Vapor Intrusion Mitigation and Remediation of Mercury-Impacted Soil and Groundwater

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ABSTRACT: Addressing vapor intrusion issues for mercury-impacted soil and groundwater is challenging due to the complexity of mercury in the environment. Because mercury in soil and groundwater is found in multiple forms with varying levels of toxicity and mobility, a complete evaluation of mercury pathways is required. To assess the pathways and mobility of mercury, speciation analysis must be conducted to establish mercury's form and its associated risks. A conceptual site model is key to understanding the risks associated with mercury impacts in the presence of other constituents of concern and developing an effective remedial approach.

Mercury speciation testing was conducted on representative soil and groundwater samples to establish the overall form and mobility of mercury. The mercury speciation results and conceptual site model identified the vapor pathway to be the major risk associated with the mercury-impacted soils. A vapor intrusion assessment was conducted to assess the potential impact of benzene and mercury vapors on nearby structures. The vapor intrusion assessment identified significant mercury vapors in sub-slab soil gas and indoor air resulting in an Immediate Environmental Concern (IEC) as defined by the New Jersey Department of Environmental Protection (NJDEP). A sub-slab depressurization system was installed to address benzene and mercury vapor intrusion. The depressurization system was effective at reducing the benzene vapors but not fully effective for mercury. Additional testing was conducted to evaluate the effectiveness of the mitigation system and the cause of continued mercury vapor detections in indoor air. This testing confirmed effective mitigation of sub-slab mercury vapors and determined that building materials were the source of continued mercury indoor air concentrations. Furthermore, treatability testing was completed on representative soil and groundwater samples to establish the fate of mercury and benzene when subjected to potential remedial alternatives. A conceptual site model based upon the results of treatability and speciation testing enabled development of an effective remedial strategy. A pilot study of several applicable soil and groundwater technologies was conducted to confirm and develop design parameters for full-scale remedial action implementation.

Based upon the findings of the conceptual site model and treatability and pilot-scale testing, an effective site-wide remedial strategy was developed to address benzene and mercury in soil and groundwater. The remedial actions completed at this site confirmed the effective use of the conceptual site model to address key risk receptors associated with the contaminants and to develop an effective remedial approach.

INTRODUCTION

A conceptual site model for mercury-impacted soil and groundwater is a critical assessment tool in developing an overall site remedial strategy. A complete evaluation of mercury pathways in the environment is required, because various forms of mercury found in soil and groundwater have different levels of toxicity and mobility. Speciation analysis is an important part of assessing the pathways, mobility and exposure risk for mercury in the environment. The conceptual site model had to account for various commingled levels of benzene and mercury and the potential synergistic effects of the two compounds interacting in the environment.

A site in New Jersey was assessed to determine the appropriate remedy to address mercury in soils and groundwater. A conceptual site model was developed to allow a better understanding of mercury occurrence and mobility. The site is complicated by benzene contamination in soils and groundwater. The conceptual site model had to account for various commingled levels of benzene and mercury and the potential synergistic effects of the two compounds interacting in the environment. Mercury speciation testing was conducted on representative soil and groundwater samples to establish the overall forms and mobility of mercury. Additionally, treatability testing was completed on representative soil and groundwater samples to evaluate the fate of mercury and benzene when subjected to potential remedial alternatives and to develop a site-specific impact to groundwater soil remediation standard.

Based upon the results of the treatability and speciation testing, a conceptual site model was developed to facilitate an effective remedial strategy. A vapor intrusion (VI) assessment was also conducted to evaluate the impact of benzene and mercury vapors on nearby structures. The VI assessment identified mercury vapors under the sub-slab of one building and at lower concentrations in the indoor air. The VI assessment helped refine the overall conceptual site model to ensure any proposed remedial actions adequately addressed the vapor migration pathway. Based upon the results of the vapor intrusion assessment, VI mitigation was conducted to address indoor air quality (IAQ).

Site Description. The site is a 0.5-acre (0.2-hectare) parcel located in a mixed commercial/ residential area, bordered by a river to the east and commercial facilities to the north, south and west. A wholesale distribution facility currently owns and operates a warehouse building and loading dock at the site. Review of historic maps and previous reports indicates that the site building was constructed in 1952, and was occupied by a chemical manufacturing company from 1968-1979. During the chemical company's occupancy, site operations consisted of a bactericide/fungicide. The wholesale distributor has occupied the site since 1999.

The site is underlain by stratified deposits of low permeability clays at depths between 12 and 34 feet (3.7 to 10.4 m) below ground surface (bgs). These clays contain silt and occasional sand lenses. The low-permeability clays are overlain by sand and gravel. Silt underlies the sand and gravel in the western portion of the site at a depth of about 15 feet (4.6 m) bgs. However, clay and silt underlies the sand and gravel unit continuously across the rest of the site. Alternating zones of sand, clay and silt occur cyclically from 12 to 15 feet (3.7 to 4.6 m) bgs down to bedrock. The discontinuity of fine-grained lenses allows pore waters to migrate downward via circuitous pathways of interconnected sand lenses within the larger clay and silt zones.

Perched water sits atop the first clay and silt horizon across portions of the site. This perched water extends across the entire eastern length of the property from north to south at between 12 to 16 feet (3.7 to 4.9 m) bgs. The sand and gravel layer in the perched zone is more permeable than the clay and silt layer and may behave as a preferential flow pathway. Soils underlying the central portion of the site consist of thin inter-fingered beds of clay, silt and sand. This zone allows more vertical flow of groundwater as the perched water does not appear.

CONSTITUENTS OF CONCERN

The site-related constituents of concern are benzene and mercury, which were used in the manufacturing of the bactericide/fungicide. Benzene and mercury have been detected in both soil and groundwater above applicable remediation criteria. The raw materials used to make the bactericide/fungicide were benzene (a volatile liquid), mercuric oxide (HgO, a powder) and acetic acid. The bactericide/fungicide (phenylmercuric acetate (PMA)) is an organomercury compound manufactured by heating benzene and mercuric acetate. Under aerobic conditions, *in situ* biological processes reverse the manufactured reaction with conversion to elemental mercury and benzene (Nelson, et al., 1973).

MERCURY DISTRIBUTION IN SOIL

Historical data indicated that mercury concentrations in soils are sporadic and heterogeneous throughout the unsaturated soil column. Total mercury concentrations exceeding 1,000 mg/kg occur in surface soils and to a maximum depth of 17 feet (5.2 m) bgs, but do not extend to groundwater. The majority of total mercury concentrations range from 100 to 500 mg/kg. In most areas there is a buffer of clean unsaturated soils below the soil exhibiting mercury concentrations above criteria.

Figure 1 illustrates the extent of mercury concentrations in soils above the most stringent residential direct contact soil remediation standard applied to a geologic cross-section, in several locations and at various depths across the site. The extent of these exceedances is discontinuous and concentrated in three areas with a few outlying occurrences.

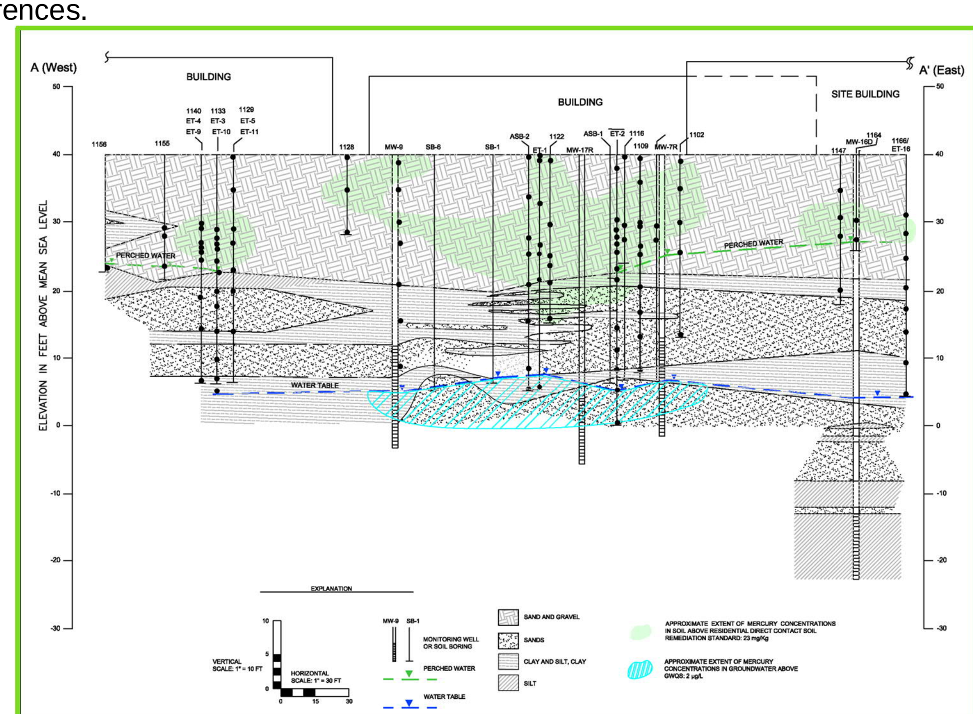

Figure 1. Mercury Concentrations in Soil

A site-specific impact-to-groundwater total mercury concentration was developed using the Synthetic Precipitation Leaching Procedure (SPLP). Representative samples from areas of concern (AOCs) with mercury impacts were sampled for total mercury and SPLP. The results were used to develop a site-specific impact-to-groundwater remediation standard of 93 mg/kg.

Mercury Speciation in Soil. Mercury speciation analysis was conducted on 10 soil samples using EPA Method 3200. In this method, the sample is divided into two phases: a liquid extract obtained by acidic treatment ("extractable mercury") and the remaining solid phase ("non-extractable mercury"). The liquid phase is further treated to separate the organic and inorganic mercury species. The solid phase is further treated to extract a semi-extractable phase. Each phase is assumed to consist of specific mercury species.

Table 1 presents a summary of the mercury speciation analysis results. The results revealed that the majority of the mercury detected in soils is in two primary forms: non-extractable/non-mobile or non-extractable/semi-mobile. The results also indicated that benzene concentrations intermixed with soils containing mercury do not appear to be affecting the form of mercury, as there was no correlation in speciation results with benzene concentrations. These results indicated that the potential for vertical migration of mercury in soils is limited considering the general absence of mercury exceedances at depths below 17 feet.

There was no correlation between lithology and the speciation of mercury in groundwater. However, the soil borings with the highest semi-mobile mercury concentrations were located in the same area. The depths of these samples were disparate at 0-1 feet (0-0.3 m) and 11-11.5 feet (3.3-3.5 m).

Table 1. Summary of Soil Mercury Delineation Results
Mercury Species by Selective Solvent Extraction and Acid Digestion

	Step Description:	Total mercury	Extractable Inorganic Mercury	Extractable Organic Mercury	Non-extractable Non-mobile Mercury	Non-extractable Semi-mobile Mercury		Methyl Mercury
	Typical Compounds:	All mercury-containing species	$HgCl_2$, $Hg(OH)_2$, $Hg(NO_3)_2$, $HgSO_4$, HgO, Hg^{2+} complexes	CH_3HgCl, CH_3CH_2HgCl	Hg_2Cl_2 (major), HgS, HgSe	Hg^o or Hg^o-M, Hg^{2+} complexes, Hg_2Cl_2 (minor)	Sum of Extraction Results	CH_3Hg+
Sample Number	**Sample Depth (feet)**	(mg/kg)	(mg/kg or percent)	(mg/kg or percent)	(mg/kg or percent)	(mg/kg or percent)	(mg/kg)	(mg/kg)
		914	0.0467	0.23	846	113	959	1.28
1101	9.5-10	--	0.005%	0.02%	88%	12%	--	--
		56.1	1.67	1.0	37.3	10.8	51	0.040
1103	11-11.5	--	3.3%	2.0%	73%	21%	--	--
		579	0.008 M	0.25	546	14	560	1.29
1104	14-14.5	--	0.001%	0.04%	98%	2.4%	--	--
		237	0.004	0.10	209	42	251	0.673
1110	10-10.5	--	0.002%	0.04%	83%	17%	--	--
		145	1.42	29.5	53.4	31.9	116	0.0495
1115	15.5-16	--	1.2%	25.4%	46%	27%	--	--
		1,770	53.3 M	0.43 M	491 M	868 M	1,413	0.649
1116	11-11.5	--	3.8%	0.03%	35%	61%	--	--
		0.167	0.0028	0.008	0.0354	0.079	0.125	0.000083 U
1122	0-1	--	2.2%	6.3%	28%	63%	--	--
		26.9	0.099 J	1.39 J	32 J	12.4 J	46	0.0894
1142	17-18	--	0.2%	3.0%	70%	27%	--	--
		413	24.4	0.09	364	0.14	389	1.32
1148	13-13.5	--	6.3%	0.02%	94%	0.04%	--	--
		325	0.0037	0.001	178	85	263	0.11
ET-1	0-0.5	--	0.001%	0.0004%	68%	32%	--	--

Notes:
Results listed in milligrams per kilogram (mg/kg) and percent of the sum of the extractions.
Shading indicates fractions that represent greater than 30% of sum of extractants.

Mercury Speciation in Groundwater. Total mercury concentrations in groundwater across the site have been horizontally and vertically delineated. Historically, mercury has been detected in 15 wells associated with this site. However, recent groundwater monitoring results indicate that mercury is only detected in one well at low concentrations just slightly above the groundwater quality standard (GWQS) of 2 µg/L.

Mercury speciation of selected groundwater samples was conducted as part of a remedial investigation to define the various fractions of mercury at the site. Methyl mercury, which is more toxic and more mobile than inorganic mercury species, was detected in all five samples at very low concentrations, ranging from 0.05 to 3.8% of total mercury. Elemental mercury is considered semi-mobile and is less toxic than more soluble inorganic mercury species such as mercury chloride. Elemental mercury was identified at concentrations that were less than methyl mercury in all but one of the wells. Acid-labile mercury is considered reactive mercury species, such as mercury chloride. The concentration of acid-labile mercury was greatest in one well, where it constituted

72% of total mercury, indicating that mercury may be more mobile at this location than at others tested. This is consistent with the nature of mercury found in soils in the vicinity of this well, which was reported to potentially be semi-mobile.

The mercury speciation groundwater results confirmed that the majority of mercury detected in groundwater is of less mobile form and significant migration of mercury would not be expected. Furthermore, minimal methyl mercury was detected in the groundwater samples, confirming that the mercury present in groundwater is a less toxic and less mobile form.

EXPOSURE PATHWAYS

Three potential exposure pathways were identified: dermal contact, ingestion, and inhalation of vapors. Mercury has been detected in surface soils, indicating that direct contact is a potential human health exposure pathway. A large portion of the site is paved, which provides an engineering control to prevent potential exposure to surface soils. Groundwater is generally encountered at 35 feet (10.7 m) bgs, and no potable wells are in the area of the site; therefore, the potential for human health exposure through ingestion is not likely.

VI assessments conducted at the site indicated that mercury and benzene are present in soil gas in the immediate areas of the occupied buildings, demonstrating the potential for vapor migration.

The primary potential ecological receptor of benzene and mercury in the site vicinity is the nearby river, which lies approximately 300 feet (91 m) east of the site. However, monitoring wells downgradient of the impacted media continue to indicate that the contaminants have not migrated toward the river. No environmentally sensitive areas are present on the site or adjacent properties so there is minimal potential impact to ecological receptors.

FATE AND TRANSPORT

The principal migration routes of mercury are similar to those for benzene. Also, mercury is present in surface soil so it may be transported in particulate form. Vertical mercury transport through subsurface soil appears to be more limited than transport for benzene, which likely reflects binding to soil that limits migration. The limited extent of mercury detections in groundwater, particularly compared to the extent of mercury detections in soil, also indicates that attenuation has been an effective mechanism for limiting mercury mobility.

The principal migration routes of benzene are transport through subsurface soil to groundwater and volatilization. Benzene concentrations in groundwater have stabilized and the benzene plume is in equilibrium with benzene adsorbed to soil. Ongoing indigenous biodegradation has caused a reduction in the size of the plume and prevented downgradient migration. Natural attenuation has resulted in decreases in benzene concentrations in the plume, in soil and in air.

CONSTITUENTS OF CONCERN IN SOIL GAS

A VI assessment revealed that mercury was detected in near-slab soil gas samples collected from the vicinity of the site building and the adjacent building to the north at concentrations ranging from 1.2 microgram per cubic meter ($\mu g/m^3$) to 4,900 $\mu g/m^3$. These results indicated that elemental mercury present in soils is volatilizing into the soil gas present in the pore space of unsaturated soils. These results are also consistent with the speciation results, as a large percentage of the mercury in soils was elemental mercury, the only form that is volatile.

The regulatory agency developed site-specific soil gas and indoor air screening levels for the site. Additional sub-slab soil gas samples and indoor air samples were collected from within the site building, and the results revealed concentrations of mercury above the site-specific screening levels. Benzene was also detected in sub-slab soil gas samples and indoor air samples above screening levels but at lower concentrations than mercury. The highest concentrations were detected in the sub-basement of the building.

VAPOR INTRUSION MITIGATION

Initial mitigation efforts included repairing damaged concrete filled trenches and sumps in the sub-basement, sealing the entire sub-basement floor with an epoxy sealant to prevent deterioration and VI, and replacement of the exhaust fan system in the sub-basement. The mitigation efforts were conducted to address potential VI into the sub-basement as well as potential migration from the sub-basement to the adjacent warehouse. Photograph 1 shows the sealed sub-basement floor.

Photograph 1. Sealed Sub-basement Floor

Once these initial mitigation measures were completed, an additional round of IAQ samples for benzene and mercury was collected to evaluate the effectiveness of the mitigation efforts. The IAQ results for the post-mitigation sampling revealed mercury concentrations still exceeded the IAQ screening levels at the two locations within the warehouse at similar concentrations to previous sampling efforts. The benzene concentrations also exceeded the IAQ screening levels but at approximately 50% lower concentrations than the initial IAQ sampling event. While mercury was detected above the indoor air screening level in the sub-basement, benzene was not.

The initial post-mitigation IAQ sampling event indicated that mitigation measures reduced benzene concentrations but were less effective in addressing mercury concentrations in indoor air.

Sub-Slab Depressurization System. Since initial mitigation measures did not effectively address IAQ impacts, a sub-slab depressurization system was installed in the sub-basement. Based upon the square footage and the slab thickness of the sub-basement, two 2-inch diameter Polyvinyl Chloride (PVC) extraction sub-slab vents were installed 8-12 inches (20-30 cm) beneath the slab. The vents were connected through a manifold to an extraction fan that provided a vacuum to the sub-slab. The manifold directed the recovered sub-slab vapors to the inlet of the extraction fan that exhausted the recovered vapors to the building exterior. The blower included controls designed to maintain continuous operation of the venting system and included an audible alarm system and indicator lights. Vacuum gauges were included to confirm the appropriate vacuum was being maintained throughout the system.

Five flush-mounted vacuum monitoring points were installed to evaluate sub-slab vacuum and to optimize the induced negative pressure gradient beneath the slab. The sub-slab depressurization system provided monitoring of the overall effectiveness of the system, including pressure gauges to confirm overall system vacuum, methods to measure system airflow and an alarm that would notify occupants of any system malfunctions.

Figure 2 presents the layout of the extraction vents, monitoring points and blower location as well as confirmatory IAQ sample locations.

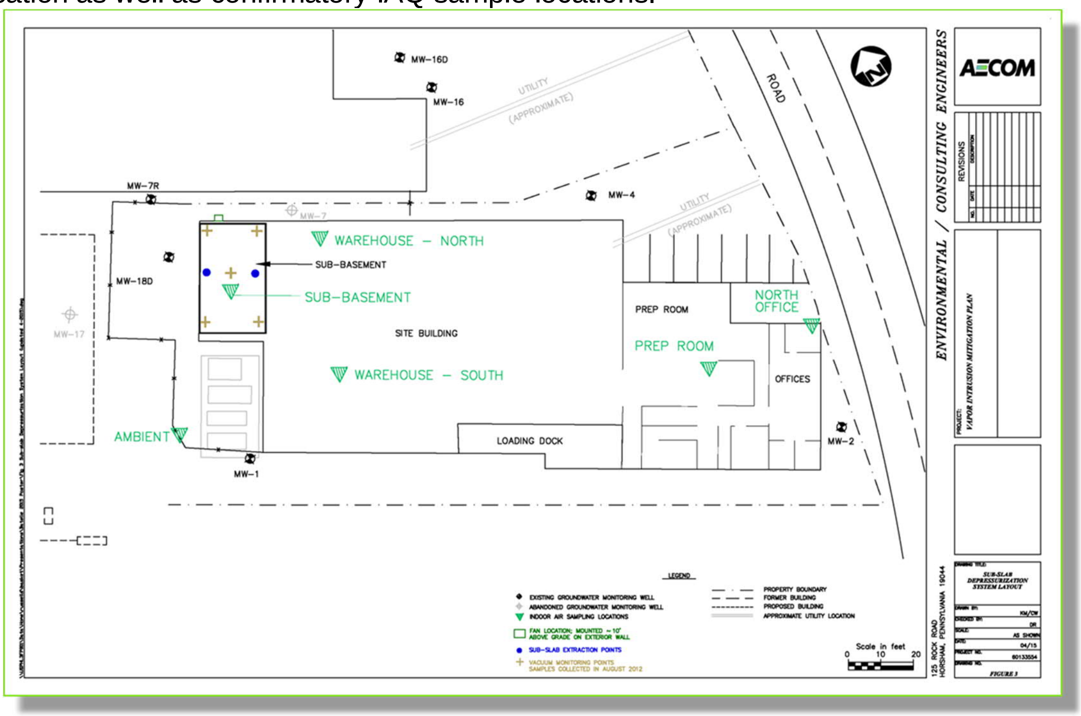

Figure 2. Vapor Intrusion Mitigation

During initial operation, the vacuum observed at the vacuum monitoring points ranged from 0.01 to 0.03 inches of water (0.025-0.075 millibar) with an overall system vacuum of eight inches of water (19.9 millibar). These measurements confirmed that the sub-slab depressurization system was effectively evacuating the sub-slab soil gas. The sub-slab depressurization system operated continuously since installation and effective depressurization has been maintained during operation.

VI Mitigation Confirmation Sampling. Approximately 40 days following continuous operation of the sub-slab depressurization system, a confirmatory IAQ assessment was conducted at locations previously identified with concentrations above indoor air screening levels. The initial mercury concentrations detected were comparable to the concentrations detected during the previous IAQ assessments with minimal reductions.

However, all benzene concentrations decreased compared to previous IAQ results to concentrations below the non-residential indoor air screening levels.

To evaluate the effectiveness of the sub-slab depressurization system, AECOM conducted sub-slab soil gas sampling for mercury with the sub-slab depressurization shut down and with the system operating to confirm effective evacuation. Based upon the results of the evaluation, the sub-slab depressurization system was determined to be effectively recovering mercury vapors from the sub-slab. Based on results from IAQ samples collected, the building materials appeared to be contributing mercury concentrations to indoor air. During the most recent IAQ sampling event, the analytical results revealed that only two IAQ samples had a mercury concentration above the site-specific non-residential IASL of 1 µg/m^3 (Table 2).

Table 2
Indoor Air Sampling Results - February 2019

			Parameter	Mercury (µg/m^3)	Benzene (µg/m^3)
			Previous Indoor Air Screening Levels (Non-residential):	1*	2
			2013 Indoor Air Screening Levels (Non-residential):	1**	2**
			Previous Indoor Air Rapid Action Level (Non-residential):	2*	14
			2013 Indoor Air Rapid Action Level (Non-residential):	2**	200
Matrix	**Location**	**Sample Type**	**Sample Date**	Mercury (µg/m^3)	Benzene (µg/m^3)
Indoor Air	Warehouse North	Monitoring	2/26/2019	**2.1**	1.7
Indoor Air	Warehouse South	Monitoring	2/26/2019	0.88	1.6
Indoor Air	Sub-Basement	Monitoring	2/26/2019	**10.0**	0.99
Indoor Air	North Office	Monitoring	2/26/2019	0.95	1.8
Indoor Air	Prep Room	Monitoring	2/26/2019	1.1	1.8
Ambient Air	Outside Upwind	Background	2/26/2019	0.14 U	0.54 J

NOTES

	Mercury and benzene concentrations are reported in micrograms per cubic meter (µg/m^3).
U	Not detected at reporting limit shown
J	Estimated concentration
2.1	Concentration exceeding respective Indoor Air Screening Levels
10.0	Concentration exceeding Indoor Air Screening Levels and Rapid Action Levels
*	Site-Specific Screening Levels are based on NJDEP memo dated January 28, 2011.
**	Analytical results for mercury and benzene were rounded to one signficant figure for comparis to screening levels in accordance with the Update To The New Jersey Department of Environmental Protection (NJDEP) Vapor Intrusion Screening Levels (March 2013)

Only the sample collected from the sub-basement sample showed a mercury concentration of 10.0 µg/m^3 above the Rapid Action Level (RAL) and Indoor Air Screening Level (IASL). One sample collected from the Warehouse area exceeded the IASL but not the RAL. All other IAQ sample mercury results, including samples from the occupied office areas and preparation room, were below the site-specific non-residential IASL and RAL. All IAQ samples had benzene concentrations at or below the non-residential IASL of 2 µg/m^3.

The mercury concentrations detected in indoor air revealed that while concentrations have decreased when compared to previous detections, it is evident that the building materials are contributing mercury concentrations to indoor air in the sub-basement.

Soil and Groundwater Remediation. Deed notices will be developed for the delineated soil impacts located at the adjacent properties in accordance with the NJDEP guidance. The deed notices will also comply with the requirements of a Remedial Action Permit (RAP). For those areas requiring engineering controls, the existing caps have been reviewed to determine if they comply with NJDEP's current requirements for capping. For those areas without a viable existing cap, engineering design of an asphalt cap has been developed for implementation in compliance with NJDEP's current capping guidance. Capping is proposed to address mercury and benzene direct contact and impact to groundwater exceedances in soils. To continue improving mercury and BTEX groundwater quality, the capping will be also designed in accordance with NJDEP's capping guidance to prevent further benzene and mercury soil impacts to groundwater due to precipitation infiltration. The post-remediation soil boring programs confirmed effective remediation of unsaturated soil benzene impacts through the interim remedial actions. In addition, the soil vapor sample collected in accordance with the NJDEP capping guidance revealed a benzene concentration below the Impact to Groundwater Soil Vapor Screening Levels (IGW-SVSLs), demonstrating that existing benzene impacts in the vadose zone do not pose a risk for impact to groundwater. Figure 3 presents the current benzene impacts and the location of the soil gas sample. Furthermore, the absence of benzene and significant mercury impacts to groundwater confirms effective remediation. Residual impacted soils will be addressed by institutional and engineering controls.

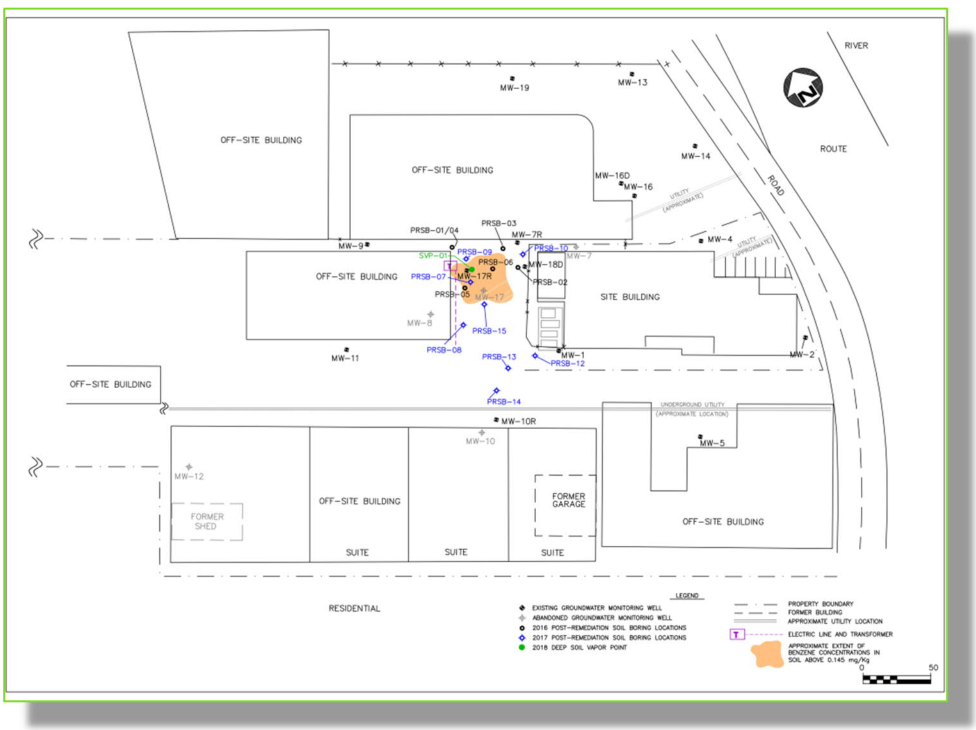

Figure 3. Benzene Concentrations in Soil

Inorganic contaminants such as mercury are primarily mobilized by and impact groundwater through groundwater recharge from infiltrating rainwater or runoff. Furthermore, the benzene soil vapor concentration in the area of vadose zone impacts was below the IGW-SVSL, indicating that capping is also applicable for residual benzene impacts. Low-permeability caps are useful as a means of addressing the IGW pathway by eliminating infiltration of rainwater. Figure 4 presents the asphalt capping plan for the impacted unpaved areas of the property.

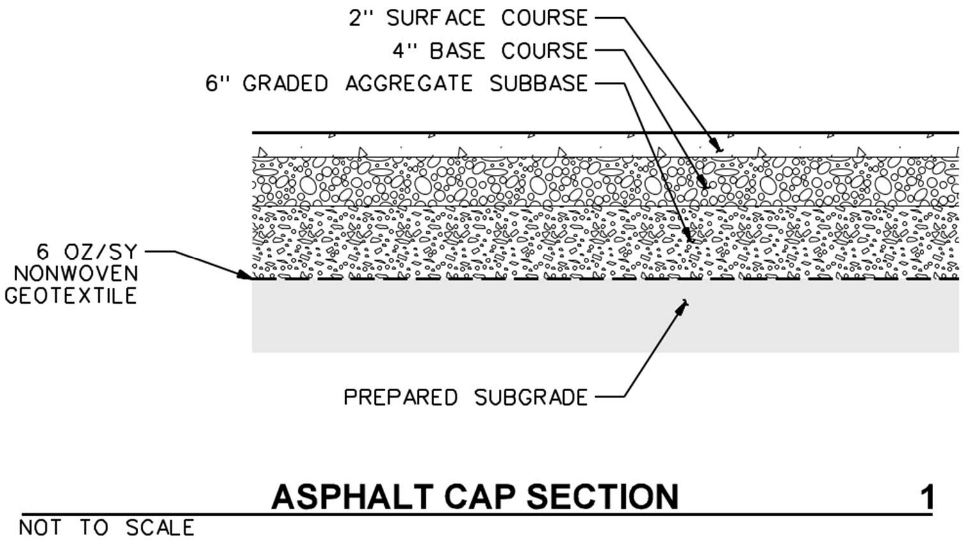

Figure 4. Capping Plan

The deed notices for each property will be filed with their associated property deed at the county clerk's office. The deed notices will include the specified engineering control as necessary. RAP applications will then be submitted for the deed notifications and engineering controls.

The remedial investigation, pilot study program, interim remedial action, and ongoing groundwater monitoring have confirmed that site groundwater conditions are amenable to a natural attenuation remedy. Natural attenuation was therefore selected as the proposed remedial action because impacts in the shallow and deep overburden groundwater have been delineated, and historical groundwater monitoring data has demonstrated that natural attenuation is occurring in the impacted aquifer. The post-remediation soil sampling program confirmed significant soil impacts have been addressed. Furthermore, the proposed engineering control (low-permeability cap) will address future infiltration to groundwater. Based on the most recent sampling event performed in March 2019, mercury is the only remaining COC detected above the GWQS. The mercury concentration is low and decreasing in this monitoring well.

Dissolved oxygen (DO) and oxidation-reduction potential (ORP) measurements of the aquifer have demonstrated aerobic conditions in the areas of impact, providing an environment conducive to aerobic biodegradation. Based upon the stable plume and overall decreasing trend in COC concentrations over time, natural attenuation is the applicable remedy for Site groundwater.

SUMMARY

Potential releases from a UST system associated with PMA manufacturing along the west side of the site building were identified as a source of benzene in soils and groundwater. Industrial sewer system discharges were identified as a potential source of mercury in subsurface soils. Other contaminant sources or manufacturing practices could have contributed to the occurrence of mercury and benzene in surface and subsurface soils in other parts of the site.

The primary forms of mercury characterized in soils have limited mobility with minimal expected impacts to groundwater. Total mercury concentrations above soil remediation standards do not extend to groundwater and in most areas there is a buffer of clean unsaturated soils below the delineated soils with mercury concentrations above criteria. The dispersed areas of mercury exceedances at the site indicate that there may be multiple sources of mercury.

The primary risk receptors at the site were potential human health exposure to impacted surface soils and VI to onsite and adjacent buildings. The groundwater plume is stable and shrinking in size and there is no evidence that the plume is migrating toward the adjacent river to the east. Groundwater use in the area is restricted, presenting minimal to no potential human health risk from groundwater. The observed concentrations of benzene and mercury in near-slab soil gas samples indicated that VI mitigation was required to address potential impacts of VI.

The VI mitigation system implemented successfully addressed benzene and mercury vapor intrusion in all occupied areas; however, the sub-basement indoor air was still impacted above screening levels. An evaluation of the sub-slab depressurization system confirmed effective recovery of sub-slab benzene and mercury vapors. The source of mercury vapors within the sub-basement has been attributed to residual mercury contamination in the building materials. Decontamination or demolition of the sub-basement would be required to further address indoor air mercury levels.

Based upon the findings of the conceptual site model and treatability and pilot-scale testing, an effective site-wide remedial strategy was developed to address benzene and mercury in soil and groundwater. The remedial actions completed at this site confirmed the value of the conceptual site model to address key risk receptors associated with the contaminants and to develop an effective remedial approach. Deed notices and engineering controls (capping) were used to address direct contact and impact to groundwater risks from impacted soils. Natural attenuation was identified as the effective remedial action for groundwater.

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