative to stationary sampling on that field. This finding suggests that *Pb* present in artificial turf fields can be resuspended by even minimal activity on the playing surface.

The most important issue is the magnitude of the increase in inhalable lead-containing PM that could occur during a game on an artificial turf field with lead contaminants. The highest observed air level was observed on the PIPER sample collected on Field 1 - 71.9 ng/m^3 on a field with PIPER wipes of 10.33 $\mu g/ft^2$. This air level approaches approximately half of the U.S.E.P.A., NAAQS of 150 ng/m^3. The NAAQS is intended to be assessed as a 3 month rolling average. Detailed information on the NAAQS can be found at http://www.epa.gov/ttn/naaqs/standards/pb/s_pb_index.html. It should also be noted that these air levels were observed when the turf wipe sample is approximately one fourth of the indoor floor lead dust sample corresponding to the HUD standard for lead in house dust - 40 $\mu g/ft^2$ (http://portal.hud.gov/hudportal/documents/huddoc?id=DOC_25495.pdf) . Another factor that is directly pertinent is that when side by side testing was carried out on a low lead field with PIPER and a 12 year old boy, the lead samples from PIPER of 5.8 ng/m^3 more closely approximated the personal sample of 8.2 ng/m^3 than the general area sample of 2.1 ng/m^3. The higher ratio of Pb as compared to PM from PIPER relative to stationary sampling suggests that the size of the lead containing particles on this particular field made them more easily resuspendable than inhalable particles in general.

The findings show that both inhalable PM, as well as inhalable lead (when present) are resuspended from even minor physical activity on an artificial surface. These data therefore indicates that human exposure from lead-containing artificial turf fields is not just limited to dermal, but also to inhalation route of exposure. What is not yet clear is the magnitude of the potential contribution the inhalation route of exposure may contribute.

PIPER was designed primarily to assess individual exposures of young children in an indoor environment and so there was never an expectation of it being capable of reproducing the level of exposures experienced by players engaging in sports on an artificial turf field. What PIPER can do, is suggest the existence of a potential problem even outdoors to exposures from resuspended particles. The questions raised by the limited testing with PIPER suggest several aspects of artificial turf products that requires follow on studies. First, how extensive is the continued use of lead containing fields that remain in recreational use? Given that the field with the elevated level was 8 years old in 2009 when it was tested, how many of these older fields exist? Second, what is the source of the lead particulate matter that was observed? The three potential avenues for lead to exist as an original constituent of artificial turf are in the blades of artificial grass, the pigment used for the lines and markings on the fields, or in the infill material placed on the field. The latter may be the most difficult to pinpoint as a number of materials are utilized for infill consisting of either new of used materials, such as recycled tires. The material may also not be uniform across an entire field as additional material may be added to only one part of the field as it ages, resulting in a patch-quilt of surface materials.

Artificial turf fields are an extremely popular option for communities looking to both decrease maintenance costs and at the same time provide a playing surface that can accommodate a broad range of sports activities and remain intact, something the can be problematic in the northeast U.S. The proliferation of outdoor sports teams including, but not limited to football, soccer, lacrosse, baseball, and field hockey have made these turf fields very popular in New Jersey both for school districts and town recreational departments. However, little data are available about the existence of potential health hazards that may exist on these fields from lead and other chemical constituents of these fields. While the Pb concentration in air observed on the one high level field from disturbance by a 10 kg robot was approximately half the EPA ambient air quality standard of 150 ng/m^3 (Note, however, that the EPA standard is applied as a rolling 3-month average and does not, strictly speaking, apply to a single 1-day sample), the question remains how high could levels reach when two teams of players are actively engaged in a sporting event on such a field. Further what levels of materials can be inhaled by football players who even in high school can weigh over 100 kg? Add the fact that 22 players are on the field at one time in both football and soccer and it is highly likely that a significant particulate cloud can be created on the field and may persist in light wind conditions and certainly on indoor fields for significant portions of the game.

For the present time, how widespread the presence of these high lead level fields is, is an unknown. At present the economic disincentive for schools or communities to measure the presence or absence of lead contamination appears to exceed any public concern for children's safety. This was clear in that less than 10% of those individuals in decision-making positions authorized testing of artificial turf fields, whom we contacted, agreed to this free testing of their fields. Absent a legislative mandate, it seems highly unlikely that any significant proportion of existing fields will be evaluated. If the fields could be induced to cooperate, a strategy to test the fields and obtain meaningful measurements would require personal sampling on the field during a game or practice. Given the level of contact in all of these sports, putting sampling equipment on players is not an attractive option. What may be an adequate approach to estimate their exposure is to place sampling equipment on officials who are on the field during the game. This would be likely to provide a better approximation of determining if an inhalation hazard exists.

Conclusions

There is no suggestion that the use of artificial turf fields has diminished due to the controversy that has been raised about lead being present in these fields. Data from the Synthetic Turf Council indicated that between 2006 and 2009 sales of turf fields in the U.S. increased by 20% (http://www.syntheticturfcouncil.org/displaycommon.cfm?an=3). They also reported that from 2003 to 2009 the number of fields installed had increased from 400 to over 1,000.

While it is not possible to draw broad conclusions from this limited sample of fields the results suggest that there is a potential for inhalable lead to be present on turf fields that have significant amounts of lead present as detectable by surface wipes. It also would appear likely from this sample that if the lead is present to any appreciable extent in the wipes it will likely be present in the breathing zone of players who are active on these fields, and that furthermore, these levels potentially exceed ambient EPA standards. Given that these are only occasional exposures this tends to reduce the risk of adverse health effects. However given that children are particulate at risk for adverse developmental effects of lead, only a comprehensive mandated testing of fields can provide assurance that no health hazard on these fields exists from lead or other metals used in their construction and maintenance.

References

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APPENDIX 1

QUALITY ASSURANCE PROJECT PLAN

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I. SELECTION OF FIELDS

II. COLLECTION OF AIR SAMPLES

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I. SELECTION OF FIELDS

Introduction

Recently, controversy has arisen as to the safety of artificial turf playing fields (Claudio, 2008). One particular question of major interest arises with regard to the presence of lead and other metals including arsenic and cadmium, which may be present either in the synthetic blades or grass or in the rubber particles used as infill. Since all of these metals are toxic if significant amounts enter the body, the question that needs to be addressed is that while it is known that these metals are present in many of these artificial turf materials, is there a risk of the material entering a person playing on the fields body in such a quantity as to pose a health hazard?

The primary routes by which materials such as metals can enter the body are through inhalation, ingestion and direct trans-dermal absorption. Because of the physical structure of these artificial turf materials and the metals involved inhalation appears as the most likely candidate as a route of exposure. There is however, a real question as to whether lead or the other metals are present in a form that can result in the formation of respirable or inhalable particulate matter and the more important question is if it is present is it present at such a level as represent a real health hazard. In order to answer these questions we are proposing a pilot study to assess the potential for exposure to lead, arsenic and cadmium as a respirable/inhalable aerosol from playing on artificial turf.

The nature of the use of these playing fields is such that the usefulness and representativeness of a static sample is questionable. There can be little doubt that with the constant activity is likely to result in the suspension and re-suspension of particulate matter present on the artificial turf. Research has shown that even limited activity on carpeted surfaces can result in multiple orders of magnitude of increases in respirable/inhalable particulate matter (Shalat, et al. 2007). It is therefore desirable to sample in a non-static fashion for any potential particulate matter that is released from the surface. Unfortunately, it is not really practical to put sampling pumps on athletes during strenuous exercise; however, an alternative is available by using a robotic sampler recently developed at EOHSI.

Objective

In the study, 12 to 15 artificial turf fields in New Jersey will be sampled using the robotic sampler. Since age may affect the abundance and dislodgeability of particles from the field, at least five fields greater than five years old will be included in the study. Data on age of field, turf type, and manufacturer will be collected on all the fields sampled.

Selection Process

The fields will be selected in consultation with the DEP Project Officer. Several municipalities and school boards have been in contact with DEP, asking for guidance on the use of their athletic fields. Data from these requests, including results of surface wipe testing, will help guide the selection process.

If additional fields are needed, a survey will be made of possible field owners in surrounding counties (Middlesex, Somerset, and Morris). School boards and municipalities will be mailed a letter explaining the study. The letter will provide two methods of response. First, the letter will contain contact information so that interested field owners can phone, mail, or email the study coordinator. Second, the letter will contain a reply postcard. The post card asks for preliminary information about the owner (municipality, department, and contact name), the number of artificial turf fields, and the number of artificial turf fields over five years of age. If the post cards are returned, this will provide some preliminary data on the scope of the artificial turf issue.

Fields will be selected from the responses to the mailing in consultation with the DEP Project Manager.

Study Letter to Potential Field Owners

Dear:

Recently, controversy has arisen about the safety of artificial turf playing fields. Just this past year, the New Jersey Department of Health and Senior Services found that 2 of the 12 artificial turf fields they tested had very high levels of lead (over 400 parts per million). This past summer, the Consumer Product Safety Commission released a report saying that fields were thought to be safe but acknowledged that small particles of lead-containing fibers may be released. As public concern grows, municipalities and boards of education face difficult decisions about the testing, use and/or replacement of their athletic fields.

Standard testing of the fields usually involves wipe sample collection. In addition to dust from the turf, varying numbers of turf fragments are dislodged in the process and may be included in sample analysis. This often leads to inconsistent results for the same field. The wipe sample also does not address the issue of possible inhalation exposure. As children run and play on the fields, small particles can be dislodged from the turf and enter the children's breathing zones.

To gain a better understanding of the potential health risks, investigators at the Environmental and Occupational Health Sciences Institute (a joint institute of Rutgers and UMDNJ) are conducting a study of artificial turf playing fields in NJ. This study, funded by the NJ Department of Environmental Protection, will use an innovative air sampler to measure the air concentrations of lead and other contaminants generated on the turf field. The PIPER (Pre-toddler Inhalable Particulate Environmental Robotic) sampler, is a mobile air monitoring system. The prototype has been used to sample for exposure to red tide toxins (see enclosed article). The robot is equipped with large, grooved tires that disturb the surface of the turf, generating particles. This mimics the disturbance caused by a child running across the field. The inlets for the air sampler are placed at a height corresponding to a small child's breathing zone. PIPER gives the best estimate of children's air exposures during play on the athletic field.

The study is beginning in August 2008. We will collect air samples from 12 to 15 artificial turf fields in NJ. The air sampling will take place on one day, over a 4-hour period. There is no cost to participation. The individual results are confidential; they will be reported only to the owners of the field and relevant New Jersey State Agencies. Published results will not identify individual fields by name or specific location.

We are asking for your help in assessing the needs of the communities in your area. We would like a representative in each community to complete and return the enclosed post card. If you are interested in participating in the study, please be sure to include a contact name and phone number. You may also call (732-235-3914) or email (blackka@umdnj.edu) our study coordinator, Dr. Kathy Black, for more information about the study.

Response Post Card

Artificial Turf Survey

Town_______________________

Department________________________

How many outdoor artificial turf fields are located in your town? ________

How many of these fields are more than 5 years old? _______

If you are interested in participating in our study, please fill in a contact name and phone number:

Name: ____

Phone: ____

II. COLLECTION OF AIR SAMPLES

Introduction

Wipe sampling of artificial turf fields has demonstrated the potential for lead exposure (http://www.state.nj.us/cgi-bin/dhss/njnewsline/view_article.pl?id=3174). A recent evaluation by the U.S. Consumer Product Safety Commission found that indirect ingestion, considered to be the most likely route of exposure, does not pose a risk to young children playing on the field (http://www.cpsc.gov/CPSCPUB/PREREL/prhtml08/08348.html). However, until recently, the inhalation of dislodged particles could not be accurately measured and assessed. Indoor experiments with a newly developed robotic sampler (PIPER: Pre-Toddler Inhalable Particulate Environmental Robot) demonstrated an increase, over static monitoring, in particle concentration in children's breathing zones during contact with carpeting (Shalat et al., 2007). PIPER has been designed to estimate children's exposure to inhalable particulates during play. The advantages of the robotic sampler over the use of a static sampler are its ability to dislodge particles through contact and its ability to change sampling height to represent the changing breathing zones experienced by a child during play.

Objective

Initially, on each field, two thirty-minute measurements of particle concentration will be taken using a nephelometer (Thermo Scientific MIE pDR-1500). The first measurement will collected at a height of 20 cm (worst-case; with the child lying on the ground) and the second measurement will be collected at a height of 80 cm (the breathing zone of a young child running). After the two particle concentration measurements are taken, a 120-minute sample of the inhalable particles will be collected on a PTFE filter in a PM_{10} (SKC Personal Environmental Monitor) sampler using a Leland Legacy pump. This sample will be analyzed to measure the concentration of lead and other metals in inhalable particulates.

Air Sampling Procedure

Materials

- Sample collection form
- Field notebook
- Sample collection sheet
- Nephelometer (Thermo Scientific MIE pDR-1500)
- IOM Sampler

- Leland Legacy Air Sampling Pump (calibrated within 5% of 10 ℓpm in laboratory with test filter).
- PEM Sampling Head
- Pre-weighed 37-mm PTFE in Petri dish with Air Sample Chain of Custody Form
- TSI thermal mass flowmeter
- Sample label
- Tygon Tubing
- Cooler with blue ice
- Kimwipes and alcohol swab
- Teflon-coated or plastic forceps
- Gloves (non-powdered)
- Bench paper (precut to approximately 18 x 18 inches)
- PIPER
- Laptop

Sample Collection

1. Prior to embarking for the sampling, supplies will be checked against the above checklist.
2. All filters will be pre-weighed and labeled according to the SOP for Filter Weighing (attached). Data on the filter weighing will be recorded on the Filter Pre-Sample Weighing Data Sheet and stored in the Sample Log. The Sample Log will be stored in Room 342.
3. All sample data will be recorded on the Sample Collection Form.
4. An Air Sample Chain of Custody Form will accompany each filter brought to the field; the form will be completed as appropriate (detailing sample collection and transport) in the field.
5. Set up PIPER in field. Download program for mobile sampling at 20 cm height.
6. Program nephelometer to sample continuously for 30 minutes.
7. Place nephelometer on PIPER using an IOM sampler (no filter) as the inlet
8. Run PIPER for 30 minutes, recording start and stop times on sample collection form.
9. At the end of sampling, download program for 80 cm height sampling. Reset nephelometer to sample continuously for 30 minutes.
10. Run PIPER for 30 minutes, recording start and stop times on sample collection form.
11. At the end of sampling, remove nephelometer.
12. Download appropriate program for 120 minutes of continuous mobile sampling with varying heights.
13. Place Leland Legacy pump into holder on PIPER.
14. Place bench paper on a flat surface. Using gloves and forceps, load PTFE filter into PEM sampling head.

15. Secure PEM sampling head to inlet arm of PIPER and connect to sampling pump.
16. Take three measurements of flow rate at the sampling using TSI thermal mass flow meter. Flow must be within 5% of 10 ℓpm.
17. Start sampling by turning on pump then activating PIPER.
18. Record the data on sample collection and chain of custody forms.
19. After 2 hours, turn off PIPER and turn off pump.
20. Take three measurements of the flow rate using TSI electronic flow meter.
21. Remove the PEM sampling head from the sampling train.
22. Place bench paper on a flat surface. Being careful not to tear the filter, use forceps to remove the PTFE filter from the sampling head. Visually inspect the filter and note the condition (torn, visible mass). Place filter into labeled Petri dish.
23. Place Petri dish into cooler with blue ice for transport to EOHSI.

Storage

1. At EOHSI, air sample filters will be placed in the weighing room for equilibration. The Air Sample Chain of Custody Form will be completed and placed with each sample.
2. Open the Petri dish to allow filter to equilibrate. Also open Petri dish of control filters. Record the date, time and initials of beginning the equilibration on the Filter Post-Sample Weighing Data Sheet..
3. After 48 hours, weigh the filter(s). Record filter weight on the Filter Post-Sample Weighing Data Sheet. This data sheet will be stored in the Sample Log in Room 342. Complete the Air Sample Chain of Custody form.
4. After weighing, the filters will be given to the laboratory analyst who will sign and date the Air Sample Chain of Custody Form. The form will remain with the samples until analysis. Afterward, the form will be returned to the principal investigator. All completed forms will be kept in a file in Room 342.

QA/QC Procedures

Sample Code

Each filter (sample, field blank, lab blank) will receive a unique numerical code when placed in the Petri dish (ATPF##). This filter ID will be used to follow the filter from pre-weighing to analysis. An Air Sample Chain of Custody Form will accompany each filter through weighing, sample collection, storage, and analysis.

Each field will be provided with a unique identification number, unrelated to the field location, to enable blind analysis of the samples. Electronic files of particle concentration collected using the nephelometer will be downloaded on the laboratory computer and coded with the field id, date, and sampling height. Immediately after downloading, an electronic copy of the data files will be transmitted to Dr. Shalat's computer. All computers used in the study are pass-word protected and stored in locked offices.

During weighing and analysis, the filter ID will be checked to match the ID on sample collection form and sample receipt log. All forms (Weighing Data Sheets, Sample Collection, completed Air Sample Custody Forms) will be stored in the Sample Log in the PIPER laboratory, Room 342. The laboratory has limited access.

Sample Custody

The field sample team will have custody of the sample from pre-weighing through sample collection and post-weighing. Afterward, the custody of the sample will be transferred, by the sample receipt log, to the laboratory analyst.

After the filters are pre-weighed, they will be stored in the PIPER laboratory. The filters, in the closed Petri dishes will be transported to the field in a sealed Ziploc bag. An Air Sample Chain of Custody Form will accompany each filter. In the field, the filters will be labeled with the date. After sampling, the filters will be removed from the sampling train and stored in the same Petri dish for transport to the laboratory. At the laboratory, the filters will be placed in the weighing room for two days for equilibration before weighing. After weighing, the filters will be placed in a cold room until analysis. The field sample team will use the Air Sample Chain of Custody Form to document and maintain custody until the air sample filters are weighed. Custody will then transfer to the laboratory analyst. The laboratory analyst will then sign the Air Sample Chain of Custody Form and document the analysis. After analysis, the laboratory analyst will give the completed Air Sample Chain of Custody Form to the principal investigator.

Quality Control Samples

Nephelometer

The pDR-1500 nephelometer is factory calibrated with SAE fine test dust (calibration date for #0813630559: 7/21/08; calibration date for #0810929178: 07/22/08) and will be zeroed prior to each days sampling. Factory recalibration for the instruments is recommended every two years. Records of calibration are kept in the instrumentation documentation stored in Room 342.

Filter Blanks

All filters used in the study will be placed individually in Petri dishes and labeled sequentially (ATPF##). Once labeled, an Air Sample Chain of Custody Form will be started for each filter. The chain of custody form will accompany each filter to the weighing room, field, and to the laboratory. Field personnel will complete the form then transfer custody of each sample to the laboratory analyst using the form. Once the sample is analyzed, the completed form will be returned to the principal investigator and stored in Room 342 in EOHSI.

Three labeled filters will be selected over the course of the study to be laboratory blank filters. They will be analyzed for all metals over the course of the sampling. The laboratory blanks will not be weighed but will be dated so to be indistinguishable from the samples. They will then be transferred to the laboratory analyst directly, using the Air Sample Chain of Custody Form.

Three field blank filters will be collected over the course of the sampling. The pre-weighed filters will be stored in Petri dishes, transported to the field with the sample filter, placed in the PEM sampler prior to sampling then immediately removed and placed back into the Petri dish. The field blanks will be labeled with the date, to be indistinguishable from the samples. The Petri dish will be stored in a cooler with blue ice and, after sampling, be transported back to the laboratory with the sample filter. The filters will be stored in the weighing room to equilibrate for a minimum of 48 hours. After weighing, the filters will be transferred to the laboratory analyst using the Air Sample Chain of Custody Form.

Aerosolized Particulate Matter from Artificial Turf Playing Fields

Sample Collection Form **Initials____________**

Location: Field ID#____________ **Date:_________________**

Field Name ____

Municipality/County____

Sample Conditions

Temp: ________RH:_________ Wind speed/direction:_______________

pDR Measurements			
Height	Start	Stop	Comments
20 cm			
80 cm			

Mass Collection Filter ID#__________	Start	Stop
Time		
Flow rate 1		
Flow rate 2		
Flow rate 3		

Field Blank Collected: Yes ID_______ No

Action	Filter (s) ID	Date	Initials
Filter(s) Transported to EOHSI			
Filters Stored in Weighing Room			
pDR data downloaded	▨		

Aerosolized Particulate Matter from Artificial Turf Playing Fields

Air Sample Chain of Custody Form

I. Sample ID #: ________________

II. Filter Weighing:

By: _______________ Date:_________________

III. Sampling

Collected by:_____________________ Date:_________________

Transported by;______________________ Date:_________________

Placed in Weighing Room by:__________Date:_________________

Post-Weighing by:____________________ Date:_________________

IV. Laboratory Analysis

Received by:__________________ Date:_________________

Analyzed by:_______________________ Date:_________________

STANDARD OPERATING PROCEDURE OF FILTER WEIGHING

A. Controlled Environment Requirements

1. Mean temperature: 20-23 degrees Celsius
2. Mean humidity: 30-40% RH
   Note: Operating at lower humidity (less than 20%) is likely to increase issues related to static charges.

B. Filter Equilibration and Weighing Requirements

1. All weighing data (weights, temperature, and relative humidity) will be recorded on a Filter Pre-/Post-Sample Weighing Data Sheet. A data sheet will accompany filters when they are placed in the weighing room. After the filters are weighed, the Filter Weighing Data Sheet will be placed in the Filter Weighing Log. The log will be kept in the laboratory (Room 342).
2. All filters will be equilibrated for at least 48 hours before weighing. The date and time filters are placed in the weighing room will be recorded on the Filter Weighing Data Sheet.
3. Filters will be handled with stainless-steel forceps.
4. During the equilibration period, the filters will be stored individually in partially-opened Petri dishes. The partial opening will allow air flow but minimize dust intrusion.
5. All Petri dishes will be labeled (top and bottom) prior to filter placement. Labels will include a unique filter ID number (ATPF##) and a batch number.
6. The temperature and relative humidity will be recorded each time a filter is weighed. Temperature measurements in the weighing room should be maintained ca. ±1 degrees Celsius between pre- and post- weighing, and reliable relative humidity measurements should be ca. ±2% RH.
7. Both pre- and post-sampling weighing should be carried out on the same balance, preferably by the same analyst.
8. In order to remove static electricity from filters, direct exposure to Polonium 210 strips is recommended.
   Note: These strips should be replaced according to the manufacturer's instructions, usually within 1 year from date of manufacture.
9. After each filter is placed on the balance, the reading will be taken after a sufficient time (ca. 1 -2 minutes) has passed for the balance to indicate the final weight.
10. For each standard and filter, the weight, temperature and relative humidity will be recorded on the Filter Pre/Post-Sample Weighing Data Sheet.

C. Filter Types

1. Control Filters: Three control filters, taken from the same batch as sample filters, will be weighed each time sample filters are weighed. The control filters will be equilibrated during the same period as the sample filters. After weighing, control filters will be stored in closed Petri dishes in the weighing room until the next equilibration period. The control filters will be labeled by study, control number (ATPF-C#) and batch number.
2. Sample Filters for pre-weighing: Clean sample filters will be visually inspected before being placed in a labeled Petri dish. The labels will include a filter ID (ATPF##) and batch number. Any damaged filters (or filters damaged during the weighing process) will be discarded. After weighing, the sample filters will be placed in the same Petri dish, the dish will be closed, and the filters will be stored in the laboratory (Room 342) until use. Field samplers will sign and date the use of the sample in the field.
3. Sample Filters for post-weighing: Filters used for sample collection will be visually inspected before weighing; any unusual appearance will be noted on the Filter Post-Sample Weighing Data Sheet. After weighing, the sample filter will be placed in the same labeled Petri dish, the dish will be closed. Custody of the samples will then be transferred to the laboratory analyst by the sample receipt log.

D. Filter Weighing

1. Check the calibration of the scale using 200.00 mg and 50.000 mg standard weights. Place each standard weight in the middle of the scale and apply the lock. Once the circle disappears from the scale's screen, record the weight if within scale's precision (0.003 mg). Record the weights, temperature and relative humidity on the Filter Weighing Data Sheet. If the weight is off, the scale should be re-zeroed and the standard weights should be measured again.
2. Once the needed accuracy is achieved, measure your three control filters. Record the weights, temperature, and relative humidity on the data sheet. In order to minimize dust intrusion, close the Petri dish for each control filter after weighing.
3. Measure the weight of the sample filters. Record the weights, temperature, and relative humidity on the data sheet.
4. Check the mass of the control filters every 10 measurements of the test filters or, if weighing less than 10 sample filters, at the end of the weighing session. Control filters should not experience a weight change of more than 10μg over a period of 24 hours.

Filter Pre-Sample Weighing Data Sheet

Filters placed in weighing room: Initials:_______

Date: _________________ Time: ________

Temp (^{o}C):_________ RH (%)_______

Filters weighed: Initials:_______

Date: _________________ Start time: ________ Stop time: ______

Filter ID	**Temp (^{o}C)**	**RH (%)**	**Weight (mg)**
Std 200 mg			
Std 50 mg			
ATPF-C1			
ATPF-C2			
ATPF-C3			

Filter Post-Sample Weighing Data Sheet

Filters placed in weighing room: Initials:_______

Date: _________________ Time: ________

Temp (^oC):_________ RH (%)_______

Filters weighed: Initials:_______

Date: _________________ Start time: ________ Stop time: ______

Filter ID	Temp (^oC)	RH (%)	Weight (mg)	Comment
Std 200 mg				
Std 50 mg				
ATPF-C1				
ATPF-C2				
ATPF-C3				

III. SAMPLE ANALYSIS

Introduction

Lead is one of the six air quality criteria pollutants. The current standard for lead was recently revised to 0.15 $\mu g/m^3$ (not to exceed in a three month average) measured in total suspended particles (TSP). Sources of lead include metals processing smelters, industrial, commercial and institutional boilers, waste incinerators, glass and cement manufacturing.

Objective

The objective is to measure the mass of lead and other metals on the air filter.

Data Usage

The data will be used to assess the possible increase in health risk from playing on artificial turf fields and determine a level of concern. The results can be used to provide guidance to turf field managers about the safety of their artificial turf fields.

Analytical Procedures

For total metals quantitation, filters will be extracted by the use of a microwave sample digestor CEM Mars X. The samples will be digested in concentrated nitric acid and diluted to a final acid concentration of approximately 5%. 2.5 ml Omni grade nitric acid will be added to the filters in a 150 ml Teflon digestion vessel. The filters will be digested in the closed pressure vessels as follows: 300 W, 100% power, 20 min ramp to 300psi with temperature limit 200C, 10 min hold time.

For metals analysis, the extract samples will be analyzed by inductively coupled plasma mass spectrometry on a Thermo-elemental X5 instrument. All the standard solutions will be prepared in 5% HNO_3. The sample masses will be scanned from Li through Uranium for semi-quantitative analysis. Although Pb is the primary element of interest, a suite of 25 elements including Cu, Pb, Sn, Cd, Cr Mn, will all be quantified during the analysis process. This will allow for concentrations of key elements to be measured and other elements found in high concentrations to be identified.

After digestion, the vessels will be stored in the cold room until they are cool. The digest will be quantitatively transferred from the pressure vessel to a 50 ml conical tube and diluted to 45 ml using DI water. The tubes will be centrifuged for about 20 min. on speed ‘8”. The supernatant will be decanted into three 15 ml centrifuge tubes and centrifuged for 30 min. on ‘max” speed. When the samples are free of particles they are ready to be analyzed by ICPMS. The three tubes are decanted back into a 50 ml conical tube and diluted to 50 ml. The detection limit for the method is dependent upon the amount of material collected onto the filter.

Where appropriate, an average of multiple isotopes will be used to quantify each element. All of the necessary QA/QC protocols will be maintained throughout the extraction and analysis process (Zhang JJ., et al., 2008).

Data Quality Requirements

The limit of quantitation (the lowest concentration of the metal that can be reliably measured during routine laboratory operating conditions.) for all metals will be calculated by applying the lowest concentration of the standard used in the generation of the calibration curve, to the final sample volume created by preparation of the sample. The resultant mass will be used to estimate the lowest detectable concentration of the metal analyte in the solid sample. . The minimum solution concentration that can be detected is 0.1 ng metal/ml which for a 50 ml sample means a mass of 5 ng of metal. Assuming a mass of 10 mg collected that means a final MDl of 5ng/10 mg = 5ug /10 g = 0.5 ppm. Detection limits will generally be higher based on the sensitivity of the metal tested and the mass of the particles collected on the filter. Blank subtraction will be used when a field blank and or laboratory blank produces a final analyte solution concentration greater than the lowest standard used to create the calibration curve. A below detection limit (the lowest concentration that can be reliably reported when the analyte is greater than 0) value will be reported when the blank concentration is greater than 0.5 of the analyte concentration found in the sample. If the any analyte blank is measured above 5 ppb the blanks and samples will be rerun. If they remain consistently high, acceptable protocols will be created by discussions between the QA officer and principal investigator.

Calibration Procedures and Preventive Maintenance: The pDR-1500 nephelometer is factory calibrated with SAE fine test dust and will be zeroed at the start of each run. The flow rate for the metal sample collection will be checked using the TSI thermal mass flowmeter at the beginning and end of each sample collection. The ICPMS will be calibrated against commercial "High Purity"standards (www.highpuritystandards.com) to generate a calibration curve for sample analyte quantitation. Calibration standards will be run from 0.1 to 10 ppb (ng metal/ml of solution) for each analyte metal.

Quality Control Checks

Quality control samples (laboratory blanks, field blanks, commercial standards) will be measured with each sample analysis by ICPMS and will be used to asses the overall quality of the run. Metals concentrations measured to within 20% RSD of the certified value will be deemed acceptable and used to validate the data reported to the investigators.

Documentation, Data Reduction, and Reporting:

Documentation: Secondary data will be generated electronically once the raw data have been transferred from the instruments acquisition computer. The secondary data will be used to generate reports. The reports will be transferred electronically to the principal investigator who is responsible for final review. Raw data will be stored electronically on the laboratory computer and archived. Only Dr. Buckley and the laboratory analyst will have access to the data. The raw data will be maintained on the instrument computer at least until the processed data is released to the principal investigator. The raw data will be copied to the analyst's computer and stored on the EOHSI server at a minimum of once a week. Data processed into final concentrations will be maintained on the analysts' computer as well as Dr. Buckley's computer again until release to the principal investigator. Once it has been released to the principal investigator and approved by both the PI and Dr. Buckley (the QA officer) it will be the principal investigators responsibility to maintain a backup of the final processed data. Data given to the principal investigator will be backed up daily on the EOHSI server. The data will however be maintained on Dr. Buckley's computer and the raw data will also be maintained on the instrument computer with backups occurring at least quarterly for no less than two years after data acquisition.

For the metals measurements, the solution concentrations are reported by the instrument and the appropriate dilution factor is applied to report the final concentration of lead in the samples. All records will be originally maintained in the metals laboratory (Room 363 in the EOHSI building) at least until the data has been approved by the principal investigator. Electronic copies of the data will be maintained in this laboratory as well as Dr. Buckley's office for at least two years after the data has been analyzed. Once Dr. Buckley has approved the data and released it to the PI, the PI will maintain the data and backup of the finished data in their office.

A data package containing sample data and a written discussion will be submitted to NJDEP electronically in conjunction with required quarterly reports. At the latest, data will be sent to the DEP 60 days after the end of each quarter. The final report will contain the particle concentrations at 20 and 80 cm height and metals concentration for each field. The report will also include statistical analyses to investigate the effect of age and product type on lead and other metals concentrations. If warranted, a health risk assessment will be included.

Data Validation

All sample data will be validated before being sent to NJDEP. Validation will take place at three levels. The laboratory analyst will first review the data then report the data to Dr. Buckley. Dr. Buckley will review the reports then send the data to Dr. Shalat. Dr. Shalat will then review the data before sending it to NJDEP. The analysts can reject the data based on QC sample failures. Dr. Buckley will check the data for other QC parameters including concentration agreement among isotopes and consistency of calculated concentrations from raw data. He can reject the data or compare it to previous analytical runs for consistency. Dr Shalat will review the data and can also reject it based on external quality control criteria such as blind QC values. All data that has been rejected will be rerun after agreement between Dr.

Buckley and Dr. Shalat. If there is disagreement the samples will be rerun for comparison of consistency with previous analytical runs.

Field sample forms, chain of custody forms, and electronic databases will be reviewed for completeness and accuracy.

Performance and Systems Audits

The principal investigator along with Dr. Buckley will review all sample collection documentation and sample results. The documentation will be reviewed first prior to the start of field activities. Both documentation and laboratory results will be reviewed approximately mid-way through the study and at study completion.

References

Buckley, B., Johnson, W., Rischer, E., Tu Q., Heintz, M., Measurement of Heavy Metals in Biological and Environmental Matrices Using Microwave Assisted Extraction, Inductively Coupled Plasma Mass Spectrometry and Ion Chromatography for Assessing Potential Risk to Human Health. *J. Environ Occup Med*. Vol 20. No 5. 10/2003.

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Shalat SL, Lioy PJ, Schmeelk K, Mainelis G. Improving estimation of indoor exposure to inhalable particulates for children in the first year of life. *J Air Waste Manag Assoc* 2007;57:934-939.

Zhang, JJ., Han IK., Zhang L., Crain W. Hazardous chemicals in synthetic turf materials and their bioaccessibility in digestive fluids. *J Expo Sci Environ Epidemiol* 2008; 18(6): 600-7.

Personnel:

Stuart L. Shalat, Sc.D. will serve as the project's Principal Investigator. He will have overall responsibility for the conduct of the project. He will:

- consult when appropriate with the DEP Project Officer with regards to the selection of sites for sampling, progress in data acquisition, problems and/or delays in the work.
- Immediately inform the DEP Project Officer of any observations or data that suggest an imminent hazard including from, but not limited to, lead .
- meet weekly with Dr. Black to assure that the work is scheduled and carried out on schedule
- have the primary responsibility for all statistical analyses
- work closely with Dr. Lioy in the preparation of all reports

Kathleen Black, Ph.D. will serve as the Study Coordinator. In this role she will:

- schedule all fieldwork and will supervise Ms. Hernandez
- meet weekly with Dr. Shalat to discuss problem or corrective action needed
- will coordinate the data entry of all metals analyses with Dr. Buckley

Brian Buckley, Ph.D. will act as Quality Assurance Officer as well as oversee all Metals Analysis. He will:

- provide expert input on all aspects of interpretation of the results of the metals analyses
- provide QA and QC of all laboratory practices
- Periodically (approximately mid-way through and at the end of the study) review data to ascertain its integrity.

Marta Hernandez is the primary Field Technician. She will:

- carry out all the field sampling, including the preparation of all sampling media
- be responsible for logging all samples and for transferring them along with chain of custody documents to Dr. Buckley's lab for analysis.

Paul J. Lioy, Ph.D. will provide expert advice and consulting on all aspects of the Exposure Assessment and will meet as needed with Dr. Shalat to discuss any problems or issues that arise in the course of the project.

APPENDIX 2

ICP-MS RESULTS

METALS IN AIR

Sample ID	Total Vol (m3)	52Cr ng	Cr - LOD	75As ng	As-LOD	111Cd ng	Cd-LOD
Turf 1 Mobile	1.88	144		2		1	1
Turf 1 Stationary	1.86	99		1	1	1	1
Turf 2 Mobile	2.40	173		2	1	2	1
Turf 2 Stationary	2.39	155		1	1	1	1
Turf 3 Mobile	2.39	3		1	1	1	1
Turf 3 Stationary	2.42	1	1	1	1	1	1
Turf 4 Mobile	2.42	1	1	1	1	1	1
Turf 4 Stationary	2.44	1	1	1		1	1
Turf 4 Mobile Soccer Player	0.60	1	1	1	1	1	1
Turf 5 Mobile	2.36	95		3	1	1	
Turf 5 Stationary	2.35	96		3	1	0.5	1

metals in ng

Blank Air Filters

Turf 1 Blank		153		1	1	1	1
Turf 5 Field Blank		106		3	1	0.5	1

Note Cr-LOD, As-LOD, Cd-LOD - if sample was <LOD (indicated by 1 in column), then the LOD was used to calculate the concentration.

206Pb ng	207Pb ng	208Pb ng	Avg Pb ng	Cr ng/m3	As ng/m3	Cd ng/m3	Pb ng/m3
134	135	137	135	76.74	1.20	0.53	72.06
14	14	14	14	53.34	0.54	0.54	7.60
21	21	21	21	72.01	0.83	0.83	8.73
9	9	9	9	64.69	0.42	0.42	3.64
12	12	12	12	1.17	0.42	0.42	5.13
10	10	10	10	0.41	0.41	0.41	4.15
13	13	14	13	0.41	0.41	0.41	5.55
5	5	5	5	0.41	0.53	0.41	1.97
5	5	5	5	1.67	1.67	1.67	8.13
15	15	15	15	40.30	1.27	0.21	6.29
15	14	15	14	41.03	1.28	0.21	6.13

5	5	5	5
3	4	4	4

Field	52Cr	75As	As LOD	111Cd	Cd LOD	Avg Pb	Cr	As	Cd	Pb
	ng	ng		ng		ng	ug/ft2	ug/ft2	ug/ft2	ug/ft2
Turf1	20,977	20		6	1	109,101	1.99	0.00	0.00	10.33
Turf2	32	8	1	8	1	112	0.01	0.00	0.00	0.02
Turf3	152	13		6	1	513	0.03	0.00	0.00	0.10
Turf4	272	28		6	1	545	0.05	0.01	0.00	0.10
Turf5	59	10		1		102	0.01	0.00	0.00	0.02

Metals are ng/15 cm2 sample

Wipe area = 196 cm2

Area sampled 138 ft2 for Turf1; 69 ft2 for Turf 2, 3, 4, and 5