DEPARTMENT OF HEALTH & HUMAN SERVICES
Agency for Toxic Substances and Disease Registry, Region 5

Public Health Service
77 W. Jackson Blvd., Room 413
Chicago, IL 60604

September 22, 2016

Ed Nam
Acting Director, Air and Radiation Division
United States Environmental Protection Agency
77 W. Jackson Blvd., Room N163
Chicago, IL 60604

Dear Mr. Nam:

On July 21st, 2016, staff from the U.S. EPA Air and Radiation Division (ARD)-Air Enforcement and Compliance Assurance Branch requested technical public health assistance from ATSDR Region 5 regarding the potential health implications from gradually increasing concentrations of manganese (Mn) being emitted from the SH Bell facility in East Liverpool, Ohio. Specifically, U.S. EPA asked, "***are current concentrations of manganese being measured in ambient air around the site a threat to human health***?"

Background
SH Bell began operations in 1963 at a small 8.5-acre parcel ("Little England facility"), which they occupied until 2011 when it was acquired by Growmark, a grain storage and transfer company. SH Bell purchased a larger 92-acre property 1 mile due east of Little England for its main operations in the late 1960s. This "State Line" facility straddles Ohio (Region 5) and Pennsylvania (Region 3), and is located on the northern bank of the Ohio River, with easy barge and rail access. Operations include storage, transfer, and warehousing of ferrous and nonferrous materials for industry. The facility is also equipped to process, dry, crush, screen, and package various materials. Receiving and shipping of materials occur through river barge, truck, and rail[1]. The State Line facility is the sole location of manganese processing of ore in East Liverpool, with the nearest similar facility about 3.5 aerial miles away in Midland, Pennsylvania.

Demographics
The population within 1 mile of the State Line facility has decreased from 1550 to 1291 from the 2000 to the 2010 census (-16%). The population is mostly white (94%) and non-Hispanic 99.3%). Approximately 8% of the population are children under the age of 6, 19.4% are women of child bearing age (15-44), and 13.4% are 65 years or older (see Enclosures for demographic maps).

Air Sampling
Since 1999, the Ohio EPA has conducted fixed-site air monitoring at three locations in the East Liverpool community (Maryland Avenue, the Port Authority, and the Michigan Avenue Water Plant), with discrete measurements available since 2005 at the Water Plant, and 2010 at Port

Authority and Maryland Avenue. Speciated metals data have also been collected in Glasgow and Midland PA (east of the State Line Facility) as well as at two monitors across the Ohio River in Lawrenceville and Chester, WV. Table 1 displays the data evaluated in this assessment; note that the data evaluated in this document includes discrete measurements only.

Table 1. Discrete TSP Metals and Meteorological Monitoring Stations near SH Bell Facility

Site Name	Operational Period	Number of samples	Frequency	Operator
Water Plant (OH)	Jan 2005-Current	1016	1 in 3 days	Ohio EPA
Maryland Ave (OH)	June 2010-Current	362	1 in 6 days	Ohio EPA
Port Authority (OH)	June 2010-Current	358	1 in 6 days	Ohio EPA
Water Plant Met Station (OH)	2006-Current	Continuous	Continuous	Ohio EPA
Glasgow (PA)	Oct 2014-July 2015	40	1 in 6 days	PA DEP
Midland (PA)	Apr 2011-Oct 2011	24	1 in 6 days	PA DEP
Midland Met Station (PA)	Feb 2011-Aug 2011	Continuous	Continuous	PA DEP
Chester (WV)	Jan 2009-Sept 2015	87	Intermittent	WV DEP
Lawrenceville (WV)	Apr 2014-Sept 2015	79	1 in 30 days	WV DEP
Lawrenceville Met Station (WV)	Jan 2008-Current	Continuous	Continuous	WV DEP

Based on data collected at the three Ohio monitoring stations through 2009, in 2010 ATSDR concluded that "Exposure to manganese concentrations in this community poses a public health hazard because the highest measured concentrations approach the low end of manganese air concentrations that have been associated with neurological impacts in occupational studies."[2]

Since 2008, substantial efforts have been undertaken by the company through enforcement agreements with Ohio EPA and U.S. EPA[3]. However, in spite of these actions, manganese concentrations have continued to increase in ambient air since a substantial reduction in 2011-2013. The highest concentration of manganese measured near the facility is 32 $\mu g/m^3$ in September 2014 at the Water Plant station. The highest monthly average of Mn at the Water Plant station is 8.6 $\mu g/m^3$ in October 2015.

Ambient Data

For this assessment, we evaluated ambient measurements from seven area total suspended particulate monitors and three area meteorological stations. We generated summary statistics, time series plots for the monitors with the most robust data sets, and generated spatial figures to help determine whether or not there are any other major sources of manganese in the community. Table 2 displays the summary statistics for each monitoring site. In general, the monitors closest to the State Line facility have the highest readings of manganese. The Water Plant continues to have the highest ambient Mn readings, followed by the Glasgow, PA monitor. Unfortunately, the latter is a limited 9-month dataset. The sites also along the river valley (Port Authority and Maryland Avenue) have higher concentrations than the Midland PA and WV stations, which are equidistant. The WV sites are at higher elevations than those along the river valley in OH and PA.

Table 2. Summary Statistics for TSP Manganese-Metals monitoring data: 2005-2016 (in µg/m^3)

	Water Plant (OH)	Maryland Ave (OH)[§]	Port Authority (OH)	Chester (WV)	Lawrenceville (WV)	Glasgow (PA)	Midland (PA)
N=	1016	362	358	87	79	39	24
Min detection	0.015	0.012	0.014	0.007	0.005	0.037	0.006
25th percentile	0.210	0.038	0.044	0.034	0.011	0.097	0.060
50th percentile	0.560	0.072	0.120	0.063	0.019	0.182	0.111
75th percentile	1.600	0.140	0.260	0.276	0.030	0.578	0.179
90th percentile	4.000	0.289	0.460	0.662	0.071	1.501	0.226
95th percentile	6.600	0.439	0.592	0.662	0.103	1.750	0.314
99th percentile	14.000	0.893	1.443	0.665	0.396	2.140	0.437
Max	32.000	2.200	2.400	0.681	0.396	2.229	0.470
N over RfC*	994	238	261	50	12	37	19
N over ATSDR MRL†	657	35	71	22	3	16	2
% over RfC	98	66	73	57	15	95	79
% over ATSDR MRL	65	10	20	25	4	41	8

[§]Maryland Avenue has two collocated TSP monitors. The higher of the two measurements are used for descriptive statistics
****RfC is U.S. EPA's reference concentration of 0.05 µg/m^3 for chronic exposure***
†ATSDR MRL is the ATSDR Minimal Risk Level of 0.3 µg/m^3 for chronic exposure

Table 3. Comparison of monthly composite data: 2010 ATSDR Health Consultation versus Recent Data (in µg/m^3)

	Water Plant (2003-2009)	Water Plant (2015-2016)	Port Authority (2003-2009)	Port Authority (2015-2016)	Maryland Avenue[§] (2003-2009)	Maryland Avenue[§] (2015-2016)
N=	81	15	81	15	81	15
Average	1.644	**2.244**	**0.299**	0.254	0.202	**0.205**
Geometric Mean	1.146	**1.578**	**0.207**	0.156	0.140	**0.147**

[§]Maryland Avenue has two collocated TSP monitors. The higher of the two measurements are used for descriptive statistics.

Table 3 compares monthly composite data ATSDR evaluated in its 2010 Health Consultation to monthly composite data collected since January 2015 at the Ohio monitors. Monthly composite data were compared because discrete filter analyses were not implemented into the sampling strategy at all three Ohio locations until January 2010. Further, only data collected from 2003-2009 are presented here because consistent monitoring at all three locations began in 2003 (partial years of data are available for 1999 (N=3); 2000 (N=10 at Water Plant and Port Authority; N=9 at Maryland Avenue); 2001 (N=2); and 2002 (N=0)). ATSDR chose to assess data since 2015 because ambient air concentrations have been markedly higher at these sites since then. Our analysis demonstrates that ambient manganese is higher at the Water Plant location, nearly the same at the Maryland Avenue location, and lower at the Port Authority location since our 2010 analysis of data. Thus, our recommendations from 2010 are still relevant—additional work should be implemented immediately to reduce off-site emissions and exposures.

Figure 1 displays a time series for Mn measurements at the Water Plant, and Figure 2 displays a time series for the monitors in East Liverpool. Chester and Lawrenceville did not report air measurements in sufficient frequency to plot over time, and only 9 months of data were collected in Glasgow. Figure 1 shows a general reduction in emissions after enforcement

actions were implemented from the 2010 Ohio EPA DFOs, but began increasing in recent years. Figure 2 indicates that the more distant Ohio monitors have been impacted more since 2015 than the rest of the sampling period in spite of enforcement actions taken.

Figure 1. Time series of TSP-Mn in ambient air at the Water Plant monitoring station

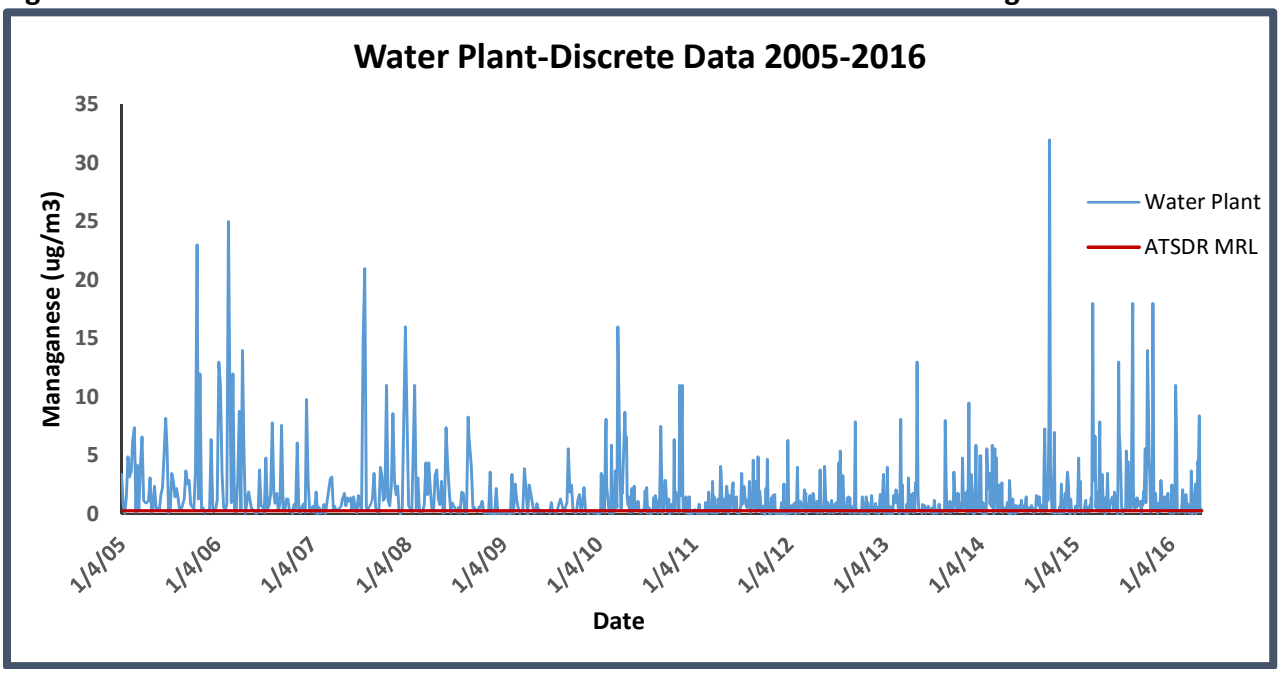
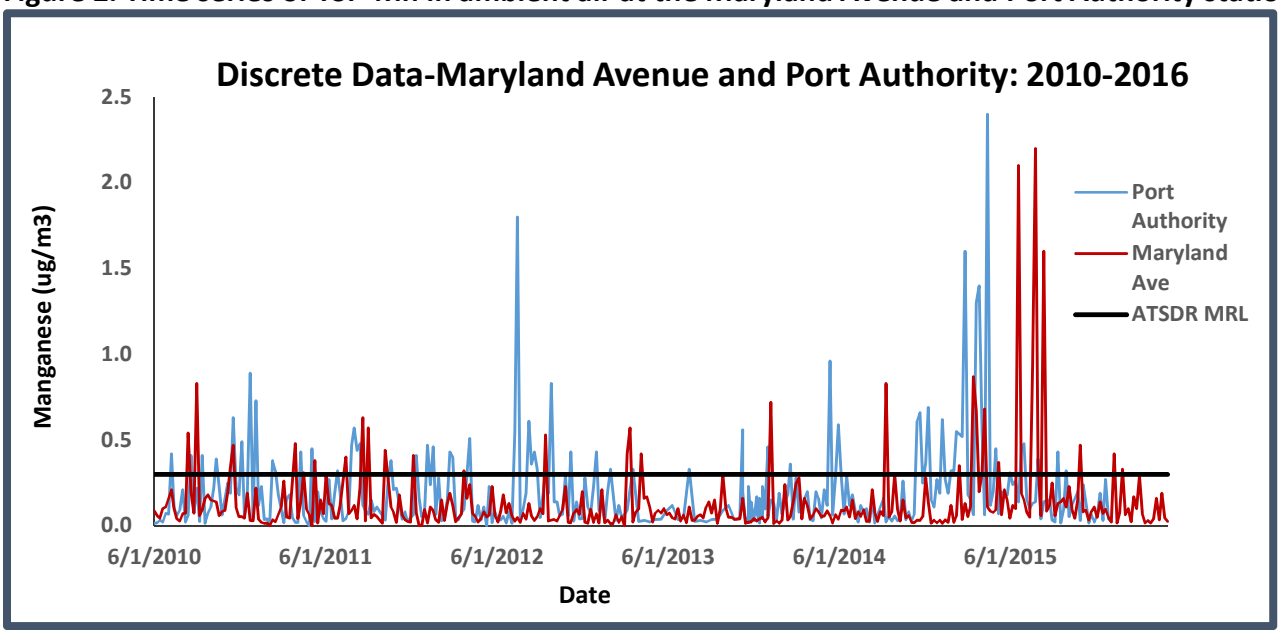


Figure 2. Time series of TSP-Mn in ambient air at the Maryland Avenue and Port Authority stations



Impacted areas

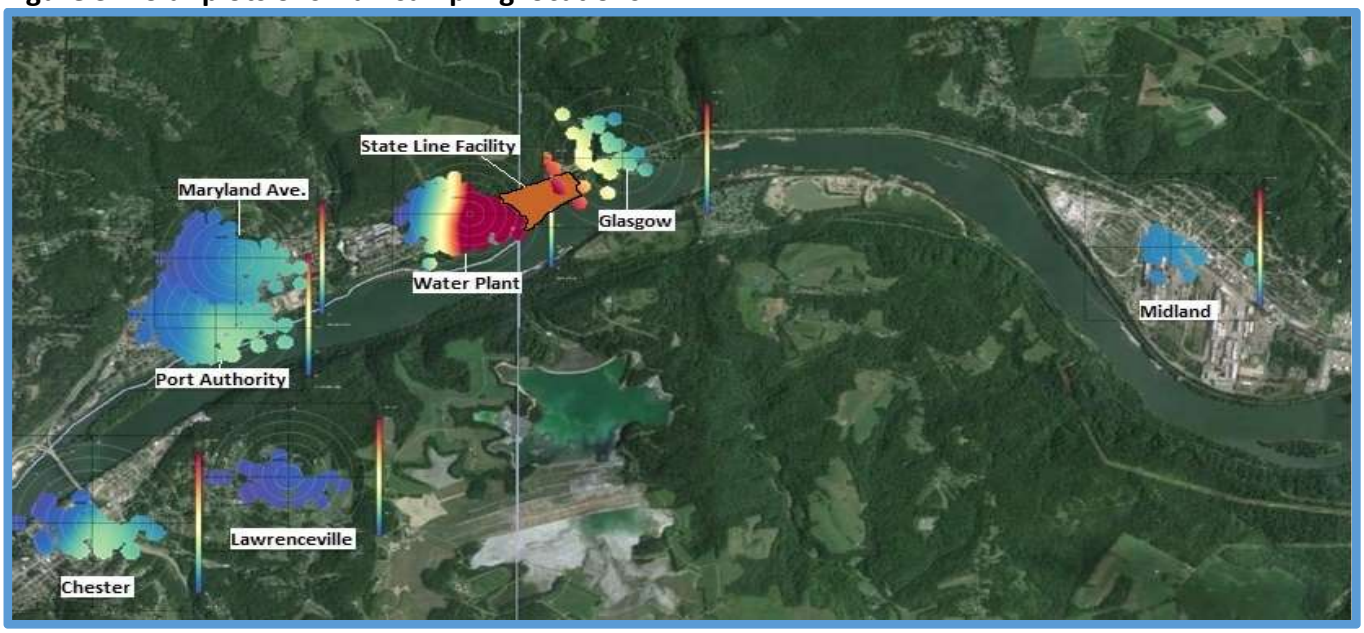
To evaluate the population at greatest risk, ATSDR assessed emissions spatially and temporally. In general, Mn concentrations are highest:

- The closer the monitor is to the property boundary of SH Bell State Line facility;
- On weekdays;
- At homes closest to the State Line facility.

Mn is higher when the monitor is close to the property boundary of SH Bell State Line facility
We evaluated the monitoring results using the *openair*[4,5] package of R statistical software[6] and generated *Polar Plots* to show the relationship between manganese concentrations and wind speed/direction. These plots display the relationship of wind direction and wind speed on pollutant concentration. The output is scaled to a polar coordinate system, which is essentially a circular axis. Wind direction data are placed in bins on the polar axis that correspond to the direction in degrees from which the wind originated, with north at 0 degrees, south at 180 degrees, east at 90 degrees and west at 270 degrees. Polar plots show wind speeds for any given direction in bins or compartments that are a proportional distance from the center of the plot, with higher wind speeds occurring further from the center. These plots will indicate the direction and the wind speed where contaminant concentrations are higher (the redder the area) or lower (the bluer the area) and can indicate the direction to potential sources.

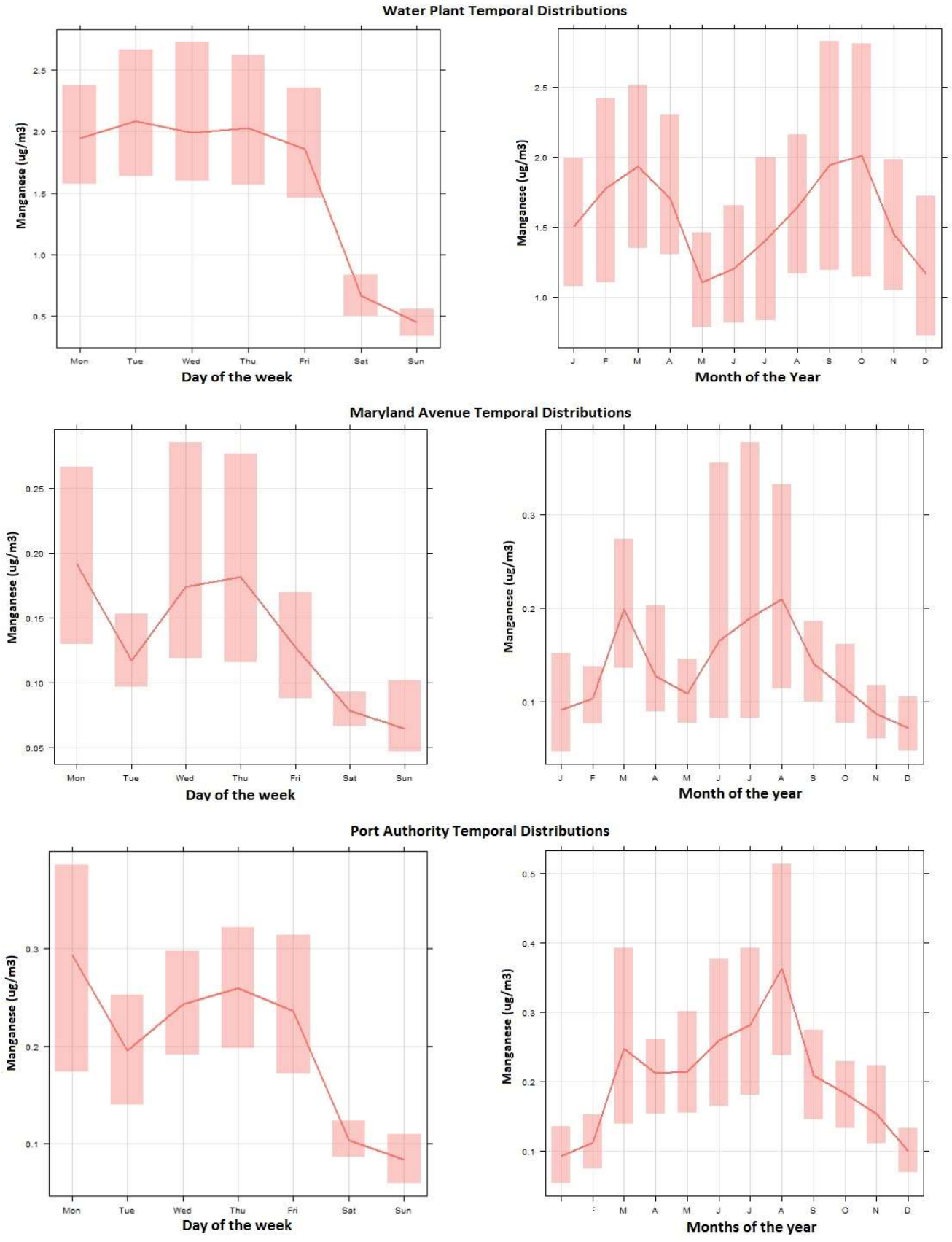
Figure 3 shows the overlay of polar plots on the sampling stations. The figure very clearly indicates that the monitors closest to the SH Bell State Line facility are most impacted. Thus the homes closest to the State Line facility are the highest exposed in the community. The red portions of the polar plots at the Water Plant indicate that the source is east/southeast of the monitoring station; the ones at Glasgow indicate that the source is west/southwest of the monitoring station. There are no obvious other sources impacting the monitoring locations.

Figure 3. Polar plots of six air sampling locations



Mn concentrations are highest on weekdays
All Ohio monitoring locations indicate that manganese is present in ambient air in the greatest quantity during week days, when SH Bell is operational. Weekend concentrations are markedly lower at all sites (Figure 4).

Figure 4. Manganese trends in air by day of week and month of year



Health Implications

ATSDR develops minimal risk levels (MRLs) based on scientific literature that evaluates exposure to specific pollutants and their associated health effects in human or animal studies. Ambient air concentrations lower than their corresponding MRL are not likely to cause harmful health effects. Because MRLs are often much lower than effect levels, ambient air concentrations greater than MRLs are not necessarily levels of air pollution that would present a possible public health hazard. Rather, these chemicals require further evaluation. In addition to the MRL, ATSDR considered health guidelines published by other agencies. In our evaluation, the air sampling results were compared to ATSDR MRLs, and U.S.EPA Reference Concentrations (RfCs). These health guidelines are defined, below:

- ***ATSDR inhalation MRLs*** are estimates of the concentrations of pollutants calculated that anyone could be exposed to without experiencing health effects, based on chronic, intermediate, and acute exposures (those occurring longer than 365 days, from between 14-365 days, and 14 days of exposure or less, respectively.)
- ***U.S. EPA RfCs*** are estimates of the concentrations of pollutants calculated that anyone could be exposed to for a lifetime without experiencing health effects. RfCs are for inhalational exposures and based on pollutant specific non-cancer health effects.

Evaluation of exposure

Manganese is a naturally occurring element that is used in steel production. It is also found in trace amounts in soils, coal, and other resources throughout the United States. Manganese is an essential nutrient for neurological function and intake from dietary sources is necessary to maintain normal health. At high concentrations, manganese is a known neurotoxin and causes neuromotor and neuropsychological deficits. Most of these studies are occupational, but some studies have evaluated non-occupational exposures to manganese from environmental exposures. Some non-occupational studies have suggested decreased neuromotor function from relatively low ambient exposures while others found no associations.[7]

The highest concentrations of manganese measured in the TSP filters during the monitoring period were at the Water Plant monitoring station; 8.6 $\mu g/m^3$ (monthly average) and 32 $\mu g/m^3$ (daily). The total average for this monitoring site from 1999 through 2009 exceeded the ATSDR chronic inhalation MRLs for manganese of 0.3 $\mu g/m^3$ and the U.S.EPA chronic RfC of 0.05 $\mu g/m^3$ 90% and 100% of the time, respectively. In the 2015-2016 monitoring data, 100% of monthly averages exceed both the ATSDR MRL and the U.S.EPA RfC. It should be noted that the MRL and RfC values are based on the respirable fraction of manganese-containing particulates (less than 10 microns in aerodynamic diameter).

Occupational and animal studies

Occupational studies have found deficits in motor skills (such as finger tapping, reaction time, hand-eye coordination, etc.) in workers with chronic manganese exposures between 27-1590 $\mu g/m^3$. [7,8,9]

The ATSDR MRL and EPA RfC are based on an occupational study of workers exposed to manganese in a battery factory.[10] These workers were exposed to an average of 215 $\mu g/m^3$ and

948 μg/m^3 manganese (respirable and total dust, respectively) for approximately 5 years. Neurobehavioral evaluation of manganese-exposed workers found that they scored significantly worse than the unexposed control group on tests of simple reaction time, eye-hand coordination, and hand steadiness. Using benchmark dose (BMD) analysis of the abnormal eye-hand coordination scores, the exposure concentration associated with a 5% response was determined to be 73.2 μg/m^3. After adjusting for continuous exposures from the intermittent to continuous exposure and the application of a 100-fold uncertainty factor (10 for human variability times 10 for database uncertainties including a lack of reproductive and developmental effects data), the ATSDR MRL was calculated to be 0.3 μg/m^3.[7]

The occupational study that is the basis of the MRL and RfC evaluated exposure for manganese particles less than 5 microns. These particle sizes are considered to be the "respirable fraction", which travel past the upper respiratory system to enter the lungs. The manganese air measurements collected in East Liverpool are total suspended particulate matter. Initial characterization of particles on the TSP filters from East Liverpool indicates an aerodynamic particle size range of 4.4-24.3 microns.

Non-occupational studies (sensitive populations)

Unborn babies, nursing infants, and young children are more likely to experience potentially damaging deposition of manganese in the brain than adults exposed to manganese. Research studies show that excess manganese deposition in the brain can occur from oral exposure in newborn rats increases (25 or 50 mg/kg/day manganese chloride) at a greater rate than adults (2-fold higher) than brain manganese concentrations in adult rats exposed to the same oral dose levels.[11] Further, newborn rats with inhalation exposure to aerosols of manganese sulfate (1 mg/m^3) showed a similar 2.6-fold increase brain manganese concentrations, compared with controls, while nursing females exposed to the same aerosol concentration showed a 1.7-fold increase compared with controls.[12] Physiologically based pharmacokinetic (PBPK) modeling validated with biological human data (blood, milk, etc.) for inhaled manganese in lactating mothers and their babies indicate that manganese air concentrations in the brains of babies and young children may increase beyond 10% of background concentrations when air concentrations exceeded 0.01 mg/m^3 (10 μg/m^3) and in nursing babies when air concentrations exceeded 0.001 mg/m^3 (1 μg/m^3).[13] This study suggests that brain concentrations begin to rise in human fetuses with maternal inhalation exposures beyond 10 μg/m^3 and nursing infants with inhalation exposures beyond 1 μg/m^3 under normal dietary manganese exposure conditions.

Only a few studies have evaluated non-occupational exposures to manganese, resulting from environmental exposures. A study of 8 communities in a mining district in Mexico found a statistically significant association between manganese concentrations in air and altered neuromotor function in the study population of 288 residents living at various distances from the mining operations.[14] Manganese concentrations in air ranged between 0.003 and 5.86 μg/m^3, with an average concentration of 0.42 μg/m^3. Interestingly, there was no correlation between blood manganese levels and the motor tests. However, since manganese is an essential nutrient for neurological function, intake from dietary sources is necessary to maintain normal health. Since the contribution of dietary sources to blood manganese levels is significant, distinguishing the impact of environmental manganese exposure can be a significant challenge.

Another study examined low-level environmental manganese exposures in southwest Quebec.[15,16,17] Limited TSP air sampling data at four locations near a closed ferro and silico-alloy plant over 4 days showed manganese concentrations in the range of 0.009-0.035 μg/m^3 (Baldwin et al., 1999). The study concluded that elevated blood manganese was associated with deficits in nervous system function.[16,17] Individuals with the highest blood manganese levels were those living in areas with highest airborne manganese and having the highest consumption of leafy green vegetables and manganese-rich cereals.[15]

Health study conducted in East Liverpool

A health study was conducted in East Liverpool and in another airborne Mn exposed community (Marietta, OH) evaluating the potential health effects from exposure to manganese in ambient air compared to an unexposed community (Mt. Vernon, OH). All participants underwent a neuropsychological battery of tests of mood, motor, and cognitive function and had a comprehensive health questionnaire administered. Exposures in both communities were estimated from ambient air measurements of manganese over 10 years.[18] In relationship to the concentrations of Mn in air, the study found:

- After taking into account levels of education and town of residence, increasing modeled airborne Mn levels were found to be associated with lower neuropsychological test scores and were also negatively correlated with motor function and tremor.[19,20]
- Associations were found between exposure and the use of prescription and over the counter medications, with increasing Mn exposure associated with an increased likelihood of taking pain medications.[21]

Conclusions and Recommendations

U.S. EPA asked, "***are current concentrations of manganese being measured in ambient air around the site a threat to human health***?" Our opinion is yes, based on the following conclusions:

- Air measurements at the Ohio monitoring locations are higher since 2015 than they were when ATSDR reviewed data for this site in 2010 and determined that emissions posed a health hazard.
- Research published since ATSDR's 2010 Health Consultation suggests that the exposure of young children to manganese in air at levels present in this community could result in increased brain deposition of manganese. Since it is a neurotoxin, high exposures resulting in brain deposition of manganese could cause decreased neuropsychological function. Further, a health study of adults in East Liverpool has demonstrated an association between manganese exposure in this community and poorer neuropsychological health outcomes.
- Previous enforcement actions have not successfully reduced long term exposure to airborne Mn.
- Residents live adjacent to where measurements of airborne Mn are highest.

Recommendation:

The exposures in this community represent a public health hazard and should be mitigated as soon as possible to reduce harmful exposures. Enforcement agencies should immediately act to identify the processes on site that are releasing manganese to the air, and work with SH Bell to implement time critical strategies to reduce airborne Mn releases into the community.

Please contact ATSDR if you require any additional assistance, and do not hesitate to contact me at 312-886-1462 if you have any questions regarding this letter.

Sincerely,

Michelle A Colledge_____

Michelle Colledge, MPH, PhD
Environmental Health Scientist
Agency for Toxic Substances and Disease Registry
Division of Community Health Investigations
Central Branch, Region 5

CC:
Shilpa Patel, U.S. EPA
John Matson, U.S. EPA
Nathan Frank, U.S. EPA
George Bollweg, U.S. EPA
Ed Nam, U.S. EPA
Eileen Furey, U.S. EPA
Mark Johnson, ATSDR/ DCHI/CB
Rick Gillig, ATSDR/ DCHI/CB
Tina Forrester, ATSDR/ DCHI/OD

Enclosures:
General Site Profile Map
Population Density Map

References

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SH Bell

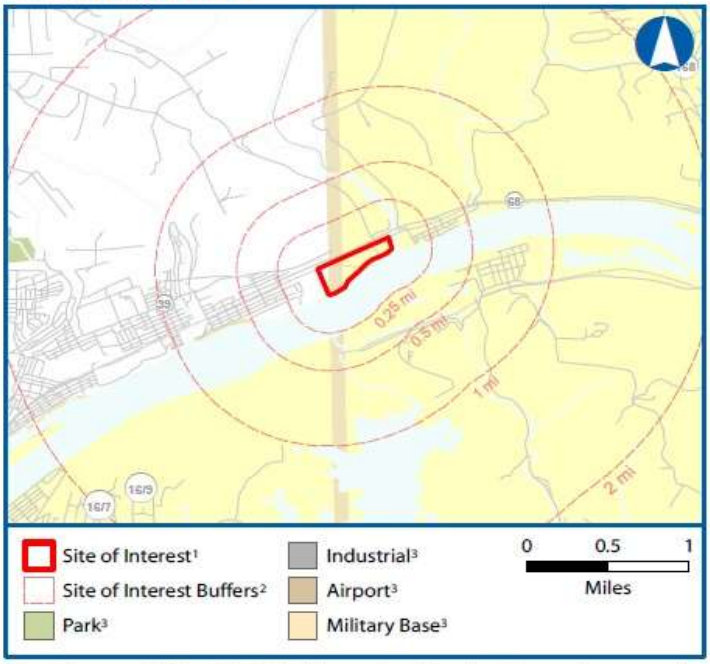
East Liverpool, Columbiana County, OH

GENERAL SITE PROFILE

EPA FACILITY ID: UNAVAILABLE

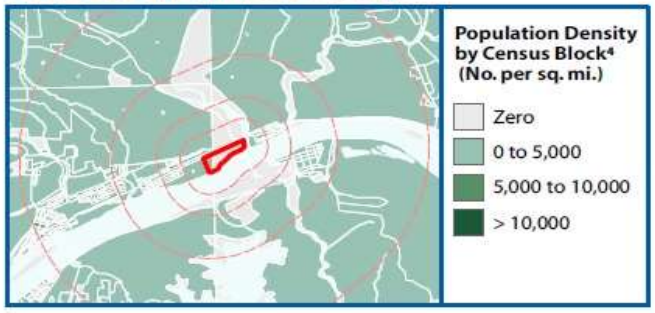
INTRODUCTORY MAP SERIES

Site Vicinity Map

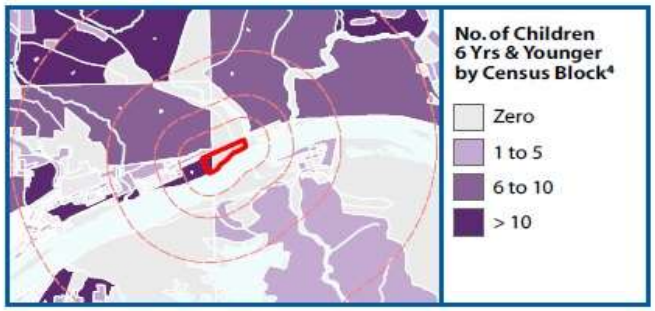


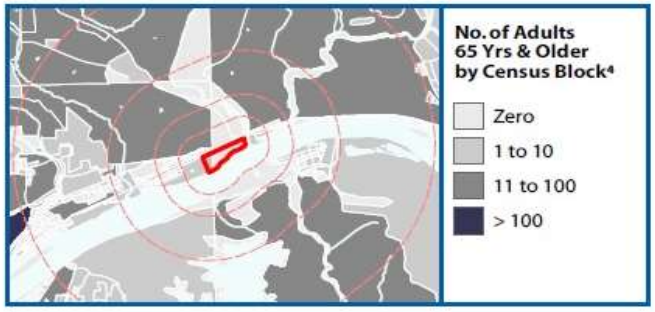
The **General Site Profile Map** depicts the hazardous waste site of interest, along with any airport, industrial, military, or park land uses. It also provides community demographic and housing statistics.

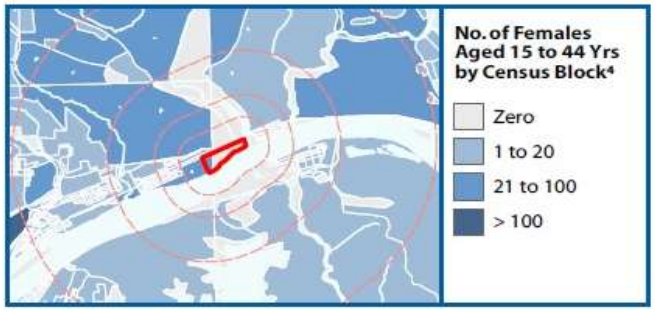
General Population Density



Sensitive Populations







Demographic Statistics[4,5]

Within 1 Miles buffer of site boundary

Measure	2000	2010	Change
Total Population	1,550	1,291	-16%
White Alone	1,462	1,215	-16%
Black Alone	57	50	-12%
Am. Indian & Alaska Native Alone	4	1	-75%
Asian Alone	4	3	-25%
Native Hawaiian & Other Pacific Islander Alone	0	1	N/A
Some Other Race Alone	0	0	+0%
Two or More Races	20	21	+5%
Hispanic or Latino[6]	11	10	-9%
Children Aged 6 and Younger	136	104	-23%
Adults Aged 65 and Older	250	173	-30%
Females Aged 15 to 44	326	251	-23%
Housing Units	633	579	-8%
Housing Units Pre 1950	429	367	-14%

Data Sources: [1]ATSDR GRASP Hazardous Waste Site Boundary Database. [2]ATSDR GRASP. [3]TomTom International BV (2012). [4]US Census 2010. **Notes:** [5]Calculated using area-proportion spatial analysis method. [6]Individuals identifying origin as Hispanic or Latino may be of any race.
Projection: Projection used for all map panels is NAD 1983 StatePlane Ohio North FIPS 3401 Feet.

PRJ 03477 JXA0 8/10/16

GRASP

Agency for Toxic Substances and Disease Registry

Division of Toxicology and Human Health Sciences

ATSDR

FINAL - FOR PUBLIC RELEASE

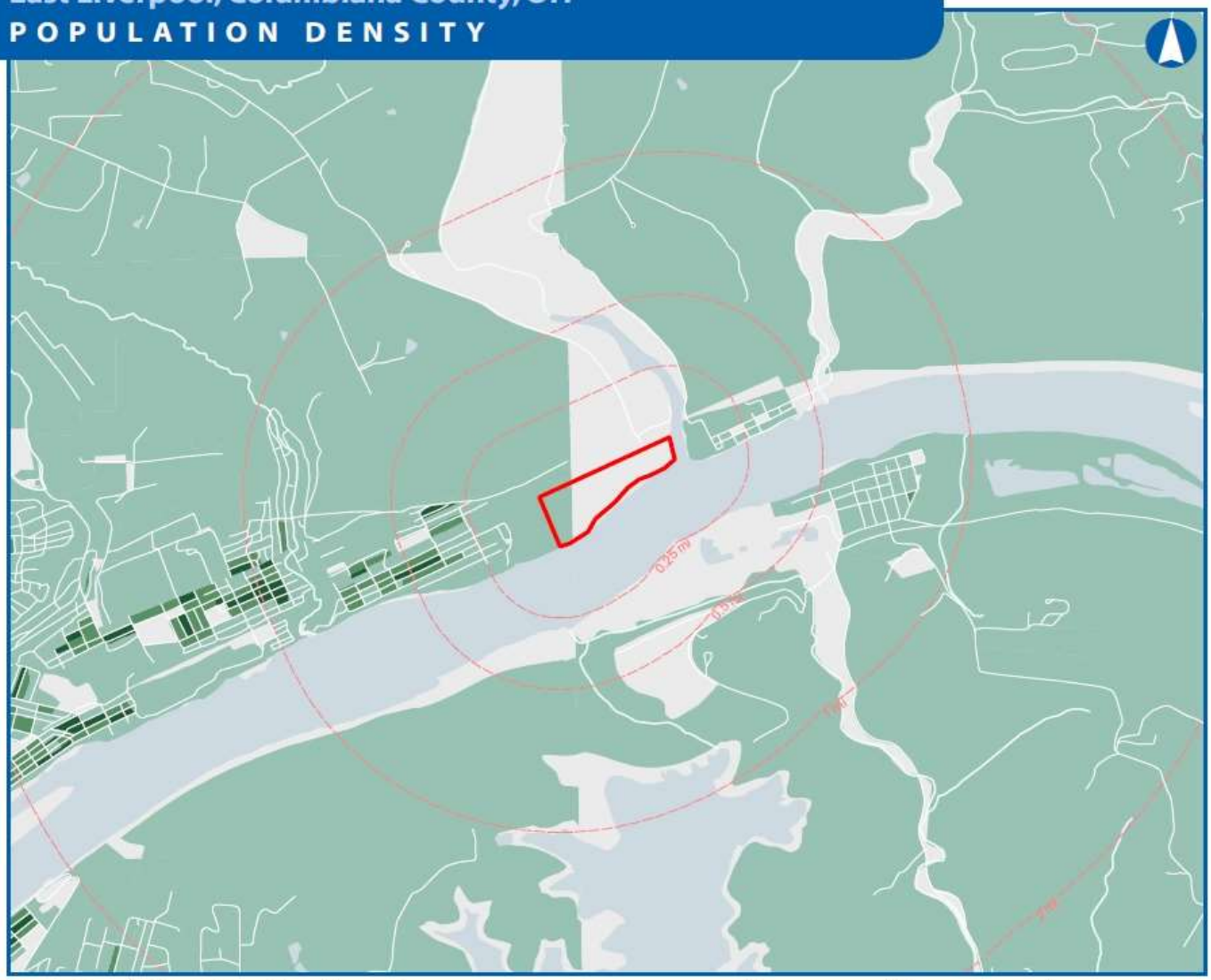
SH Bell

East Liverpool, Columbiana County, OH

POPULATION DENSITY

EPA FACILITY ID: UNAVAILABLE

INTRODUCTORY MAP SERIES



The **Population Density Map** depicts the site of interest and the distribution and number of people residing in the surrounding community. The distribution of population in and around a site is critical to understanding a community's potential for exposure to hazardous substances.

Based on US Census 2010 statistics, **32,950** individuals reside within a **5-mile buffer** of the site of interest.

Site of Interest

- Site of Interest[1]
- Site of Interest Buffers[2]

Population Density by Census Block[3] (No. per sq. mi.)

- Zero
- 0 to 5,000
- 5,000 to 10,000
- > 10,000

Healthcare Facilities

- Hospitals[4]
- Urgent Care[5]

0 0.5 1

Miles

Total Population[3,6]

Within specified distance of site boundary

Distance	2000	2010	Change
0.25 mile	122	115	-5%
0.50 mile	463	428	-7%
1 mile	1,550	1,291	-16%
3 miles[7]	16,030	14,539	-9%
5 miles[7]	36,666	32,950	-10%

Data Sources: [1]ATSDR GRASP Hazardous Waste Site Boundary Database. [2]ATSDR GRASP. [3]US Census 2010. [4]Oak Ridge National Laboratory (2013).[5] TomTom International BV (2012).
Notes: [6]Calculated using area-proportion spatial analysis method. [7]Buffer not shown.
Projection: NAD 1983 StatePlane Ohio North FIPS 3401 Feet.

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GRASP

Agency for Toxic Substances and Disease Registry

Division of Toxicology and Human Health Sciences

ATSDR

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