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

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Abstract

In response to numerous community concerns starting in 2008 regarding the safety of artificial turf fields, the New Jersey Department of Environmental Protection (NJDEP) funded a study by the Environmental and Occupational Health Sciences Institute (EOHSI) to measure lead (Pb) concentrations in wipe samples and in air at artificial turf fields. Sampling was conducted at five fields in New Jersey using an autonomous, programmable robot that agitated the turf surface and collected air samples above the turf in the breathing zone of a child. Other potentially toxic metals were also measured including chromium, cadmium and arsenic. Although considerable efforts were made to gain access to more fields, schools and community facilities were reluctant to participate. Pb was significantly elevated at one of the five fields. Although the measured levels of Pb at this field did not approach standards for protection of health, the small number of fields sampled makes it difficult to generalize the conclusions of this study to other artificial turf fields. On the basis of these results, it is recommended that artificial turf fields, particularly those older than three years, be screened for Pb using wipe sampling. If wipe samples show elevated levels of Pb, more intensive sampling of air with agitation of the turf is recommended.

Introduction

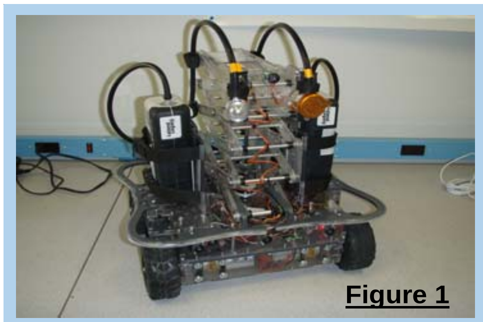
Artificial turf is widely used in place of natural grass-covered turf for outdoor (and to a lesser extent, indoor) athletic fields. These generally consist of an artificial grass-like surface consisting of synthetic, plastic-type “grass” stalks dyed a variety of colors, but often green. The “grass” is set into a mat, and an infill material is placed on top of the mat to provide cushioning and traction. Infill material can consist of a variety of materials. Frequently, however, the infill consists of crumb rubber. Shredded tires are often the source for this crumb rubber.

Recently, concerns have arisen as to the safety of artificial turf playing fields (Claudio, 2008). Of particular concern is the potential presence of lead. In 2008, the New Jersey Department of Health and Senior Services (NJDHSS) detected elevated levels of lead (Pb) in bulk samples of artificial turf material taken from three artificial turf fields (http://www.state.nj.us/health/artificialturf/documents/cpsc_letter_0608.pdf). Lead has been reported to be a major constituent of some of the dyes used in the “grass” stalk material. Pb may also be present in the material used as infill. Given the chemical and physical properties of Pb and its compounds, if a significant potential exists for exposure to Pb present in artificial turf fields, inhalation appears as the most likely candidate for the primary route of exposure. However, as the physical characteristics of Pb in artificial turf fields have not be determined it was unknown whether the lead that occurs on some of these artificial turf fields can be entrained into the air as respirable or inhalable particulate matter.

A pilot study was conducted to assess the potential for exposure to lead as well as chromium, arsenic and cadmium as a respirable/inhalable aerosol that may be mobilized to the air as a result of activity on 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). As an alternative to the practical problems presented by a direct sampling approach involving sampling pumps and collecting filters on active athletes, air sampling was conducted using a robotic sampler recently developed at EOHSI, the PIPER Mk IV, that can simulate activity on the artificial turf surface.

Methods

The PIPER Mk IV is an autonomous, fully 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 including air sampling equip-



ment. It is capable of avoidance maneuvering through the use of active infrared and sonar sensing modules. The PIPER sampler can be programmed to sample from a designated area such as an athletic field and can operate continuously for up to 2.5 hours (Figures 1 and 2). PIPER can also be equipped with a filter-type pad on its underside set at adjustable heights above the ground surface that can be used to collect wipe samples from surfaces (Figure 3).

Air samples were collected by PIPER during a programmed run in a rectangular pattern across the central part of the field. In order to account for background sources of airborne Pb and Pb that was potentially mobilized by passive (wind) sources, simultaneous air samples were collected by stationary samplers located on the midfield, sideline of each field. During sampling at one field, a 12 year old boy equipped with a personal sampler was recruited to generate a personal breathing zone sample on one end of the field while PIPER simultaneously sampled at the other end. The boy was instructed to jog, run, 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. PIPER also collected wipe samples. Air samples were collected on filters that were subsequently analyzed for particulates (PM_{100}) and metals.

Air sample filters were analyzed for Pb and other metals (arsenic [As], cadmium [Cd], and chromium [Cr]) by inductively coupled plasma mass spectrometry. Inhalable particulates (PM_{100}) were determined by measuring the change in mass of the filter pre- and post-sampling.

Results and Discussion

Forty-seven schools and community recreation facilities were initially contacted as potential sampling locations. In many cases, it was not known beforehand whether these facilities had artificial turf fields. Seven of these facilities were contacted, however, in response to an initial request to the NJDEP or the NJDHSS from their communities for an assessment of the potential hazard of their artificial turf fields. Of these seven, two consented to participate in the study. An additional three other facilities eventually agreed to participate. Thus, a total of five fields were sampled.

Characteristics of the five sampled fields are presented in Table 1

Table 1: Characteristics of sampled artificial turf fields.

Field	Age of Field (yrs)	Season	Temperature °F	Rel. Humidity	Wipe Samples Pb (ng/ft²)
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

Figure 4. Comparison of total inhalable particulate as sampled by stationary versus PIPER sampling (µg/m3).

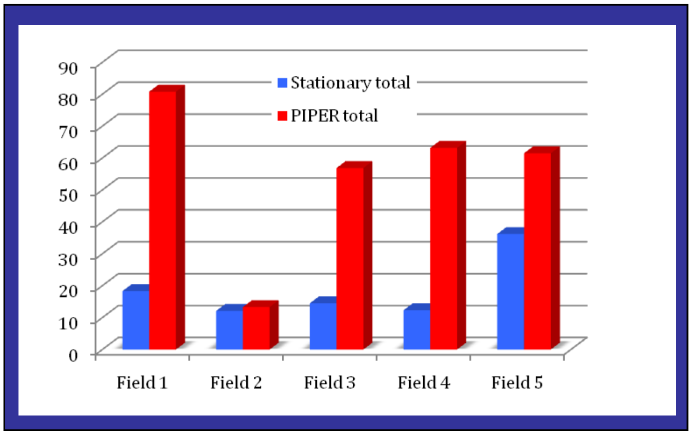


Figure 5. Comparison of total inhalable lead particulate as sampled by stationary versus PIPER sampling (ng/m3).

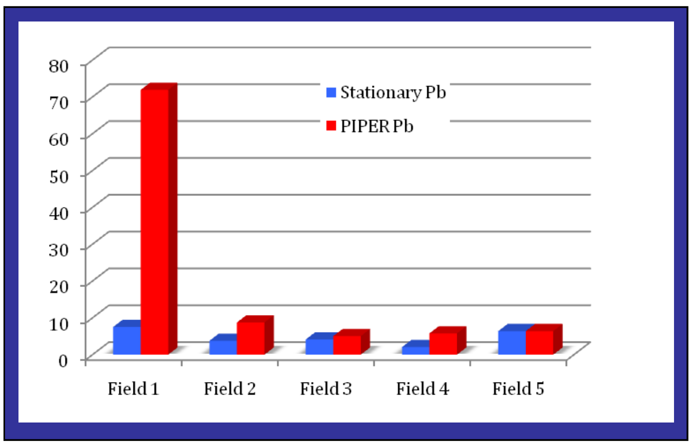


Figure 5 shows the concentration of inhalable particulates (PM_{100}) collected by PIPER and the stationary sampler from each field. Figure 6 shows the corresponding Pb concentrations.

PIPER was effective mobilizing particulates from the artificial turf. In 4 of the 5 fields, PIPER measured approximately 2 to 8 times the particulate concentration measured by the stationary samplers. On Field 1, however, PIPER measured Pb levels that greatly exceeded those measured on the other fields. The wipe sample results for Pb (Table 1) show that Field 1 had 500-1,000 times the Pb concentration of the other fields. On this field, it appears that a significant amount of Pb was present in the artificial turf, but that the Pb was mobilized into the air only when agitated by PIPER. This suggests that a similar situation would occur when the turf was agitated by play on the field. Given both the wipe sample results and the air sample results, it seem likely that Fields 2-5 did not contain Pb as a significant constituent of their artificial turf and the Pb that was measured may occur, at least in part, from atmospheric deposition. It is worth noting that Field 1 is the oldest of the five fields.

Figures 6 and 7 show the comparisons for Field 4 for the particulates and Pb sampled by the stationary sampler, PIPER and the personal sampler on the 12-year old boy playing on the field. The comparison to the personal sampler on the boy provides a basis for extrapolating the PIPER results to exposure under realistic activity on the field.

Figure 6. Comparison of PM_{100} measurements from stationary, PIPER and child soccer player (mg/m^3).

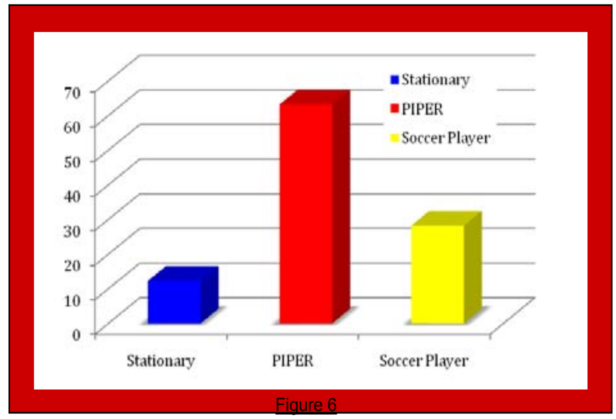
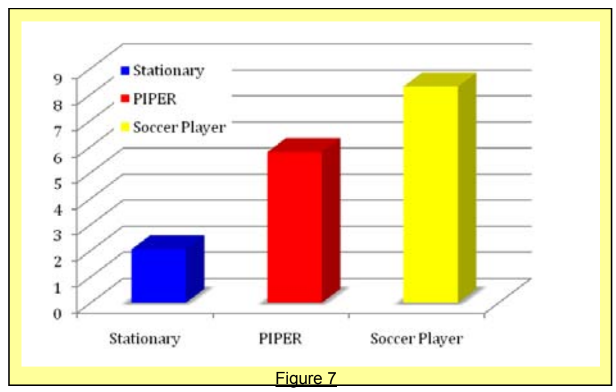


Figure 7. Comparison of Pb levels in inhalable particulate matter on Field 4 (ng/m3).



PIPER measured about twice the concentration of particulates measured by the personal sampler on the boy, but measured a comparable concentration of Pb. This suggests that PIPER may provide a reasonable estimate of the Pb exposure on an artificial turf field for a single occupant of the field. However, since Field 4 did not have highly elevated levels of Pb, this relationship may not hold for more contaminated fields. It is also likely that when many more athletes are active on a field (e.g., 22 in a football game), the “cloud” of particulates that is generated may result in an elevated exposure relative to the particulates mobilized by a single occupant.

Exposure on an artificial turf field is likely to be episodic. That is, exposure will occur when there is a game or a practice. Thus, even if an individual uses the field daily, an individual’s exposure will be limited to approximately 1-2 hours each day. This will likely be further limited in New Jersey by season – especially if the field is located outdoors. Standards for non-occupational inhalation exposure to Pb generally address Pb as an ambient air pollutant and thus, are framed in terms of concentrations of Pb in air for continuous exposure. Therefore, comparison of the Pb concentration measured in this study to existing standards for the protection of public health is problematic. The USEPA National Ambient Air Quality Standard (NAAQS) for Pb is 150 ng/m^3 calculated as a 3-month rolling average (http://www.epa.gov/air/criteria.html). The highest Pb concentration in air measured in this study was 71.9 ng/m^3. Thus, notwithstanding that the NAAQS for Pb is likely to be an overly stringent basis for evaluating the acceptability of non-continuous exposures, the highest Pb concentration measured in this study did not approach the NAAQS. However, the significant elevation in Pb concentration found from a single field in this study does not permit conclusions about all Pb-containing artificial turf fields. Based on this single observation, it appears possible (although not necessarily likely) that individual fields could contain sufficient levels of Pb to pose a concern for public health, especially with repeated use by the same individuals.

For the other metals that could pose a potential health concern, it is assumed that the endogenous Cr present in the artificial turf occurs as lead chromate ($PbCrO_4$), used as a pigment in the "grass" stalks. This assumption is consistent with the observation that the highest Cr air concentration occurred on Field 1, which was also the field with the highest Pb concentration. Lead chromate is a compound of hexavalent chromium. Hexavalent chromium is recognized as a human carcinogen by the inhalation route of exposure. However, it is generally not considered appropriate to estimate lifetime cancer risk under conditions of episodic or intermittent exposure. Therefore, the more appropriate basis for assessing the health implication of the levels measured in this study is the USEPA non-cancer Reference Concentration (RfC), 1.4 x 10^{-4} mg/m^3 (140 ng/m^3). As was discussed relative to the NAAQS for Pb, the RfC is intended to apply to continuous chronic duration exposure. Thus, the RfC is also likely to be overly stringent when used in assessing episodic exposures. The highest concentration of Cr measured in this study was 76.7 ng/m^3. Notwithstanding the stringent nature of this comparison, the highest observed Cr concentration does not approach the RfC.

Cd is recognized by the USEPA as a "probable human carcinogen" by the inhalation route of exposure. There is no non-cancer RfC for Cd. Comparing the highest measured concentration of Cd, 0.83 ng/m^3 to the estimated cancer potency for Cd under the assumption of continuous inhalation exposure at that concentration yields a lifetime cancer risk of approximately 1 x 10^{-6} (one-in-one million). Despite the highly conservative nature of this comparison given the non-continuous nature of the potential exposure, this level of risk is generally considered inconsequential.

For As, the highest concentration measured in this study was 1.7 ng/m^3. As with Cd, there is no non-cancer RfC. Comparison under the same conservative caveats yields a lifetime cancer risk for continuous exposure of 1 x 10^{-5} (one-in-a hundred thousand). This too, is considered to be an inconsequential risk.

Conclusions and Recommendations

Of the five artificial turf fields available for sampling in this study, only one was found to have Pb levels that were significantly elevated above background. Air concentrations of Pb and other metals measured by PIPER in this study did not approach levels that would trigger concern from a health perspective. However, the small number of fields sampled during this study makes it difficult to generalize the conclusions of this study to other artificial turf fields.

The PIPER sampling robot appears to be a useful tool for investigating the potential for inhalation exposure to particulates, particularly children's exposure, when a surface is agitated. The wipe sample ability also appears useful for screening the chemical content of a surface for the purpose of evaluating the potential for inhalation or dermal exposure.

It is recommended that artificial turf fields, particularly those older than 3 years be screened for Pb by surface wipe sampling. If Pb levels in the wipe samples exceed 10,000 ng/ft^2, it would be advisable to proceed to measurement of airborne concentrations of Pb generated with activity on the field.

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