

Comparison of Exposures for Conducting Environmental Work

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Abstract

Assessment and remedial activities can create human and ecological exposures. These exposures can be greater than or similar to what existed at a site prior to beginning such work. In many cases, subsurface soil and groundwater impacts do not represent either an immediate or practical long term exposure concern. Prior to the consideration of non-time critical cleanup projects, a comparison of exposures should be conducted. Such an evaluation would show that certain environmental projects should be limited or not performed.

This discussion follows from the paper “The Environmental Impact of Conducting Environmental Work”. While the previous paper described the means for evaluating the impact of conducting environmental work, this discussion focuses on the means for comparing potential exposures.

Comparison of Exposures for Conducting Environmental Work

BACKGROUND

Potential Exposure and Manufactured Gas Plant Sites

The contaminants of concern (COCs) associated with former manufactured gas plant (MGP) sites will be used for comparing potential exposures. These sites are common across Europe and North America and their COCs are also prevalent in our everyday lives.

The potential exposures associated with MGP sites include two different causes. One is the potential exposure to the insitu by-product materials originally released into the environment and the other is the potential exposure to these same materials caused by any assessment and remediation work that may be conducted. The primary by-product materials typically identified with MGP sites include non aqueous phase liquid (NAPL) and coal tar. The primary COCs contained within these materials are volatile and semi-volatile aromatic compounds including benzene, toluene, ethylbenzene, and xylenes (BTEX) and polynuclear aromatic hydrocarbons (PAHs). Of these, benzene in groundwater and benzo(a)pyrene (BAP) in soil are the most significant COCs for MGP sites. This is because these two compounds are usually the “regulatory drivers” for MGP sites. Their presence, concentration, and extent determine the level of work that will ultimately be required for a site.

Understanding that environmental work causes impacts to the environment begins with an understanding that every action has an associated environmental impact. Normal everyday activities have an environmental affect and present the potential for exposures to human health. As we will see, inhalation of BTEX compounds and ingestion of PAHs are prevalent in our everyday lives and can represent a similar or greater exposure concern than that associated with former MGP sites.

Exposure Measurement

Human and ecological risk calculations utilize contaminant mass data along with assumptions of toxicity and potential exposure. These calculations then produce a risk index for various site uses for people and animals. The assumptions employed in the standard risk calculations are intentionally conservative to be protective of human health. While this intention is good, it does not allow for an accurate assessment of the actual exposure. This then can result in the performance of environmental work which may cause a greater exposure concern than that associated with an undisturbed albeit affected site.

Important Considerations

When planning an environmental project on the basis of exposure, the following questions should be asked prior to initiating the work:

- 1) Does the affected site, in its existing undisturbed condition, represent an exposure to human health that exceeds the baseline level of exposure associated with everyday activities?
- 2) Does the actual site exposure exceed the level of exposure that would be caused by conducting any assessment and remediation activities? and
- 3) Will the environmental work result in a net positive benefit to the environment?

If all of the above conditions are met for a site, then clearly the environmental work should be conducted. If however the following conditions are observed:

- A) The levels of our everyday exposure is greater than or equal to that attributable to the existing site exposure; and/or
- B) Conducting the environmental work causes a greater exposure than is associated with the existing site; and/or
- C) Conducting the environmental work results in a negative impact to the environment; then

The merit of conducting such work should be reconsidered. Similar to the discussion of “The Environmental Impact of Conducting Environmental Work”, in most cases the evaluation of the potential impacts and benefits of conducting a project will show that its merit will be conditional. And as before, it should be recognized that when environmental work is performed for the benefit of a specific location, it is often at the expense of another.

DISCUSION OF EXPOSURES

The air emissions from diesel exhaust (DE) represent one of the larger impacts associated with site work. The construction of diesel engines and composition of diesel fuels and associated exhaust products differ based on type and use. These include on-road vehicles (both light-duty and heavy-duty trucks) and non-road (drilling rigs, tractors, construction equipment, and locomotives including line-haul and switch). Diesel fuel is a mixture of many different hydrocarbon molecules. The combustion, both complete and incomplete, of diesel fuel forms a complex mixture of hundreds of organic and inorganic compounds in the gas and particulate phases. The gaseous constituents include carbon dioxide, oxygen, nitrogen, water vapor, carbon monoxide, nitrogen compounds, sulfur compounds, and low-molecular-weight hydrocarbons. The toxicologically relevant gaseous compounds include Aldehydes (formaldehyde, acetaldehyde, and acrolein), benzene, 1,3-butadiene, PAHs, and nitro-PAHs.

The particulate phase of DE is termed diesel particulate matter (DPM) and it includes elemental carbon, adsorbed organic compounds, and small amounts of sulfate, nitrate, metals, and other trace elements. The toxicologically relevant compounds associated with DPM are the PAHs, including nitro-PAHs, and oxidized PAH derivatives. Although PAHs comprise less than 1% of the DPM, diesel emissions have been observed to have elevated concentrations of certain low molecular weight PAHs compared to other combustion aerosols. Enrichment of high molecular weight PAHs such as benzo(a)anthracene and benzo(a)pyrene has also been observed under some conditions. Regardless of the studies referencing specific PAH species, it appears that fuel chemistry ultimately dictates the emission compounds released into the environment. This is because PAH molecules are relatively refractory in nature and this results in a significant fraction surviving the combustion process. Therefore, emissions of PAHs are more a function of the PAH content of the parent diesel fuel than of engine technology or combustion. It is interesting to note that changes in the fuel production processes over time would indicate that diesel PAH content has increased over the past 40 years.

Exposure of Site Work

The exposure resulting from the performance of investigation and remediation work includes the inhalation, ingestion, and dermal contact with COCs. Specifically, the exposure includes the inhalation of volatile compounds during site work, inhalation and ingestion of fugitive dust containing MGP constituents, and the inhalation of DE from heavy equipment.

When air monitoring for organic vapors is conducted during investigation and remediation work at an MGP site, the results usually range from 0 to 1 parts per million (ppm). The majority of the time however the monitoring results shows 0 ppm due to the diffusion and dispersion properties of outdoor air. There are occasionally short duration (less than 5 second) peeks where readings can range as high as from 5 to 10 ppm in the immediate work area. But these are not common within the breathing zone. Peeks usually occur when an excavator bucket is exposing NAPL saturated soils. Obviously, there are considerably higher concentrations of volatile compounds present in the air during site work verses times when a site is inactive. But the majority of the monitoring that is conducted is not within the range of detection required to see such low concentrations. Air monitoring that measures compounds in units of milligrams/cubic meter (mg/m^3) are capable of detecting lower concentrations but while more compounds would be detected, the reported concentrations would remain relatively low.

The greater exposure concern during site work is probably related to inhalation and ingestion of fugitive dust. The dust particles may contain PAHs and metals. However, similar to the results for volatile compounds, monitoring for particulate matter seldom shows reason for concern. In both cases, the monitoring is designed to demonstrate compliance with certain standards and not to determine exposure. An example of air monitoring for an active MGP site can be found at:

<http://www.we-energies.com/environment/mgp_appleton_data.htm#Stationary>

This link provides the monitoring results for the Appleton MGP site remediation project located in Wisconsin. As shown by the results, the highest benzene level reported was $0.0097 \text{ mg}/\text{m}^3$, which is well below the site action level of $1.6 \text{ mg}/\text{m}^3$. The highest naphthalene reading was $0.02 \text{ mg}/\text{m}^3$ and the highest particulates reading was $0.05 \text{ mg}/\text{m}^3$. All the air monitoring results are within accepted exposure ranges. The additional EPA link below can be used to convert the monitoring results for each compound into other values if desired. This is a useful tool although it is intended for the conversion of indoor air concentrations. Care must be taken to fully understand the units and conversions involved.

<http://www.epa.gov/athens/learn2model/part-two/onsite/ia_unit_conversion.htm>

The performance of site work causes DE emissions and exposure to the components of these emissions are a concern for the following reasons:

- DE emissions including DPM include over 40 substances that are listed by the U.S. EPA as hazardous air pollutants. These include arsenic, benzene, formaldehyde, nickel, and PAHs. The inhalation of these compounds can cause adverse health effects including cancer, pulmonary and cardiovascular diseases.
- DPM is very small making it easy to respire deep into the lung.
- There are many irritants and toxic chemicals in the gaseous phase of DE.
- According to the EPA, studies show workers exposed to higher levels of DE are more likely to develop lung cancer and has proposed classifying DE as a probable human carcinogen.

- The International Agency for Research on Cancer has concluded that DE probably causes cancer in humans.

The amount of DE including DPM and associated compounds has been measured by the U.S. EPA and is presented in the document "Health Assessment Document For Diesel Engine Exhaust" dated May 2002. This is a large (670 page) comprehensive report. Within it are emissions rates (expressed in grams or micrograms/brake horse power-hour and in grams/gallon) of specific compounds from specific make and model trucks, tractors, and other heavy equipment. Using this document, one can calculate the amount of DE emissions for almost any project.

Once a removal action, groundwater pump and treat, or soil washing project has been completed, affected materials must then be transported for offsite disposal. This creates potential exposures to people living and working in the area and even more so for anyone driving behind the dump and tanker trucks. We have all been pelted by soil and gravel hauling trucks for example and at times this would also likely include those carrying affected materials. As discussed under air monitoring, it is doubtful that one could measure any volatile compounds in these situations because outside air (particularly moving air) very effectively diffuses and disperses contaminants. What can be quantified is the loss of volatile compounds due to site work. Volatilization occurs during excavation and staging operations. This fact is often observed between the analytical results of insitu soil samples verses those obtained later from stockpiles or roll-off boxes. And each movement or management of the soil further reduces the volatile concentrations. By the time the soil reaches the disposal facility, there is a high level of confidence that it will pass any applicable landfill restrictions.

In summary then, the volatile compounds associated with site work usually end up in the air. This appears to be the case regardless of whether the host media is soil or water. The COCs contained in water are and can be treated but they are also often discharged. The difference here is that these discharges are permitted while those migrating from an MGP site are not. The PAHs and certain other COCs associated with site work usually end up at a landfill regardless of the type of cleanup method selected. Since landfills require active management such as erosion control and leachate collection systems, there is no assurance of long term exposure control. While all of the negative affects of conducting site work can not be practically measured, it is obvious that impacts and exposures are generated by the work. It would also seem obvious that many of the MGP projects cause more of an impact to the environment than that associated with the no-work scenario.

Exposure from Inactive MGP Sites

What is the actual exposure of contaminants associated with an MGP site? This question is seldom asked. The current practice of evaluating risk in the environmental industry involves the use of standardized assumptions that are designed to be protective of potential site residents, recreational users, and workers. Worst case scenarios are applied in the risk process and an estimate of potential exposures is derived. These risk assessments do not produce nor are they designed to produce actual exposure figures. Even more unrealistic are the standardized soil and groundwater contaminant risk-based screening levels commonly employed in the environmental industry. While these have also been designed to be protective of human health and the environment, their application as remedial goals results in far too many "cleanup" projects that adversely affect the environment.

To date, the investigation of hundreds of MGP sites has adequately revealed the nature of their impacts. We know that an average MGP site will contain tar and NAPL and that these materials contain BTEX and PAHs. We know that we will find affected soil and groundwater and that the concentrations of COCs will vary from “non-detected” in some areas to concentrations surpassing their solubility limits in others. We also know that the COCs and their host materials are typically buried by a minimum of two feet of soil (the location of the original working surface). Most often the heaviest MGP impacts are found between 4 to 12 feet below the surface. These are impacts that remain mostly unexposed and unavailable for exposure until disturbed. So what is the actual exposure to these impacts? When we look at the possible exposure pathways from air, soil, and water, we are able to accurately determine the concentrations of the COCs contained in them. No modeling is required.

Air

When air monitoring equipment is placed within the breathing zone of an inactive MGP site, rarely are COCs detected above background concentrations. This is true even for those sites in which an MGP odor is observed. The reason for this relates to the fact that the concentration of the COCs in the soil-to-air interface is usually low for an undisturbed site. Also, the diffusion and dispersion effects of outdoor air are sufficiently high that COCs will rarely be detectable. These observations are fairly conservative.

Based on the conditions existing at most MGP sites, the air pathway does not necessarily present a practical concern. Although benzene and naphthalene are present at most MGP sites, it is difficult to understand how a passive MGP site would exhibit an exposure concern to air beyond what would happen if the site were excavated. The air monitoring results for the Appleton MGP site alone shows that site work does not necessarily produce an unacceptable exposure so therefore an inactive site would appear to pose an even lower exposure. Certainly the air pathway can be made into a concern however. If a building has been constructed upon an MGP site having substantial impacts that contact the foundation or other subsurface features, then vapor intrusion is possible. But even in extreme cases it is highly unlikely that vapor intrusion will result in an exposure concern that would exceed the background levels common in many indoor environments. The section presented later on background exposure discusses the inhalation of volatile compounds that occur in everyday settings such as office buildings and from activities such as fueling an automobile. These are exposures we readily accept and comprise “background”.

Soil

Incidental ingestion can occur at uncontrolled waste sites. The soil exposure pathway often combines dermal absorption, incidental ingestion, and inhalation of particulates. While each of these exposures can occur at a site, the significance of these exposures is debatable. Certainly their true significance pales in comparison to the standardized risk assumptions that include the unrealistic scenario of soil ingestion. We know that ingestion is not a realistic concern. Quite simply people do not eat soil at MGP sites (contrary to risk assessment assumptions). As we will see however, people do regularly ingest PAHs with their food. It is true that tar, NAPL, and heavily affected soils exist in the subsurface of most MGP sites. In some cases, tar and pitch are exposed at the surface. But there is no realistic exposure to these materials, except for perhaps intrusive workers. Institutional and site controls can manage this concern however. Certainly the exposure to MGP impacts must be greater to site workers conducting investigation and remediation activities. This scenario is not addressed beyond the assumption that site workers must comply with certain regulations and protocols and therefore they are “protected”. This assumption is somewhat a matter of necessity but it is not realistic. Conducting site work will always cause more exposures than not conducting the work.

Water

The final pathway to consider is groundwater. And of all the pathways, this represents probably the greatest realistic concern for an inactive MGP site. Not so much from the standpoint of potential ingestion of affected groundwater, but more from the migration of contaminants in the groundwater in general. Considerable environmental efforts are concentrated on insuring clean drinking water. Because of this, the consumption of contaminated water is now a much lower possibility for most of Europe and the U.S. Municipal water supplies, ordinance restrictions, and knowledge of MGP sites have gone far to address potable water concerns.

But for all the institutional precautions, affected groundwater associated with MGP sites can still migrate and this water carries dissolved COCs, and sometimes NAPL itself may migrate. Although the amount of work required to address groundwater quality issues appears to impact the environment far more than the water itself, it is difficult to overcome regulatory and public opinion driven initiatives. In the case of MGP sites, the soil and groundwater releases occurred long ago. In fact, the maximum extent of groundwater impacts (the size of the contaminant plume) was also reached long ago in most cases. An average MGP site was operated somewhere between the 1850s to the 1950s. The age of the related impacts vary between 150 to 50 years old. Conducting environmental work now can not prevent those impacts, they are there already and have been for a very long time. Conducting work can address some to most of these impacts but not all. Technology is improving and helping to reduce the adverse affects of site work but the economic and environmental cost of addressing these impacts is very high.

Background Exposure

Volatile compounds, PAHs, metals, and pesticides are inhaled, ingested, or otherwise contacted through normal daily activities such as eating, fueling a car, waking in the city, and working. These exposures comprise our everyday background exposure level. The following discussion concentrates primarily on benzene and BAP.

Studies have been conducted to determine the exposure to benzene during automobile refueling. These include the paper by Peter P. Egeghy, Rogelio Tornero-Valez, and Stephen M. Rappaport appearing in the Environmental Health Perspectives dated December 2000, the Clayton Environmental Consultants study appearing in the API Publication dated 1993, and the LC Backer et al. study appearing in the Environmental Health Perspectives dated 1997. The results of these studies show that the mean concentration of benzene ranged from 2.9 to 1.3 mg/m³. The highest reading was 36 mg/m³. Compare these results with the highest reported benzene concentration from the Appleton MGP remediation project of 0.0097 mg/m³. If the typical benzene concentrations that people regularly inhale while fueling up at the pumps were observed at Appleton, the remediation work would be stopped immediately. Workers would have scrambled to upgrade to level C or B respiratory protection based on the site's action level of 1.6 mg/m³. It is recognized that the concentrations referenced in the studies quoted above may be lower today due to the implementation of vapor recovery systems at most retail fueling stations. The effectiveness of these systems in reducing the inhalation of volatile compounds is not known here but it is possible. Additionally, the comparison presented here may be one of comparing short-term exposure to long-term exposure in some situations.

Inhalation of benzene and other volatile compounds is not limited to service stations. The JR Girman, et al study conducted on 56 randomly selected office buildings across the U.S. demonstrated what our exposure levels are in an office environment. Benzene averaged 3.7 micrograms per cubic meter (ug/m³) and ranged from 0.6 to 17 ug/m³. The highest benzene level

reported during the remediation of the Appleton MGP site falls within this same range. Benzene was not the only compound identified in the office study. The most common compounds included acetone, toluene, and xylenes.

The exposure and ingestion of PAHs has been studied for two primary reasons. They are known to be widespread in our environment and they are considered relatively toxic. The study of PAHs in the UK diet showed that the average adult dietary intake of BAP was 1.6 nanogram/kilogram (ng/kg) bodyweight/day. This means that a 180 pound adult (81.65 kg) will ingest on average 0.13 ug/day or approximately 1 ug of pure BAP per week. The high level adult intake was 2.7 ng/kg bodyweight/day. While we know that people do not intentionally eat soil at MGP sites, they do ingest BAP every day. Another study concentrated on the PAHs emitted from restaurant exhaust stacks. A comparison was made of the emission of different kinds of food including Chinese, Western, Fast food, and Japanese. The results showed that the mean total PAH concentrations ranged from 55.5 ug/m³ for Japanese food to 92.9 ug/m³ for Western food. The mean for BAP ranged from 0.28 ug/m³ for Japanese food to 1.59 ug/m³ for Western food. These values are not direct ingestion rates, however, the concentrations are closely related.

The majority of the background PAH studies that have been conducted concern surface soil conditions. Many studies have now been completed which consistently show the prevalence of PAHs in urban environments. One study evaluated the background levels of PAHs, arsenic, and lead in Baltimore (Logan et al., Background PAH study). The results show that the urban background concentration for BAP in surface soils was 2.5 mg/kg. The reported concentrations ranged from 78 mg/kg to as low as less than 0.6 mg/kg. These results are similar to other studies.

Background groundwater conditions in urban environments often include the presence of BTEX and lower molecular weight PAHs. However people rarely ingest measurable quantities of these compounds in their drinking water due to the use of municipal drinking water supplies and local restrictions. Calculating a background exposure to such compounds, rather MGP related or not, is therefore not practical. The comparison that can be performed however would be the toxicological effects associated with the long term exposure of chlorinated compounds found in municipal drinking water supplies to the toxicological effects of any "actual" exposure to MGP COCs in groundwater that may be attributed to a specific site. Such a comparison would require a known situation where people drink MGP affected groundwater and this is not likely today.

CONCLUSIONS

It is important to understand that we are all exposed to COCs in our everyday lives. That exposure is no less than that associated with an undisturbed MGP site. An evaluation of the technical aspects surrounding former MGP sites indicates that site work is often conducted when it should not be.

Site work can adversely affect the environment and also create exposure concerns beyond that associated with the original site itself. Exposure to benzene and BAP in our normal everyday lives is comparable to that associated with an MGP site. To prevent unnecessary and costly cleanup actions, a more realistic and technical approach should be available to determine if site work should be conducted.

The forgoing discussion focused upon only one type of the many different environmental projects that are conducted regularly. The evaluation process provided here however is valid for most situations for determining the environmental impact of conducting environmental work. A further review of potential exposures would also reveal that it is not only BTEX and PAHs that

are prevalent in our everyday lives but also chlorinated compounds, pesticides, metals, and many other COCs. Many of the "cleanup" projects conducted for these other concerns can also cause an unnecessary impact to the environment.

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