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Evaluation of Site Investigation/Closure Requirements and Their Applicability to Residuals from Former Manufactured Gas Plants

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PRODUCT DESCRIPTION

Free product is defined as the concentration of non-aqueous phase liquid (NAPL) that is present in concentrations greater than the residual saturation point of the site media at a contaminated location. Identifying free product is important for the management of former Manufactured Gas Plant (MGP) sites because the free product is mobile and has the potential to migrate off site. The report provides a review of the regulatory programs for six states in the mid-west and northeast with regard to closure requirements for source material and free product and evaluates their applicability to the effective management of former MGP sites.

Results and Findings

The regulatory review indicates that the issues related to environmental risk from free product are adequately addressed by the regulations and that the principal issue related to site closure is product mobility and its potential effect on the long-term success of the remedy. A review of the various approaches used by the states to identify and characterize free product indicates that approaches based on an evaluation of residual saturation provided the most appropriate evaluation of product mobility.

Challenges and Objectives

The information in the report may be useful to utility company managers and state regulators that are managing site investigation and remediation activities at former MGP sites in support of risk-based closure.

Applications, Values, and Use

The report provides a summary of representative regulatory requirements for identifying free product, and an evaluation of their applicability to MGP residuals. The evaluation also includes a review of state requirements for managing free product in support of site closure and provides several case studies to illustrate how free product has been delineated and closure effectively implemented.

EPRI Perspective

Field observations and constituent-based approaches (soil saturation and aqueous solubility) may not provide an accurate evaluation of mobile product at MGP sites. The results from these evaluations may be most appropriately used to supplement soil/groundwater information from site investigations to identify significantly impacted areas that require further evaluation for the presence of mobile product. More accurate information can be obtained from evaluations that use saturation/solubility values that reflect the effect of the complex composition of coal tar. Specific evaluations of mobile coal tar may best be conducted on the basis of residual saturation.

Approach

The preparation of the report included a review of the regulatory programs from six states with significant populations of former MGP sites. The authors reviewed regulations to determine the approaches provided for identifying free product and associated requirements for site closure. They subsequently reviewed the approaches with regard to the specific characteristics of coal tar to evaluate their appropriateness in managing the investigation and closure of former MGP sites.

Keywords
Non Aqueous Phase Liquid (NAPL)
Free Product
Residual Saturation
Soil Saturation
Aqueous Solubility

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1
INTRODUCTION

The Electric Power Research Institute (EPRI) has prepared this document to develop a basis to better understand the range of approaches that state regulatory agencies are using to define, delineate and regulate free product at contaminated sites. Free product has been defined in the technical literature as a non-aqueous phase liquid (NAPL) that is present at concentrations that are greater than the residual saturation point of the site media (EPRI, 2004b). When concentrations are less than the residual saturation point, the NAPL is immobile. Residual saturation is defined as the concentration of NAPL in media at which capillary forces are greater than gravity and hydraulic forces (Cohen and Mercer, 1993).The following discussion provides a summary of representative regulatory requirements for identifying free product, and an evaluation of their applicability to MGP residuals. The evaluation also includes a review of state requirements for managing free product in support of site closure, and provides several case studies to illustrate how free product has been delineated and closure effectively implemented.

2
STATE REGULATIONS

The evaluation has been conducted using regulatory information from six representative states where a significant number of former MGP sites are located. They are: Illinois, Ohio, Massachusetts, Wisconsin, Pennsylvania and Indiana. The evaluation includes a review of the definitions, identification criteria and closure requirements for free product, as well as a discussion of the associated regulatory mechanisms for closure, and criteria for the re-opening of a site. Discussions of the information for the individual sites are provided in the following sections and summarized in Table 2-1.

2.1 Illinois

The state of Illinois uses a risk-based program, Tiered Approach to Corrective Action Objectives (TACO), to manage contaminated sites in several regulatory programs including: the voluntary program, petroleum program; site remediation program; and RCRA program. The regulations are promulgated as Title 35, Section 742 of Illinois Administrative Code (IAC). The program is intended to provide a defined basis for site remediation, with the progress of site activities evaluated by Illinois EPA (IEPA) staff.

2.1.1 Definition and Criteria for Free Product

The TACO regulations define free product as "a contaminant that is present as a non-aqueous phase liquid for chemicals whose melting point is less than 30° C (e.g., liquid not dissolved in water)" (IAC 742.200). However, the regulations do not provide specific criteria for identification.

2.1.2 Closure Requirements and Mechanism

The TACO program was established to facilitate the redevelopment of contaminated properties through the cost-effective closure of sites based on practical approaches to eliminate risk. Potential human health/ecological risk can be addressed by several means, including: elimination of exposure pathways through legally enforceable instruments such as Groundwater Use Ordinances and Environmental Land Use Controls; compliance with risk-based constituent concentration levels in site media; and demonstration that constituent levels are similar to, or less than, background levels established by IEPA.

The program provides the following additional requirement that is not specifically related to risk: "to remove free product to the maximum extent practicable" (IAC 742.320(b)). Although the regulations do not provide a quantitative means to identify free product, they do include the following requirements in the form of maximum constituent levels in soil (soil attenuation capacity and saturation limit) and groundwater (aqueous solubility) that may indicate the potential for its presence.

Table 2-1
Summary of State Program Requirements Related to Free Product and Site Closure

State	Program and Goal	Free Product Definition	Identification Criteria	Closure Mechanisms		
				Risk	Free Product	Equivalent Requirement
Illinois	Tiered Approach to Corrective Action Objectives (TACO) - defined basis for site remediation	defined as non-aqueous phase liquid	no criteria provided	Pathway Elimination (Institutional Controls, GW Use Ordinances) Compliance with Risk Based Values or Background	removal to maximum extent practicable[1]	max. concentrations based on soil attenuation, soil saturation and aqueous solubility
Ohio	Voluntary Action Program (VAP)- liability protection	no specific definition	no criteria provided	Pathway Elimination (Institutional Controls) Compliance with Risk Based Values		max. concentration based on soil saturation
Wisconsin	Voluntary Party Liability Exemption (VPLE) - liability protection	defined as floating or sinking non-aqueous phase liquid	no criteria provided	Pathway Elimination (Institutional Controls) Compliance with Risk Based Values Listing with GIS Registry	removal to maximum extent practicable[1]	
Massachusetts	Mass. Contingency Plan - defined basis for site remediation	defined as a continuous separate phase observed in the environment	no criteria provided	Pathway Elimination (Institutional Controls) Compliance with Risk Based Values Temporary Solutions must be re-evaluated every 5 years	removal to <1/2 inch	
Pennsylvania	Act-2 Program - liability protection	no-specific definition, but evaluation underway to bring consistency to the Act -2 and UST programs	no criteria provided	Pathway Elimination (Institutional Controls, GW Use Ordinances) Compliance with Risk Based Values	no requirement	

State	Program and Goal	Free Product Definition	Identification Criteria	Closure Mechanisms		
				Risk	Free Product	Equivalent Requirement
Indiana	Voluntary Remediation Program (VRP) - liability protection	-1996 guidance references residual saturation	no criteria provided	Pathway Elimination (Institutional Controls) Compliance with Risk Based Values	removal to maximum extent practicable[2]	
		-2001 guidance references material that presents an acute threat; a material in excess of its solubility limit	-exceedance of soil saturation limits	Policy statement indicates preference for treatment/removal over Institutional/Engineering controls		max. concentrations based on soil saturation and aqueous solubility
		- proposed revision to 2001 guidance references a nonaqueous phase liquid	-exceedance of soil saturation limits			max. concentrations based on soil saturation

Notes: [1] Definition of "maximum extent practicable" not provided in state regulations

[2] Draft Guidance for Technical Impracticability currently under review

Soil – The TACO regulations provide the following requirements for site closure:

- "The sum of the concentrations of all organic contaminants of concern shall not exceed the attenuation capacity of the soil." (IAC 742.305). The evaluation is based on the natural organic carbon fraction of the soil. Default values are provided and a method is referenced for site-specific determination of organic content.
- "The concentrations of any organic contaminants of concern remaining in the soil shall not exceed the soil saturation limit." (IAC 742.305). The regulations provide default values as well as an equation for site-specific determinations.

Groundwater – "*A groundwater remediation objective that exceeds the water solubility of that chemical .. is not allowed*" (IAC 742.805 (b)). The regulations provide default values for aqueous solubilities.

IEPA issues a "No further Remediation Letter" once it has been demonstrated that the closure requirements of the program have been met. The regulations include a provision that sites can be re-opened if subsequent information determines that the remediation has failed to address significant harm to human health or the environment.

2.2 Ohio

The state of Ohio has developed a Voluntary Action Program (VAP) as a means to manage the investigation and clean up of contaminated sites and provide liability relief for site owners. The VAP is presented in the Ohio Administrative Code (OAC) 3745-300. Site progress under the VAP is evaluated by a Certified Professional (CP) rather than staff from the Ohio EPA.

2.2.1 Definition and Identification Criteria for Free Product

The VAP regulations do not provide a specific definition or criteria for free product, although the associated petroleum program uses a criterion of "0.01 ft. thickness of separate phase" (Revised Ohio Code 1301:7-9-02(B)(22)).

2.2.2 Closure Requirements and Mechanism

The VAP program provides closure for sites after a demonstration that there is no potential risk from current or future activities. The program provides default risk-based values for industrial and residential exposure scenarios, and allows for the use of Activity Use Limitations (AULs) to eliminate pathways when constituent concentrations exceed residential risk criteria.

Closure requirements under the VAP do not include a specific criterion for free product removal/treatment. However, they do include separate requirements for soil and groundwater that may affect the way that free product is addressed during remedial activities. For soil, the concentrations of constituents must meet a soil saturation limit. The soil saturation limits are constituent-specific, and can be derived from default values or from an equation to provide site-specific values (OAC 3745-300-08). The regulations also include a general requirement to prevent migration of dissolved phase contamination to a deeper aquifer (if not already contaminated) or off-site locations.

Case Study – Chlorinated Solvent Site, Norwood, Ohio

The property is located in a mixed commercial and residential area of Norwood, Ohio. The property is an approximately 15-acre asphalt-paved parking lot, with no visible structures. It is surrounded by commercial establishments, manufacturing properties and residential neighborhoods. Subsurface contamination in soil and groundwater have previously been detected on site. Historic contaminants include BTEX compounds, chlorinated solvents (primarily trichloroethene) and heavy metals. The owner of the property conducted a Phase I assessment to determine eligibility of the site for entry into the Ohio Voluntary Action Program (VAP), and to identify those areas that required investigation under OAC 3745-300-06(F).

The Phase II Assessment identified detectable levels of volatile organics, semi-volatile organics, polychlorinated biphenyls, metals and/or petroleum hydrocarbons in soil samples from the six areas. Groundwater from the following "zones" were classified in accordance with the requirements of OAC 3745-300-10:

- Groundwater from the Fill/Upper Till and Upper Sand-Layer Zones (Class B groundwater based on historic well yields (low) and hydraulic conductivity data) was confirmed to be contaminated by contaminants of concern above unrestricted potable use standards. In addition, these zones contained chlorinated solvent DNAPL detected in select monitoring wells. These zones did not require groundwater protection as specified in OAC 3745-300-10(E).
- The Lower Sand and Gravel Zone (classified as Class A (potable) groundwater based on historical yields reported in Ohio Department of Natural Resource (ODNR) documentation) met unrestricted potable use standards, and therefore required consideration for groundwater protection.
- A Lower Till and Lacustrine Clay Zone was determined not to contain VAP definable groundwater based on yield test results.

An Exposure Pathway Assessment was prepared in accordance with the guidance in OAC 3745-300-09 to evaluate potentially exposed human receptors, current and future, and identify potential exposure pathways associated with the property.

Important ecological resources were not identified as being present in or around the site during the Phase I and Phase II activities. The site is situated in a highly urbanized area and does not constitute a viable habitat for wildlife.

Site Closure
In response to the findings of the Exposure Pathway Evaluation, the owner filed the following deed restrictions:

- The site may only be used for commercial development and use.
- No person shall use the groundwater at, in, or under the site for any purposes, including potable and non-potable uses.
- No person shall in any way modify, alter, disturb, or divert the sewers located on, in, or under the site.
- The Owner must meet the requirements/restrictions for development of and construction at the site as detailed in the deed restriction language.
- No person shall excavate or cause or allow excavation of any soils located at, in, or under certain areas of the site without prior soil characterization, risk analysis, and proper soil management in accordance with the requirements set forth in OAC 3745-300 and as detailed in the deed restriction language.

- The Owner shall comply and shall ensure compliance with all applicable federal, state, and local environmental laws, regulations, and ordinances in connection with all uses and operations at the site.

Since the current and foreseeable land use at the site is commercial, the generic direct-contact soil standards for the commercial land use category were determined to be applicable standards for soil. The results from the Phase II demonstrated that soil sample results were in compliance with the Generic Direct-Contact Soil Standards for the Commercial Land Use Category.

- The applicable standards for groundwater at the site were met based on the following:
- On site groundwater use is prohibited through deed restriction.
- Engineering controls that include extraction of groundwater to control migration in the vicinity of the sewer backfill to eliminate future off site groundwater exposures.
- Exposures from volatilization of contaminants of concern from groundwater to indoor pathways was quantitatively eliminated due to the depth of groundwater and the deed restriction for no basements and/or building construction to include vapor liners, positive pressure buildings and/or sub-slab ventilation systems in certain restricted areas.

Based on the above, there were no complete exposure pathways at the site, and A No Further Action Letter was submitted to the Ohio Environmental Protection Agency (OEPA) on behalf of the site owner. The Ohio EPA concurred with the NFA and issued a Covenant Not to Sue for the site.

The regulations provide a provision for obtaining a variance from standards if it can be demonstrated that remediation is technically infeasible, or if "the costs of complying…substantially exceed the economic benefit;" and "the proposed alternative results in an improvement of environmental conditions at the affected property and will ensure that public health and safety will be protected" (OAC 3745-300-12).

Upon approval of a No Further Action Letter by the CP, the site owner is issued a Covenant Not to Sue by the Ohio EPA. The agency maintains the right to audit No Further Action Letters on the basis of a change in conditions or evidence of risk (OAC 3745- 300-14). Sites can be re-opened based on new conditions/information. The Covenant Not to Sue can be revoked under the following provisions:

- If it is determined that the work was done improperly or fraudulently
- If the requirements of the No Further Action Letter for additional work, maintenance of controls, or enforcement of use restrictions are not met
- If the remedial action no longer meets the regulatory performance requirements that were in effect at the time the covenant was approved.

However, the VAP does not include a provision to revoke a Covenant Not to Sue due to a change in regulation.

2.3 Wisconsin

The state of Wisconsin has created the Voluntary Party Liability Exemption, a process that is implemented by the Wisconsin Department of Natural Resources (WDNR) to guide the investigation and closure of impacted sites. The program is risk-based and relies on the use of Institutional and Engineering controls to eliminate exposure pathways as well as compliance with risk-based criteria for soil and groundwater. The regulations related to the investigation and

closure of contaminated sites are provided in the Wisconsin NR 700 series rules. Site progress in the program is evaluated by WDNR.

2.3.1 Definition and Identification Criteria for Free Product

The Wisconsin regulations define free product as "Discharged hazardous substance present as a floating or sinking non-aqueous phase liquid" (NR 700.03 (22)). The regulations do not provide specific criteria for identifying free product, although the associated petroleum program uses a criterion of "a thickness of > 0.01 ft as verified by more than one sampling event" (NR 746.03 (4)).

2.3.2 Closure Requirements and Mechanism

The closure requirements for the Wisconsin program mandate the elimination of human health/ecological risk. Deed restrictions are allowed to meet standards; however the sites must be listed with the WDNR GIS registry. Site owners must demonstrate that adequate source control measures have been taken and document plume stability within areas protected by deed restrictions.

The regulations require the "removal of free product to maximum extent practicable whenever it's necessary to halt or contain discharge of a hazardous substance or minimize harmful effects of the discharge" (NR 708.13).

A Certificate of Completion is issued by WDNR upon the determination that no further action is required. The certificate exempts the site owner from future liability. The conditions of the determination may require on-going inspections/monitoring as part of deed restrictions and the purchase of liability insurance may be required of the owner. Cases can be re-opened if information indicates a potential risk to human health/environment, and WDNR may establish a schedule for compliance.

Case Study – Former MGP Site, Wisconsin

The former MGP site operated during the period of 1910 to 1929. Site investigations conducted in 1996 identified an area of tarry soils in both the vadose and saturated zones that had adversely affected groundwater quality. Monitoring activities conducted from 1997 to 1999 demonstrated that the groundwater plume, i.e. constituent concentrations in excess of Wisconsin DNR Preventative Action Limits or Enforcement Standards, had not migrated to off-site locations.

In 2001, the utility company conducted a remediation program to reduce the mass of contaminant at the site, and eliminate the potential for direct contact with MGP residuals. The program resulted in the excavation of approximately 22,000 tons of impacted soil from the vadose zone (up to 18 ft. below ground surface). The excavated soil was processed in a direct-fired thermal desorption system, with the treated solids used as backfill at the site. Although MGP residuals remained in the saturated zone, with associated exceedances of Enforcement Standards, the utility company conducted a groundwater study that successfully demonstrated that natural attenuation processes were active at the site, and the plume of impacted groundwater was stable/shrinking.

In 2002, the Wisconsin DNR determined that the site had been "investigated and remediated to the extent practicable under site conditions" and closed the site. The site was then listed on the DNR Remediation and Redevelopment GIS Registry of Closed Remediation Sites without restrictions for future use.

2.4 Massachusetts

The Massachusetts Contingency Plan (MCP) provides a risk-based means of investigating/ closing contaminated sites. The MCP is presented in the Code of Massachusetts Regulations as 310 CMR 40, and is intended to evaluate potential risks and associated remedial actions, as well as prescribe the roles of agencies and responsible parties. Site progress is evaluated by a Licensed Site Professional (LSP), although the Massachusetts Department of Environmental Protection (MADEP) maintains the authority to audit the technical and administrative processes used to close specific sites.

2.4.1 Definition and Identification Criteria for Free Product

The MCP defines free product as "a continuous separate phase as measured in a groundwater monitoring well or otherwise observed in the environment" (310 CMR 40.0006), although no specific criteria are provided.

2.4.2 Closure Requirements and Mechanism

Under the MCP, site closure can be granted for the site or individual parcels based on the requirements of the following Response Action Outcomes (RAO):

- RAO A – when active remediation has occurred and there is a demonstration of no significant risk for current/future activities;
- RAO B – when there has been an elimination of exposure pathways through the use of Institutional Controls or risk evaluation and there is a demonstration that there is no significant risk for current/future activities; and
- RAO C – when a temporary solution has been used to achieve "no substantial hazard" from current site conditions. This approach is used when it is not feasible to achieve an RAO A/B and must be reviewed every 5 years.

The MCP requires compliance with Upper Concentration Limits (UCL) to support site closure and provides the following requirement applicable to free product: "The presence of non-aqueous phase liquids (NAPL) having a thickness equal to or greater than ½ inch in any environmental medium shall be considered a level which exceeds Upper Concentration Limits" (301 CMR 40.0996 (6)).

Sites can be re-opened upon findings of MADEP audit, or new information. Because of the recognized need to provide site owners with certainty regarding cleanups, MADEP will typically not revisit RAOs based on changing standards (MADEP 2007). However, they do have the authority to take or compel action on a case-by-case basis where the department identifies conditions at any site, old or new, that pose unacceptable risks to health, safety, public welfare or the environment.

Case Study - Former MGP Site Cambridge, MA

From 1850 to 1960, the Cambridge Gas and Light Company operated a manufactured gas plant (MGP) in Cambridge, Massachusetts. Despite its desirable urban location, the property remained undeveloped due in part to the significant subsurface contamination from the operation of the MGP.

In 1998, a private developer purchased 10 acres of land from the successor to Cambridge Gas and Light Company, for the purpose of redeveloping the site into a mixed-use planned unit development. The developer conducted a comprehensive site investigation and instituted a remedy under the Massachusetts Contingency plan. The remedy consisted of the excavation of over 400,000 tons of soil in a moderately impacted area to enable construction of an underground parking garage, and the in situ solidification of 100,000 cubic yards of soil and saturated media where free product was present at thicknesses ranging up to six feet. These materials were treated to remove the free product and meet the associated Upper Concentration Limit (UCL) requirement for site closure, i.e. a product thickness of < ½ inch in any environmental medium.

Partial Response Action Outcomes (RAOs) were filed for each parcel of the property, facilitating phased redevelopment and future sale of the parcels within the property. A total of five Class A RAOs were filed for the property.

Subsequent redevelopment included: construction of a 1,400-car underground parking garage, two commercial buildings totaling over 500,000 square feet, and open space that includes an outdoor public skating rink. One of the buildings is a highly acclaimed green building and the world headquarters for Genzyme Corporation. Other planned uses for the development include a second underground parking garage and an additional 750,000 square feet of space consisting of a hotel, a performing arts center, and mixed-use retail, office and residential space.

2.5 Pennsylvania

The Pennsylvania Land Recycling Program (Act-2) has been developed to facilitate the redevelopment of impacted properties. The regulations are promulgated in Pennsylvania Code Chapter 250. Site progress is evaluated by the Pennsylvania Department of Environmental Protection (PADEP).

2.5.1 Definition and Identification Criteria for Free Product

The Act-2 regulations do not provide a specific definition or criteria for free product. However PADEP is currently reviewing approaches to make Act-2 and the petroleum program consistent with respect to Separate Phase Liquids (SPLs).

2.5.2 Closure Requirements and Mechanism

The Act-2 program allows site owners to mitigate risk through the elimination of exposure pathways using Groundwater Use Ordinances and Institutional/Engineering Controls; as well as compliance with default constituent concentration criteria for site media. Free product can remain in place if the exposure pathway is eliminated.

PADEP provides a formal approval of the Final Report that documents the remediation activities and compliance with closure requirements and co-signs an Environmental Covenant if Institutional Controls are used to achieve site closure. A Post Remediation Care Plan is required if Institutional Controls are used, and requirements for routine inspection and monitoring are included in the Environmental Covenant. PADEP has authority to enforce controls if they prove to be ineffective in protecting human health and the environment.

Case Study - Former MGP Site, York, PA

The Grant Street site in York, Pennsylvania is the former location of a manufactured gas plant (MGP) that operated at the site from 1885 to 1950. The MGP was fully decommissioned in 1981 and was subsequently used by the utility company as a service center. During the period of 1985 to 1997, several site investigations and a remedial action were conducted at the site to meet the closure requirements of the PADEP Land Recycling Act. The remedy included four basic components:

- Removal and off-site disposal of approximately 12,000 gallons of "mobile" product from a former gas holder. The remaining soil and debris within the structure were solidified, using cement, to limit future impacts to groundwater.
- Paving of the ground surface of the principal processing areas of the site to eliminate the potential for direct contact risk from site soil.
- A subsurface barrier wall and collection wells were installed along the edge of the site (from the ground surface to the top of the bedrock) to contain the migration of MGP residuals to an adjacent water body (Codorus Creek).
- Deed restrictions were put in place to prohibit the use of site groundwater and disturbance/excavation of site soils without appropriate notification and precautions in place.

The utility company initiated an operation, maintenance and monitoring program to optimize the operation of the pumping system and document discharges to Codorus Creek.

Subsequently, PADEP, the utility company, and the Redevelopment Authority of the City of York signed an agreement that allowed for the future reuse of the property. The property was sold to Susquehanna Pfaltzgraff for commercial development which included the restoration of a former building from the MGP site, as well as the construction of two new office buildings and a multi-level parking garage.

In 2002, PADEP informed the utility company of a continuing discharge of MGP residuals to Codorus Creek. The discharge appeared as seeps of by-product within a limited area of the creek bed, and as associated sheen on the water. The utility entered into a Consent Order and Agreement with PADEP to address the public nuisance caused by the continuing discharge to the creek, and to meet the completion goals of the original remedial action.

The results from a field investigation program demonstrated the presence of mobile MGP by-product in a defined area outside of the barrier wall that was installed previously, and indications of the migration of the material through a number of small fractures in the bedrock. The investigation also indicated that surfaces of rocks and sediment in the bank along the immediate downstream reach of the creek bank had likely been impacted by the re-deposition of this material.

A field construction program was conducted during the period of June 2004 to January 2005 to eliminate the preferential migration pathways of MGP residuals from the site to the creek. The remedy consisted of the installation of a portable cofferdam to divert the creek flow around the work area and the subsequent excavation of an interceptor trench (240 ft. long, 3 ft. wide, 10 ft. deep) in the bedrock along the creek bank to collect MGP residuals migrating through the surface media, or through bedrock fractures towards the creek. The trench was backfilled with a stone sand mixture, and a recovery sump and submersible pump were installed. The trench was then "sealed" using a sheet of HDPE membrane that was tied into the bank at a point above the seasonal high stage of the creek. A protective layer of crushed stone was placed on top of the liner as an erosion-control measure to complete the installation.

A pumping system is currently used to maintain hydraulic control of the trench, with collected water/residuals managed in an on-site water treatment system. The utility company continues to conduct routine inspections of the creek adjacent to the site, and monitor the operation of the recovery/treatment system. The results are documented in monthly reports and summarized to PADEP in an Annual Attainment Report.

2.6 Indiana

The state of Indiana has promulgated regulations related to the management of contaminated sites under the Indiana Administrative code (IAC) Section 329. The Indiana Department of Environmental Management (IDEM) has developed a Voluntary Remediation Program (VRP) to provide a risk-based closure mechanism for contaminated sites and provide liability relief for the owners of the properties. Investigation/remediation activities for sites that were entered into the VRP prior to 2001 are managed under a set of 1996 guidance criteria, while sites entered after that time are managed using the 2001 Risk Integrated System of Closure (RISC) guidance (IDEM, 2001). IDEM staff evaluate the progress of sites in the VRP.

2.6.1 Definition and Identification Criteria for Free Product

The 1996 Resource Guide (IDEM, 1996) references regulations from New Jersey and defines free product as "*the separate phase material present in concentrations greater than the contaminant's residual saturation point.*" (IDEM, 1996, Appendix E: Technical Standards). RISC guidance defines free product as: "*1. Any material that has been released from a container of process and presents a potential acute threat to human health of the environment; 2. A material in excess of its solubility limit.*" (IDEM, 2001, Appendix G: Glossary and Abbreviations).

Proposed guidance (currently under review) adopts language from the Indiana UST program that defines free product as "*regulated substance that is present as a nonaqueous phase liquid, for example, liquid not dissolved in water*". (329 IAC 9-1-23).

The 1996 guidance does not provide a qualitative approach for evaluating Residual Soil Points (RSP) although several potential methods are provided in the New Jersey references. These methods include: "*visual identification of sheens or other visible product, measurable thickness of product on the water table, the use of field instruments, ultraviolet fluorescence, soil-water agitation, centrifuging, and hydrophobic dye testing.*"(NJ Code 7:26E-2.1(a)11).

RISC guidance provides the following criteria for identifying free product in soil (vadose zone media as defined by 1996 and 2001 guidance) "*constituent concentrations that exceed the soil saturation limit may be present in free phase*" (IDEM, 2001, Section 7.1.3 Site-Specific Data for the Soil Saturation Limit Equation). An equation is provided for calculation of site-specific values of soil saturation limits. Default values are provided in Appendix A of the current guidance, but are not yet available for the proposed revisions.

2.6.2 Closure Requirements and Mechanism

Both the 1996 and 2001 guidance documents indicate that closure can be achieved through the use of Institutional Controls, site-specific risk assessment, or compliance with default constituent closure levels for site media. However, in a recent policy statement, IDEM has indicated that "to the extent practicable, source materials and contamination that exceeds risk-based levels will be addressed, in preferential order, by removal or treatment, containment, engineering controls, and institutional controls. Institutional controls may not be selected as the sole remedial action at a site unless removal, treatment and engineering controls are not practicable." Additionally, the statement indicates the following: "*When calculating site-specific closure levels, exposure pathways are assumed to be complete*" (IDEM, 2008).

The 1996 VRP guidance provides the following separate performance requirements for source material and free product:

- Source material – must be "*removed or controlled by the remediation*"
- Free product – "*has been removed from the site or that a system is in place to remove all free product from the site*."

The site owner may provide evidence if compliance with these performance standards is "*technologically impracticable or infeasible*" (IDEM, 1996, Appendix E: Technical Standards).

RISC guidance states that "free product must be removed from groundwater to the maximum extent practicable," and that "a constituent may not be present at concentrations that exceed the constituent's aqueous solubility" (IDEM, 2001, Section 1.4 Constituent Concentration Limits). Default values for aqueous solubilities are provided in Appendix A of the RISC guidance. The proposed revisions to RISC guidance do not include a need for groundwater constituent concentrations to comply with aqueous solubility values as a closure requirement.

Site owners that meet the closure requirements are issued a No further Action by IDEM and a Covenant Not to Sue by the Indiana Governor's Office.

Case Study – Former MGP Site, Goshen, Indiana

The Goshen former Manufactured Gas Plant (MGP) operated from approximately 1874 to 1930. The site is currently used to periodically stage maintenance vehicles and store equipment, and is surrounded by rights-of-way (ROW), commercial/residential areas, and municipal facilities.

Initial investigation and characterization of the site began in 1992 and continued with several mobilizations until 1997. The site was entered into the Indiana Department of Environmental Management (IDEM) Voluntary Remediation Program (VRP), and a soil remediation program was conducted in 1997-1998. Remediation activities included the removal of over 27,300 tons of impacted soil in accordance with the requirements of the VRP. In 2001, a Covenant Not To Sue (CNTS) was issued by the State of Indiana for site soils, i.e. vadose zone media.

Observations and results from post-remediation groundwater monitoring indicated the presence of continuing dissolved-phase impacts near the upgradient boundary of the site, as well a location in the center of the site where dense non-aqueous phase liquid (DNAPL) was encountered.

In January 2004, the site was entered into the IDEM Risk Integrated System of Closure (RISC) program to address the residual impacts to groundwater. As part of that effort, field programs were conducted to delineate the nature and extent of source material, i.e. impacted media that was adversely affecting groundwater quality, and to further define source material that was present as "free product". Discussions of the results from those activities are provided below.

Source Material

A source material evaluation was conducted using a field screening technique developed by Dakota Technologies, Inc. of Fargo, North Dakota. The Tar-Specific Green Optical Screening Tool (TarGOST) system uses laser light that fluoresces in the presence of high molecular weight organic constituents, such as polycyclic aromatic hydrocarbons (PAHs), to provide a relative response for MGP residuals in the subsurface. The response is expressed in terms of percent reflective energy (%RE).

The TarGOST probe was advanced into the subsurface using standard direct push drilling methods at 40 locations to provide a real-time illustration of PAH response across the entire depth of the borings. Separate Geoprobe borings were completed concurrently at 40 % of the TarGOST locations to verify the screening results. At these locations, soil samples were collected continuously from the ground surface to the top of a confining layer (till). The samples underwent a field screening process, which included

visual and olfactory observations, and a general evaluation of organic content using a photoionization detector.

A review of the field data indicates the response from the TarGOST screening ranged from <10 to 1,700 %RE. A separate review of the data from unimpacted areas of the site provided response values up to approximately 60% RE, which was used a "background" value for the evaluation.

The results from historic dissolved phase monitoring and constituent data/observations (odors, sheens or staining) from the verification samples discussed above were used as indicators to identify those TarGOST response values that were thought to be indicative of potential source material. The results from the evaluation indicated that an average response of approximately 100% RE provided an appropriate site-specific criterion for delineating potential source material. TarGOST responses greater than this level occurred in two areas of the site, identified as the Central Area and Upgradient Area, that were consistent with the locations of dissolved-phase impacts. Information on findings from the evaluation is provided below:

- Central Area – Source material impacts are generally aligned with the locations of the former gas holders. The potential source material was less than 2 feet in thickness, and present at two distinct depth horizons across the investigation area: at the water table and in a sand and gravel unit overlying the dense silt unit.
- Upgradient Area – Impacts extend along the western and northern property boundaries, with source material evident at the following depth intervals: at the water table, on top of the confining layer, and within the confining layer. A subsequent TarGOST evaluation was conducted to delineate source material at off-site locations in the ROW and on adjacent properties. These results indicated that the thickness of the impacted intervals decreased significantly with distance from the site, and was generally reduced to intermittent "stringers" (< 0.5 inches thick) within 20 ft. of the site boundary. A subsequent evaluation of groundwater quality and potential for vapor intrusion demonstrated that there is no risk to potential off-site receptors.

Free Product Evaluation

An additional characterization of the saturated media was conducted to further identify those areas of source material that may contain free product. The evaluation was based on the definition provided in IDEM's 1996 VRP Guidance: "separate phase material present in concentrations greater than a contaminant's residual saturation point".

Soil borings were advanced at seven selected locations that exhibited an elevated TarGOST response (150 – 560 %RE) using a hollow stem auger and Shelby tubes. The collected samples were analyzed by PTS Laboratory, in Santa Fe Springs, California to determine their organic content and Residual Saturation Point (RSP).

Initially, the organic content of the samples was determined gravimetrically using the Dean-Stark extraction method (API RP40). The results were expressed on a volume basis as percent of available pore volume (%PV) using data from associated analyses for porosity, bulk density, and moisture content (ASTM D2216). The organic content of the samples was determined to range from 0.2 to 21.4 %PV.

A second aliquot of the samples from each location was tested to determine the RSP of the sample media. In an initial preparation step, the samples were saturated with product collected from the site, and centrifuged for 1 hour at an acceleration of 1,000 times the normal force of gravity (1,000 Gs) in accordance with the procedures detailed in ASTM 425. Note that these aggressive preparation steps are intended to establish a highly conservative media condition for defining "saturation". The samples were then analyzed using the Dean Stark method to quantify their organic content, i.e. the RSP. The associated RSPs of the samples ranged from 1.8 to 14.2 %PV. The organic content of the initial samples was determined to be greater than the RSP of the media in 5 of the 7 locations evaluated, indicating the presence of free product. These samples were collected from areas of the site that were adjacent to the monitoring well where mobile product has been observed. Furthermore, the limited data set suggested

some correlation between TarGOST response and free product. The samples exhibiting evidence of free product were all associated with TarGOST responses greater than 200 %RE.

The utility company is currently evaluating approaches for remediating impacted media associated with the free product in the Central Area, and reviewing guidance provided by IDEM related to the Technical Impracticability of addressing impacts in the ROW and intermittent stringers along the upgradient boundary of the site.

3
APPLICABILITY OF CRITERIA TO MGP RESIDUALS

The following discussion provides a general overview of the nature of residuals that may be present as free product at former MGP sites, and a review of the applicability of identification criteria presented in the state regulations that were reviewed as part of this paper.

3.1 Characteristics of MGP Residuals

The residuals from former MGP operations can consist of a number of materials including: ash, clinker, purifier waste and by-products. Solid residuals such as ash, clinker and purifier waste were generally stored/managed in surface structures, and during site investigations are typically encountered in surface and subsurface soil. These materials are generally of limited interest when evaluating potential groundwater impacts and discussing free product issues. The potential for significant groundwater impacts is typically limited to MGP by-products, e.g. coal tar and oil gas tar. These by-products are generally present in the environment as a result of accidental releases from subsurface structures (gas holders, tar wells). Since the majority of plants were decommissioned in the mid 1900's, these releases are typically historic in nature (Hayes, et al 1996).

MGP by-products are a complex mixture of aromatic hydrocarbons with densities that are typically greater than water (EPRI, 2004c). However, "lighter" materials may be present depending on the gas production process used and the relative composition of volatile and semi-volatile fractions. The individual MGP constituents also have widely varying aqueous solubilities. Components in the volatile fraction, e.g., benzene, naphthalene, are highly soluble, while semi-volatile constituents such as benzo(a)pyrene are essentially insoluble and are typically present in the environment as solids (EPRI, 2004a).

Since the by-products were typically released from subsurface structures, they are generally identified in the saturated zone and, due to their specific gravity, are more likely to migrate horizontally than vertically. Although MGP by-products may collect on top of a confining layer, they are more likely to be present as thin and inconsistent "stringers" in more permeable media and move as blobs, blebs or ganglia (EPRI 2004c). The volatile fraction of the material typically degrades in the environment and it generally becomes less mobile over time (EPRI 2005).

Given these attributes, the risk exposure pathways for MGP by-products are generally related to groundwater exposure rather than direct physical contact. Groundwater impacts above regulatory default criteria are typically related to the presence of highly soluble constituents such as benzene and naphthalene. Given the insoluble nature of the heavier fractions, elevated concentrations of the principal semi-volatile components, polycyclic aromatic hydrocarbons (PAHs), in the dissolved phase are generally related to turbidity in the collected samples.

3.2 Criteria for Identification and Delineation of Free Product

The principal criteria used by the six states for identifying free product were evaluated for their specific applicability to complex mixtures, such as MGP by-products. The findings from the

evaluation of aqueous solubility, soil saturation, residual saturation, and field observations are summarized below.

3.2.1 Aqueous Solubility

The approach presented in the regulations for using aqueous solubility as a criterion for identification may not accurately reflect the presence of mobile product when applied at MGP sites. It is based on a comparison of constituent concentrations in groundwater to their published solubility values, but is complicated by the fact that a constituent's "effective" solubility, i.e. solubility when present as part of a mixture, may be significantly less than it's published value (EPRI 2004b). For example, the aqueous solubility for benzene is presented in the literature to be 1800 mg/L (IDEM 2001). However, calculations conducted using Raoult's Law and site data collected by EPRI indicate that the effective solubility for benzene in coal tar samples from nine former MGP sites ranged from 10 to 40 mg/L (EPRI 2004b). Therefore, evaluations at MGP sites that are conducted using literature values for aqueous solubility may fail to identify coal tar impacts that have the potential to be mobile.

The particular composition of coal tar can further complicate the accuracy of free product determinations based on solubility. The inadvertent introduction of trace levels of entrained particulate matter (turbidity) during groundwater sampling can result in apparent aqueous concentrations of semi-volatile constituents, such as benzo(a)pyrene and benzo(k)fluoranthene, that exceed their aqueous solubility values. In these instances, the results can provide a false indication of the presence of free product.

3.2.2 Soil Saturation

The approaches using soil saturation as the criterion for identifying the potential for free product are based on a comparison of a constituent concentration to an associated soil saturation value for that compound. For the reason stated in the previous section, i.e. the possibility of not identifying coal tar impacts that have the potential to be mobile, it is important that the evaluation reflect the effect of the multiple component coal tar mixture on the soil saturation values used in the comparison. Additionally, the process used for developing the soil saturation values should incorporate the flexibility to be applied in both the vadose and saturated zones, e.g. have provisions to include/exclude terms for air porosity.

3.2.3 Residual Saturation

The methods associated with the use of residual saturation provide a range of qualitative and quantitative means of identifying mobile product. Qualitative evaluations of the potential for mobile product can be made by the physical processing of samples by centrifuge, soil/water agitation, etc.. These approaches provide a means to evaluate the potential mobility of the residuals through the observation of separate-phase organic in the resulting centrate or extract. They can be effective in instances where the results are definitive, e.g., significant product or no product, but may be less useful when "sheen" or "trace levels of organic" are observed.

Laboratory methods for determining residual saturation can provide a quantitative means for evaluating the presence of free product. One method uses a sample preparation step by ASTM D-425 and analysis by Dean Stark extraction to make separate determinations of the organic content of the sample, and the associated residual saturation point of the site media (PTS, 2000). The determination of free product is made in samples where the organic content is greater than

the residual saturation point. However, this approach requires a complicated set of analyses that are conducted on small aliquots of sample. As a result, a large number of replicate analyses are frequently required to obtain results that are meaningful for evaluating site-wide impacts.

In response to these limitations, EPRI has developed a field tool (Res-SAT™) to evaluate the mobility of coal tar. The tool provides the capability to subject samples of site media to capillary pressures that have been determined, on a site-specific basis, to be appropriate to mobilize NAPL from the sample. The generated sample extract can then be evaluated by qualitative/quantitative means for the presence of coal tar to determine product mobility (EPRI, 2004c, EPRI, 2005).

All of these qualitative/quantitative approaches require the collection of subsurface samples of solid/saturated media for ex-situ analysis. It should be noted that the collection of these samples may alter the pore volume of the media, although it is unclear if the change would provide a significant bias in the residual saturation results.

3.2.4 Field Observations

The initial indications of the presence of free product typically come from observations made during the collection of samples from site borings and test pits. Field staff can frequently identify visual/olfactory evidence of MGP impacts during these activities. However, these observations are qualitative in nature and may not provide an accurate evaluation of in-situ mobility.

Consistent visual observations of separate phase organic impacts in groundwater monitoring wells over time can provide a more meaningful indication of the mobility of the source material. However, given the nature of MGP residuals in the environment (low vertical mobility, presence in isolated stringers) it is possible for well networks that are initially designed to delineate dissolved phase impacts to “miss” specific areas of source material.

4
SUMMARY

The regulatory objectives of the six programs that were reviewed are two fold: to eliminate human health/ecological risk; and ensure the long-term success of the implemented remedy. The programs generally recognize that sites are complex and that as conditions change, and if the risk of harm to health, safety, public welfare or the environment cannot be adequately controlled by the remedy or remedies in place, sites can and will be reopened. The in-place closure mechanisms (No further Action agreements or Covenant Not to Sue) are not jeopardized, but states work with the responsible parties under new agreements to manage the new risks appropriately. Since many of the programs are voluntary in nature, financial assurance by the site owner is typically not required.

Given the physical characteristics and typical location of MGP by-products in the environment, the potential risks associated with free product can generally be addressed using a combination of legally enforceable Institutional Controls to eliminate exposure pathways, and required compliance with constituent-specific criteria in site media. As a result, the specific and principal concern for free product lies in its mobility and associated potential effect on the reliability of a remedy. In several states, sites can be closed with free product in-place as long as the potential risks are addressed and managed.

As discussed above, field observations and constituent-based approaches (soil saturation and aqueous solubility) may not provide an accurate evaluation of mobile product at MGP sites. The results from these evaluations may be most appropriately used to supplement soil/groundwater information from site investigations to identify significantly impacted areas that require further evaluation for the presence of mobile product. Additionally, the most accurate information would be obtained from evaluations that use saturation/solubility values that reflect the effect of the complex composition of coal tar. As a result, specific evaluations of mobile coal tar may best be conducted on the basis of residual saturation. One example of an approach that integrates the most appropriate applications of these methods for the identification of mobile coal tar is provided below:

- The results from groundwater monitoring are used to identify potential areas of source material in the subsurface.
- The results from field observations and constituent analysis of soil/groundwater are used to identify the potential locations of source material. These results can be supplemented with data from field screening techniques (remote optical approaches such as TarGOST) to refine the vertical and horizontal extent of the source areas.
- Samples of media from the defined source area(s) are analyzed for constituent concentrations and the results are compared to effective soil saturation/aqueous solubility values to identify areas of source material that have the potential to contain NAPL.
- Samples from locations exhibiting the potential for NAPL are analyzed for residual saturation using laboratory or field techniques to delineate the source area that likely contains mobile product. Information from locations that provide inconclusive results, e.g. significant variability, can be validated by the placement of temporary monitoring points (piezometers,

direct-push wells) and observations of separate-phase organic over time. The observations can be compared to a defined criterion for separate phase organic, e.g. measurable thickness (> 0.1 inch), for multiple monitoring events to provide evidence of free product.

The locations of the wells exhibiting free product on a consistent basis over time can subsequently provide an appropriate delineation of impacted media to support the development of a remedy for the site.

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