Health Consultation

Evaluation of Arsenic in Soil at Kokomo School and City Properties

KOKOMO SCHOOL AND CITY PROPERTIES

KOKOMO, HOWARD COUNTY, INDIANA

SEPTEMBER 29, 2009

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Agency for Toxic Substances and Disease Registry
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Health Consultation: A Note of Explanation

An ATSDR health consultation is a verbal or written response from ATSDR to a specific request for information about health risks related to a specific site, a chemical release, or the presence of hazardous material. In order to prevent or mitigate exposures, a consultation may lead to specific actions, such as restricting use of or replacing water supplies; intensifying environmental sampling; restricting site access; or removing the contaminated material.

In addition, consultations may recommend additional public health actions, such as conducting health surveillance activities to evaluate exposure or trends in adverse health outcomes; conducting biological indicators of exposure studies to assess exposure; and providing health education for health care providers and community members. This concludes the health consultation process for this site, unless additional information is obtained by ATSDR which, in the Agency's opinion, indicates a need to revise or append the conclusions previously issued.

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HEALTH CONSULTATION

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Prepared By:

U.S. Department of Health and Human Services
Agency for Toxic Substances and Disease Registry

Statement of Issues

On August 13, 2009, the Indiana Department of Environmental Management (IDEM) requested the Agency for Toxic Substances and Disease Registry (ATSDR) review sampling data for arsenic in surface soil to determine whether there should be any restrictions on current or future use of the Central Middle School Football Field, an adjacent city property to the south of the school, or the athletic fields at the Eastside Park in Kokomo, Indiana. This health consultation provides a public health evaluation of the available data on arsenic levels in surface soil.

Site Description and History

Kokomo, Indiana, is located approximately 60 miles north of Indianapolis. During the early to mid 1900s, PPG Industries (PPG) manufactured plate glass at its facility, which is located near the Central Middle School. Arsenic is used in the glass manufacturing process at PPG. Waste material containing arsenic was used as fill material widely across the area where Central Middle School exists today. It has not been confirmed that PPG was the sole contributor to this spread of arsenic contaminated wastes. The areas of concern for this health consultation are Central Middle School football field, an adjacent city property immediately south of the football field, and the city of Kokomo's Eastside Park property.

The current use Central Middle School football field is for physical education classes and no other routine use of the field is expected. The adjacent city property located to the south of the football field is used occasionally for science classes and is also used by the public as a recreational area. The city of Kokomo's Eastside Park property consists of baseball diamonds and playground equipment. The baseball diamonds are utilized by youth leagues for both games and practices. Frequency of use and exposure scenarios for each of the aforementioned locations will be addressed in the Discussion section of this health consultation.

Environmental Data

Under Indiana's Voluntary Remediation Program, PPG contracted a consultant to collect soils samples from the three areas in question [Tetra Tech 2009]. Discrete samples were collected from 18 different sample locations. Of note, ATSDR did not review the sampling plans, the raw sample data, or the quality assurance/quality control information for sample collection and analysis.

Samples included surface (0-2 inches) and subsurface (2-6 inches and 6-24 inches) soil samples. For each sample location, the arsenic levels detected at the different depth ranges were fairly consistent. Given the current uses of the recreational areas in question, soil at 0-2 inch depth range is the most likely to contribute to an individual's exposure. ATSDR's evaluation focused on average arsenic levels in the 0-2 inch depth range for chronic exposures and the maximum value detected overall for acute exposures.

Of note, the available data were limited to 18 discrete soil samples. The same number of composite samples would have provided a better representation of the average arsenic concentration in soil. A composite sample is typically made by combining samples from

five or more locations. Composite sampling can improve spatial coverage of an area without increasing sample number and provide more representative estimates of average concentrations than could be achieved by the same number of discrete samples.

Discrete soil samples were taken at six sample locations at the Central Middle School field, six sample locations at the adjacent city property just south of the school, and six sample locations at Kokomo's Eastside Park property. IDEM collected split samples at three sample locations.

For the Central Middle School field and the Eastside Park property, the sample locations appear to be distributed rather evenly throughout the area of concern (see Figure 1 and Figure 2). Although the sampling data were limited to six discrete samples for each of these two locations, ATSDR assumed the available data were representative of arsenic levels throughout each of these two areas in our public health evaluation.

However, for the city park property adjacent to the school, the sample locations were all along the perimeter of the park; no samples were collected from within the center of the park (see Figure 1). Because the data are insufficient to evaluate the level of potential exposures in the park area that is immediately to the south of the Central Middle School football field, ATSDR is not able to make a public health hazard determination for this area.

Discussion

In this section, ATSDR addresses the question of whether exposure to arsenic in the surface soil at Central Middle School football field and the city of Kokomo's Eastside Park property could result in harmful health effects. Although the inherent toxicity of a chemical is important to consider, the human body's response to a chemical exposure is determined by several additional factors, among which are

- the concentration (how much) of the chemical to which the person was exposed,
- the amount of time the person was exposed (how long), and
- the way the person was exposed (through breathing, eating, drinking, or direct contact with something containing the chemical).

Lifestyle factors such as occupation, personal habits, and play activities have a major impact on the likelihood, magnitude, and duration of exposure. Individual characteristics such as age, sex, nutritional status, overall health, and genetic constitution affect how the human body absorbs, distributes, metabolizes, and eliminates a contaminant. A unique combination of all these factors will determine the individual's physiologic response to a chemical contaminant and the possibility of harmful health effects, if any, that the individual could experience as a result of the chemical exposure.

As an initial screen, ATSDR reviewed surface soil data to determine whether the maximum detected chemical concentrations were above arsenic's protective health-based comparison values (CVs). Health-based CVs are estimates of daily human exposure to a chemical that is not likely to result in harmful health effects over a specified duration of exposure. ATSDR CVs are developed for specific environmental media (air, water, and

soil) and for specific durations of exposure (acute [≤14 days], intermediate [15–364 days], and chronic [≥365 days]).

Some of the CVs and health guidelines used by ATSDR scientists include ATSDR's cancer risk evaluation guides (CREGs), environmental media evaluation guides (EMEGs), and minimal risk levels (MRLs). If an ATSDR CV is not available for a particular chemical, ATSDR will screen environmental data with CVs developed by other sources such as the Environmental Protection Agency (EPA). These CVs and health guidelines, as well as all other health-based screening criteria, represent conservative levels of safety, not thresholds of toxicity. Although concentrations at or below a CV may reasonably be considered safe, concentrations above a CV will not necessarily be harmful. To ensure that even the most sensitive populations, such as children and the elderly, are protected, CVs are intentionally designed to be much lower, usually by two or three orders of magnitude, than the corresponding no-observed-adverse-effect-levels (NOAELs) or lowest-observed-adverse-effect-levels (LOAELs) on which the CVs were based. Most NOAELs and LOAELs are established in laboratory animals; relatively few are derived from epidemiologic (chiefly occupational) studies. All ATSDR health-based CVs are non-enforceable and are used for screening purposes only.

ATSDR selects chemicals for further consideration if their maximum concentrations exceed those of a CV. When a chemical exceeds its CV, ATSDR begins a process that includes several steps. The first step in understanding the public health significance of exceeding the CV of a chemical is to review and understand the basis for that chemical's guideline. Two key steps in this analysis involve (1) comparing site-specific exposure doses to observed effect levels reported in critical studies and (2) carefully considering study parameters in the context of site exposures [ATSDR 2005].

Arsenic levels at the Kokomo School and City Properties site, which were 2.5 – 108 milligrams per kilogram (mg/kg), exceeded ATSDR's CV of 20 mg/kg for child exposures. Therefore, further evaluation was needed. In the following text, ATSDR first provides health effects information on arsenic. Then ATSDR describes its public health evaluation of the arsenic levels detected at the Kokomo School and City Properties site, and explains why no public health hazard exists.

Arsenic

Arsenic, a naturally occurring element, is widely distributed in the Earth's crust. Natural levels of arsenic in soil usually range from 1 to 40 mg/kg, with a mean of 5 mg/kg, although much higher levels may occur in mining areas, at waste sites, near high geological deposits of arsenic-rich minerals, or from pesticide application [ATSDR 2007]. Most arsenic compounds have no smell or distinctive taste. Although elemental arsenic sometimes occurs naturally, arsenic is usually found in the environment in two forms—inorganic (arsenic combined with oxygen, chlorine, and sulfur) and organic (arsenic combined with carbon and hydrogen).

Current understanding of arsenic's toxicology suggests that at low-level exposures, arsenic compounds are detoxified—that is, changed into less harmful forms—and then excreted in the urine. At higher-level exposures, however, the body may not have the

ability to detoxify the increased amount of arsenic. When this overload happens, blood levels of arsenic increase and adverse health effects may occur. Arsenic, like some other chemicals, does not seem to cause adverse health effects until a certain amount, or threshold, of the chemical has entered the body. Once the threshold, also known as the minimal effective dose, is reached, and the body is no longer able to detoxify arsenic compounds, adverse health effects may result [ATSDR 2007].

Ingestion of arsenic-contaminated water and soil are ways that arsenic can enter the body. Dermal exposure to arsenic is usually not of concern because only a small amount will pass through skin and into the body (4.5% of inorganic arsenic in soil) [Wester et al. 1993]. The metabolism of inorganic arsenic has been extensively studied in humans and animals. Several studies in humans indicate that arsenic is well absorbed across the gastrointestinal tract (approximately 95% absorption for inorganic arsenic compounds and 75–85% for organic arsenic compounds) [Bettley and O'Shea 1975, Buchet et al. 1981, Marafante et al. 1987, Zheng et al. 2002]. Once in the body, the liver changes (i.e., through methylation) some of the inorganic arsenic to less harmful organic forms that are more readily excreted in urine. Most forms of organic arsenic appear to undergo little metabolism and are quickly excreted from the body. Both inorganic and organic forms of arsenic leave the body in urine. It is estimated that more than 75% of the absorbed arsenic dose is excreted in urine [Marcus and Rispin 1988]. Studies have shown that 45–85% of arsenic is eliminated within one to three days [Apostoli et al. 1999, Buchet et al. 1981, Crecelius 1977, Tam et al. 1979]. However, there appears to be an upper-dose limit to this mechanism working successfully to reduce arsenic toxicity [ATSDR 2007].

As noted above, water-soluble forms of inorganic arsenic are well absorbed. Ingesting less soluble forms of arsenic results in reduced absorption. Studies in laboratory animals show that arsenic in some soil is only one-half to one-tenth as bioavailable as soluble arsenic forms [Casteel et al. 1997, Freeman et al. 1993, Freeman et al. 1995, Groen et al. 1994, Rodriguez et al. 1999]. In one study, approximately 80% of the arsenic from ingested soil was eliminated in the feces compared with 50% of the soluble oral dose [Freeman et al. 1993]. The bioavailability of arsenic in soil may be reduced due to low solubility and inaccessibility [Davis et al. 1992]. Most of the bioavailable arsenic in water and soil is expected to be present as inorganic arsenic (trivalent arsenic and pentavalent arsenic, specifically) [Health Canada 1993].

ATSDR’s acute oral MRL (0.005 mg/kg/day) is based on a study in which 220 people in Japan were exposed to arsenic contaminated soy sauce for a 2–3 week period. Their exposure dose was estimated to be 0.05 mg/kg/day. This is considered the LOAEL for acute exposures of less than 2 weeks. Facial edema and gastrointestinal symptoms (nausea, vomiting, and diarrhea) were considered to be the critical effects seen at this dose [Mizuta et al. 1956]. The MRL is further supported by the case of a man and woman in upstate New York who experienced gastrointestinal symptoms after drinking arsenic-tainted water at an estimated dose of 0.05 mg/kg/day [Franzblau and Lilis 1989].

The chronic oral MRL (0.0003 mg/kg/day) is based on a study in which a large number of farmers (both male and female) were exposed to high levels of arsenic in well water in Taiwan. EPA’s oral reference dose (RfD) is also 0.0003 mg/kg/day [EPA 2008]. A clear dose-response relationship was observed for characteristic skin lesions. A control group

consisting of 17,000 people was exposed to 0.0008 mg/kg/day and did not experience adverse health effects. This is considered to be the lowest NOAEL. Hyperpigmentation and keratosis of the skin were reported in farmers exposed to 0.014 mg/kg/day (less serious LOAEL). Arsenic-induced skin lesions have also been observed at 0.0014 mg/kg/day [Guo et al. 2001]. The MRL is supported by a number of well conducted epidemiological studies that identify reliable NOAELs and LOAELs for dermal effects as well as cardiovascular and hematological effects at low doses [Borgoño and Greiber 1972, Cebrían et al. 1983, EPA 1981, Guha Mazumder et al. 1988, Haque et al. 2003, Harrington et al. 1978, Valentine et al. 1985, Zaldívar 1974, Hopenhayn 2006, Chiou 1997)]. Collectively, these studies indicate that the threshold dose for dermal effects (e.g., hyperpigmentation and hyperkeratosis), cardiovascular effects, and hematological effects is approximately 0.001 to 0.002 mg/kg/day depending on the effect.

Arsenic is classified as a human carcinogen. Several epidemiological studies conducted in other countries, including Taiwan and Chile, have reported that chronic ingestion of water that contains arsenic at several hundred parts per billion can increase the risk of cancer in the skin, liver, bladder, kidneys, prostate, and lungs [ATSDR 2007]. EPA's oral cancer slope factor (CSF) for arsenic is 1.5 $(mg/kg/day)^{-1}$. CSFs are generated from mathematical models applied to human epidemiologic or animal experimental data for carcinogenic effects. These models extrapolate from higher experimental doses to lower environmental doses.

Site-specific Exposure Doses

For this health consultation, ATSDR derived exposure doses for both adults and children. Exposure doses help determine the extent to which ingesting soil might be associated with harmful health effects. ATSDR then compared the site-specific exposures doses to the observed effect levels reported in critical studies.

Estimating an exposure dose requires identifying how much, how often, and how long a person may come in contact with some concentration of the contaminant in a specific medium (air, water, soil). The equation and assumptions used to estimate exposure doses from ingesting soil follow.

Exhibit 1: Exposure Dose Equation for Ingestion

$$\mathbf{D = \frac{C \times IR \times EF \times CF}{BW}}$$

where,

D	=	exposure dose in milligrams per kilogram per day (mg/kg/day)
C	=	chemical concentration in milligrams per kilogram (mg/kg)
IR	=	intake rate in milligrams per day (mg/day)
EF	=	exposure factor (unitless)
CF	=	conversion factor, 1×10^{-6} kilograms/milligram (kg/mg)
BW	=	body weight in kilograms (kg)

In the absence of complete exposure-specific information, ATSDR applied several conservative exposure assumptions to define site-specific arsenic exposures as accurately as possible. For the Central Middle School football field location, ATSDR evaluated middle school children's exposure for recess and gym activities and assumed that a teacher would be present during these activities. For the Eastside Park Property, all age groups were evaluated. Specifically, ATSDR estimated arsenic exposure doses using the following assumptions and default intake rates for exposure through soil ingestion:

- The maximum level of arsenic in soil of 108 mg/kg, which was detected at the Central Middle School field at 2-6 inches, was used when calculating the exposure doses for acute (short-term) exposures. In addition, an exposure factor of 5/7 was used for the Central Middle School football field to represent five days of the week and an exposure factor of 3/7 was used for the Eastside Park property to represent three days of the week.
- The 95% upper confidence limit (UCL) of the mean arsenic concentration for both of the areas (Central Middle School football field and the city of Kokomo's Eastside Park property) of 60.4 mg/kg and 57.2 mg/kg, respectively, were used when calculating the exposure doses for chronic (long-term) exposures.
- Soil intake rates for 12, 13, and 14 year olds, and adults were assumed to be 100 mg/day for the Central Middle School field.
- The soil intake rate for preschool children and elementary school children was assumed to be 200 mg/day, and for teenagers and adults was assumed to be 100 mg/day, for Kokomo's Eastside Park property.
- The exposure factor for the Central Middle School football field was assumed to be 0.49, which is a conservative estimate that assumes the children and adults will use the field 180 days of the year.
- The exposure factor for Kokomo's Eastside Park Property was assumed to be 0.29, which would constitute a visit to the park 3 days per week, 8 months out of the year, or 105 days.
- The body weights of 12, 13, and 14 year olds were assumed to be 51.2, 55.8, and 61.9 kg, respectively, for the Central Middle School field scenario. The adult weight was considered to be 80.8 kg. Of note, all weights used in ATSDR's calculations in this health consultation were taken from the findings of the National Health and Nutrition Examination Survey (NHANES) [CDC 2004].
- The body weights of preschool children, elementary school children, teenagers, and adults were assumed to be 18.2, 33.8, 65.0, and 80.8 kg, respectively for Kokomo's Eastside Park Property.
- The bioavailability of arsenic was assumed to be 100%—that is, all of the arsenic in soil that a person ingested was assumed to enter the bloodstream.

ATSDR, on the basis of these conservative assumptions, derived estimated exposure doses. The estimated doses for chronic exposures are listed in Tables 1 and 2. As part

of its evaluation, ATSDR also calculated cancer risk estimates, which are listed in Tables 1 and 2. Under quantitative cancer risk assessment methodology, cancer risk estimates are expressed as follows.

Exhibit 2: Cancer Risk

Cancer Risk = (annual dose) × (cancer slope factor) × (# years of exposure/70 years)

Cancer risk estimates are expressed as a probability; that is, the proportion of a population that may be affected by a carcinogen during a lifetime of exposure (24 hours/day, 365 days/year, for life). For example, an estimated cancer risk of 2×10^{-6} represents potentially two excess cancer cases in a population of one million over a lifetime of continuous exposure.

Of note, cancer risk was calculated for each year of exposure for 12, 13, and 14 year olds at the Kokomo football field and for 20 years of exposures for their teachers. Also, a total cancer risk was calculated for a child who plays in the Central Middle School football field throughout their three middle school years. As for Kokomo's Eastside Park Property, cancer risk was calculated for 3, 6, 6, and 30 years of exposure for preschool children, elementary school children, teenagers, and adults, respectively. In addition, a total cancer risk was calculated for an individual who plays at Eastside Park throughout their childhood years.

Chronic Arsenic Doses and Cancer Risk Calculations for Kokomo School and City Properties

Table 1

95% UCL arsenic concentration in soil	**Central Middle School Property**	
	60.4 ppm	
	Dose Calculation (mg/kg/day)	**Cancer Risk Calculation**
12 year old	0.000058	1.2E-06
13 year old	0.000053	1.1E-06
14 year old	0.000048	1.0E-06
Total middle school years		3.3E-06
Adults	0.000037	1.6E-05

Table 2

95% UCL arsenic concentration in soil	City of Kokomo Property (Eastside Park) 57.2 ppm	
	Dose Calculation (mg/kg/day)	**Cancer Risk Calculation**
Preschool children	0.00018	1.2E-05
Elementary school children	0.000097	1.3E-05
Teenagers	0.000025	3.3E-06
Total childhood years		2.8E-05
Adults	0.000020	1.3E-05

Public Health Implications

Exposure doses in this health consultation were estimated using the 95% UCL of the average arsenic concentration, which is a conservative approach when estimating the average concentration for a limited number of samples. For both the Central Middle School property and Kokomo's Eastside Park property, results show that the estimated arsenic doses (0.00002 – 0.00018 mg/kg/day) for all age groups do not exceed ATSDR's chronic oral MRL of 0.0003 mg/kg/day. Therefore, non-cancerous harmful effects are not expected in adults or children who use the Central Middle School football field or Eastside Park.

Based on ATSDR's conservative assumptions and using the maximum arsenic value (108 mg/kg) found at the site, the estimated arsenic doses (0.000016 – 0.00051 mg/kg/day) for adults and for children are below ATSDR's acute oral MRL of 0.005 mg/kg/day. Therefore, non-cancerous harmful effects are not expected in people who use the Central Middle School football field or Eastside Park.

Based on its calculations, ATSDR's estimated cancer risks range from 1.0×10^{-6} to 2.8×10^{-5}. The cumulative cancer risk for an individual who plays at Eastside Park throughout their childhood years is 2.8×10^{-5}. This means that if 100,000 people used the Eastside Park, the number of extra cases of cancer is less than 3 and might be zero. The cumulative cancer risk for a child who plays in the Central Middle School football field throughout their middle school years is 3.3×10^{-6}. ATSDR finds all of these cancer risk estimates to be very low increased risks of cancer. Also, arsenic is not expected to be 100% bioavailable in soil as assumed in ATSDR's dose calculations; therefore, the upper cancer risk estimate is probably less than one in 100,000.

Conclusions

ATSDR supports the continued recreational use of the Central Middle School Football Field and the city of Kokomo's Eastside Park property. This statement is based on ATSDR's evaluation of the limited discrete samples that were available for our review. Because the data were limited in scope, ATSDR took a conservative approach when calculating site-specific exposure doses and cancer risks. Even when taking this conservative approach, the calculated arsenic doses and cancer risks were not at levels of public health concern.

Of note, ATSDR was not able to make a public health determination for the city property just south of the school. Additional soil data showing arsenic levels detected in the center of this park would be needed to determine whether arsenic is of public health concern in this area.

Also of note, ATSDR based our conclusions on the *current* use of the Central Middle School football field and the city of Kokomo's Eastside Park property. If future use of the recreational areas in question changes from the scenarios described in this health consultation, ATSDR would suggest re-evaluating the site to ensure that the levels of arsenic that remain onsite are not of public health concern for the new exposure scenario.

Should the exposure scenarios change or relevant new information become available, ATSDR will revisit its conclusions and recommendations.

Recommendations

ATSDR recommends that additional soil samples be collected from the park just south of the Central Middle School football field. A sample design needs to be developed that consists of a series of composite samples made up of many discrete samples. ATSDR would be available to review any proposed sampling plan to further characterize arsenic contamination in this area.

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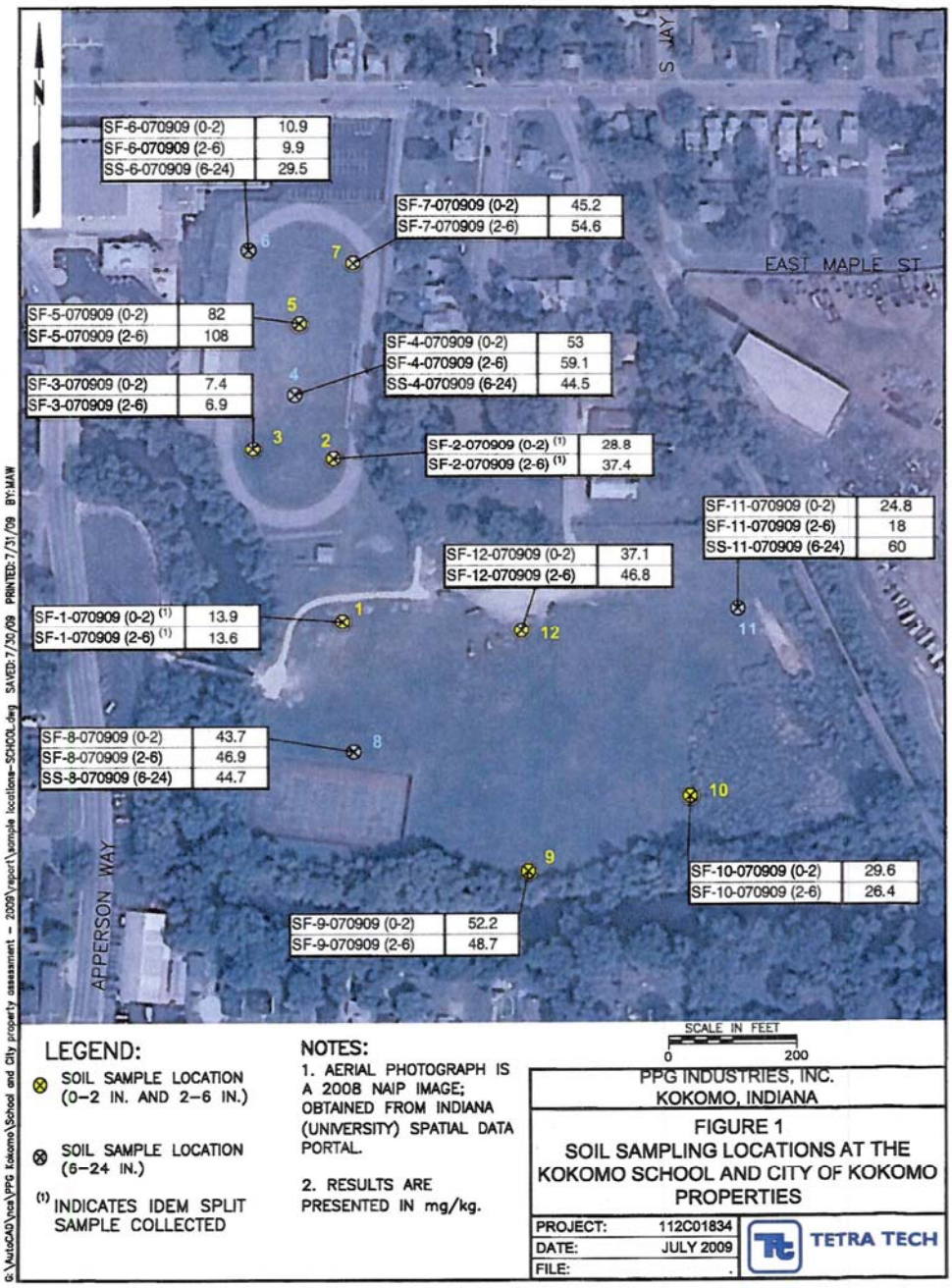

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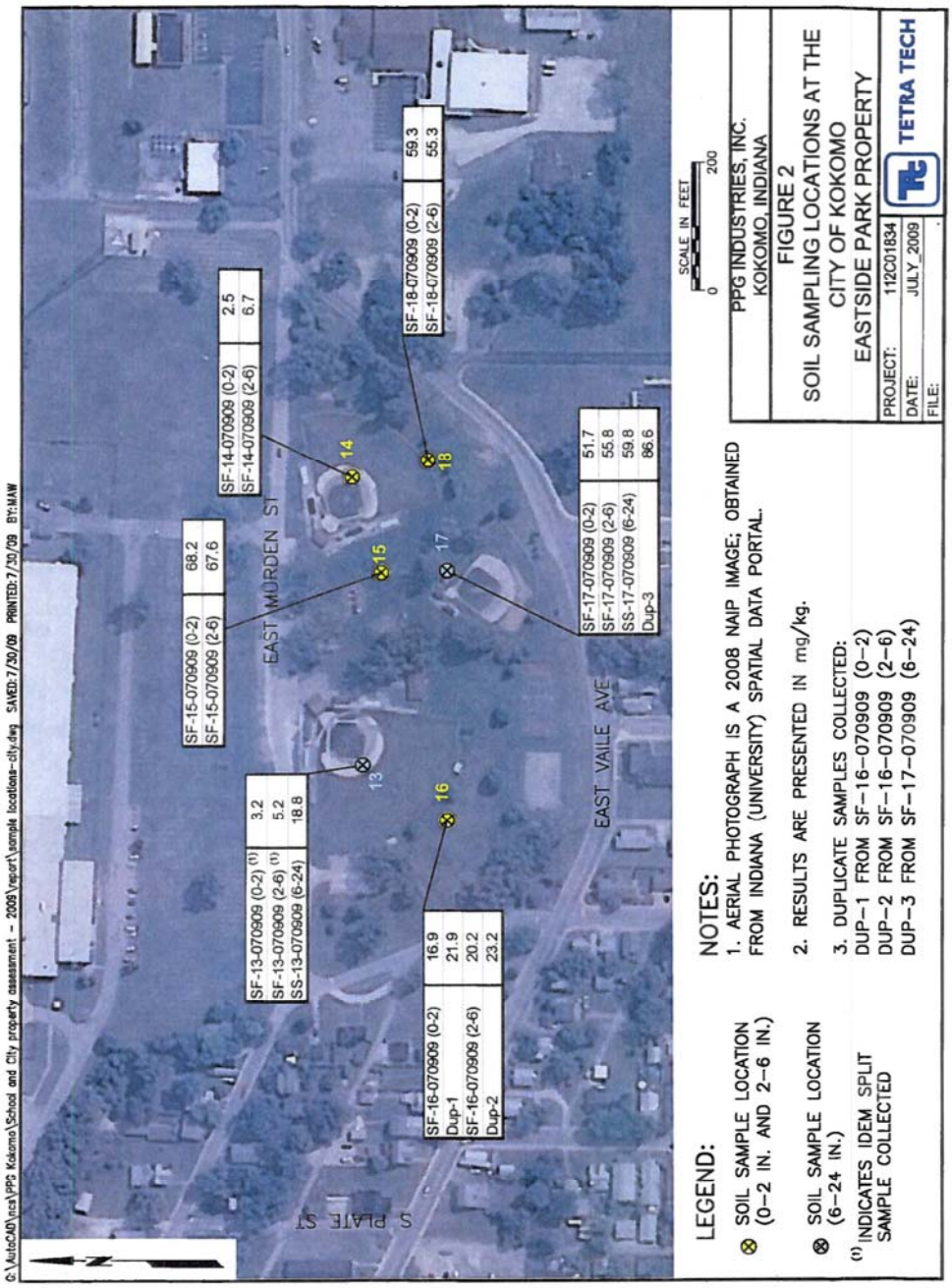

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