The Environmental Impact of Conducting Environmental Work

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Abstract

Performing environmental work creates environmental impacts. Assessment and remedial activities consume natural resources, produce waste products, and create exposures. Activities such as subsurface drilling, well installation, sampling, dewatering, excavation, treatment, and disposal require equipment, material, fuel, air, and water. These resources are consumed by the work leaving waste products that must then be dealt with. These include particulate matter, greenhouse gases such as CO_2, wastewater discharges, and various soil and material waste streams. Assessment and remedial activities can also create human and ecological exposures that are higher than what existed prior to beginning the work.

While it is true that the performance of almost any activity has an associated environmental impact, projects such as building a road, a bridge, or a school are not conducted under the onus of protecting the environment. Prior to the consideration of non-time critical cleanup projects, a resource, risk, and remediation evaluation should be conducted. Such an evaluation would show that certain environmental projects should be limited or not performed.

This discussion describes the means for evaluating the impact of conducting environmental work. This includes the calculation of resource consumption and waste streams. The means for comparing exposures is described in the paper “Comparison of Exposures for Conducting Environmental Work”. The technical arguments provided by such evaluations and comparisons could assist with expediting and economizing overall environmental liabilities. This discussion also shows the considerable volume of CO_2 which is produced by performing environmental work.

The Environmental Impact of Conducting Environmental Work

BACKGROUND

Environmental Projects and Environmental Impacts

Environmental work covers a broad range of projects and disciplines. Typical projects include permitting, investigation, remedial design, remedial action, and emergency response operations. Many of these projects can be divided into two categories; those that are considered time critical in nature verses those that are non-time critical. Examples of time critical projects include responding to a recent fuel or chemical spill or containing a biological release. The timely commitment of resources for these kinds of projects can have a measurable benefit to the environment. Non-time critical projects however are usually those where the release of contaminants into the environment occurred at some point in the past. These projects usually include many of those associated with the Comprehensive Environmental Response Compensation and Liability Act (CERCLA). Examples include sites identified with chlorinated compounds, petroleum, creosote, coal tar, metals, pesticides, and many other chemicals or contaminants of concern (COCs).

Manufactured Gas Plant Sites

For the purposes of evaluating the environmental impact of conducting environmental work, we will discuss projects associated with former manufactured gas plant (MGP) sites. MGP facilities historically produced gas for heating, lighting, and manufacturing which helped advance Europe and North America through the later stages of the industrial revolution. These days, MGP projects involve the assessment and remediation of by-product materials that were released into the environment during a period of time ranging from about 140 to 50 years ago. Given the age and history of their operation, MGP sites are situations where the maximum extent of soil and groundwater impacts was usually reached long ago. MGP sites were selected for this discussion because of their common occurrence in Europe and North America and also because the COCs associated with them are prevalent in our everyday lives. Although we are focusing on one type of environmental project, the process of evaluating the environmental impact of conducting environmental work is valid for most situations.

The impacts associated with MGP sites include the potential exposure to the by-product materials originally released into the environment and also the potential impacts caused from any investigation 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 sties. 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.

Impact Measurement

The quantification or measurement of environmental impacts can be accomplished using both primary and relative methods. Primary indications include the analysis of soil, water, air, and material samples for determining the concentration or contaminant mass present in a tested media. These measurements can be translated into more relative indexes such as the conversion of individual PAH concentrations to BAP equivalents. Other measurements involve the quantification of greenhouse gas emissions which can be translated into CO_2 equivalents. The EU carbon trading schemes for example utilizes such data.

The Key Question

When planning an environmental project, specifically a non-time critical cleanup, rarely is an objective evaluation made of the potential benefits of the work as compared to the impacts that may be caused by it. To facilitate this evaluation, the following question should be asked prior to initiating the work: Will the environmental work result in a net positive benefit to the environment? In most cases the evaluation of the potential impacts and benefits of conducting a project will show that its merit will be conditional. And 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.

Environmental Cleanups

The question of whether site work results in an environmental benefit or not becomes even more relevant when it is realized that the very term “environmental cleanup” is misleading. Rarely is a site or affected material actually “cleaned up”. What typically occurs as part of the environmental remediation are removal actions and media transfer operations. It should be acknowledged however that chemical oxidation and biodegradation remedies can accomplish actual cleanup but these represent a minority of cleanups.

Removal Actions

The traditional excavation with offsite disposal is an example of a removal action. This work involves exposing affected material via excavation, transporting the material away from a site, and then disposing of it at a landfill. Technically the impacts are not actually cleaned but rather moved from one point to another. The original site is usually cleaner than it was prior to initiating the work but not without having generated considerable work related impacts and potential exposures in the process. Further reducing the overall environmental benefit of offsite disposal is the fact that most landfills leak. Leachate collection systems are installed near landfills for this very reason. The resulting collected leachate then requires its own treatment and disposal. But the final environmental detractor of conducting a removal action may not actually be realized for many years however. This occurs when remedial activities are eventually conducted at the landfill where the impacts were transported to. This situation is observed with increasing frequency as land values and the demands for land continue to increase. Aside from regulatory requirements and public opinion driven initiatives, the argument then for conducting many environmental projects is that the work will result in contaminants being moved or transformed from an area of higher risk to one of lower risk. However this argument fails when we consider the impacts and potential exposure caused by the work and we understand the true end point for most of the contaminants.

Media Transfer Operations

Operations involving media transfer technology include soil washing, traditional groundwater pump and treat, and to a certain extent thermal treatment.

Groundwater Treatment

In groundwater pump and treat, affected groundwater is usually pumped into air stripping towers where volatile compounds such as BTEX are transferred to the air. The semi volatile compounds, if present, are often treated (adsorbed) by activated carbon. The transfer to carbon creates an additional waste stream requiring treatment and disposal.

Soil Washing

The principal of soil washing involves a separation of contaminants from soil. Contaminants that are sorbed onto soil particles are separated from bulk soil in an aqueous-based system on the basis of particle size. The process involves the excavation of affected materials, the separation of differing soil types, "washing" the soil in various aqueous solutions, reuse of the cleaned soil (primarily sand and gravel), management of solid wastes (organics and fines filter cake) usually by landfilling, and management of liquid waste streams (disposal at a municipal or industrial wastewater treatment facility or by some other permitted means). Since the ultimate "drivers" for the assessment and remediation of MGP sites are often benzene in groundwater and BAP in soil, the media transfer of BTEX and PAH compounds are usually the primary concern.

In soil washing, BTEX and semi-volatile compounds such as naphthalene are transferred from affected soil/materials to a water solution. Most certainly a portion of these compounds are transferred to the air due to the agitation of water during the soil washing process. Also when the aqueous soil washing solution is processed at a wastewater treatment plant, the facilities aeration basins can then act as air strippers for the volatile and semi-volatile compounds.

Compounds such as higher molecular weight PAHs and metals typically adhere to organic material and finer grained soils such as silts and clay. The transfer of these compounds during soil washing relates more to the separation of soil particles based on grain size rather than to the removal of the compounds from the soil itself. The fine grained soil and organic material are separated from the coarser sands and gravels. During the process, the suspended sediments and organic material settle into a solid organic and filter cake waste. It is interesting to note that the PAHs and metals being "washed" still end up at landfill just as they would for dig and haul operations. Also, due to the large throughput requirements of wastewater treatment plants, if it were not for biodegradation and the potential media transfer to air, a larger amount of BTEX compounds would probably be discharged with the effluent. The concentration of these compounds however will almost always be within permit requirements due to dilution. In other words, the discharge of these compounds from a waste water treatment facility to a river or ocean will usually be permitted while the leaching of compounds from an MGP site into a nearby water body will not. In both cases the result is the same.

Soil washing and groundwater pump and treat both produce air emissions and both require the disposal of the transferred contaminants. But there are some important benefits, particularly for soil washing that are outlined below and include:

- The reduction in the amount of material requiring transportation and offsite disposal;
- It can provide a cost effective alternative to landfill disposal in areas with high disposal costs (such as in Europe and the UK);
- Soil washing can be conducted on relatively small sites and in sensitive areas;
- The use of various soil washing solutions can treat a broad range of contaminants as compared to bioremediation;

- The treatment efficiencies for PAHs, mineral oil, petroleum, and other select contaminants are reported as relatively high; and

- For larger projects, the daily process rates can achieve the throughput approaching that associated with excavation and offsite disposal.

The cost of soil washing can be formidable for smaller projects and in areas such as the U.S. where other cleanup options are less expensive. However in areas such as the UK, where the cost of dumping hazardous waste has increased significantly due to the second round of the European Union's Landfill Directive, soil washing is more viable. Higher average land values and a relative scarcity of land also contribute to making soil washing an acceptable alternative. Like all cleanup actions, there are of course environmental impacts associated with conducting soil washing. These include potential exposure to COCs, the consumption of water and fuel, and the generation of waste products.

Like all remedial actions, soil washing at an MGP site first requires an assessment of the extent of impacts. This is then followed by the excavation of affected soil which can cause exposures to BTEX and PAHs. After the soil has been excavated, the operation of the soil washing equipment requires considerable water and fuel and this then produces considerable air emissions and waste. All of these contribute to soil washing's environmental impact. The assessment of the Basford Gasworks located near Nottingham City Centre in the U.K., for example, included 350 exploratory soil borings and 2,500 analytical tests. This work represents a certain amount of impact to the environment and all occurring prior to the initiation of any site cleanup. Soil washing was ultimately performed at the Basford MGP site and the process was both impressive and successful in terms of "cleaning up" a specific property. Approximately 162,000 tons of material was washed. Of this amount, 125,000 tons of clean material, mostly sand and gravel, were generated along with 32,000 tons of filter cake. The reduction in the number of trucks movements alone has been estimated at over 14,500. It is also estimated that 86,000 gallons of diesel fuel and associated air emissions were saved by conducting soil washing verses offsite disposal.

The soil washing at Basford appears to have resulted in a significantly lower environmental impact than what would have been associated with dig and haul. This is an example of how technology can reduce the adverse affects of conducting environmental work. To fully benefit from the work conducted at Basford however and for environmental purposes, the evaluation of this project's air emissions, solid waste, and wastewater discharges and the exposures generated by the work should be compared with those associated with the original site. That evaluation has not been conducted. Such data could then be used when considering future soil washing projects.

Other remedial actions such as on-site thermal treatment would appear to also be better for the environment as a whole verses offsite disposal but there is still exposure and work related impacts that should be considered. An interesting and possibly important comparison should be made between the CO_2 emissions generated from onsite thermal treatment and those associated from dig and haul operations. Certainly, the total CO_2 associated with offsite thermal treatment would appear to be relatively high due to the transportation requirements. However, onsite thermal treatment will also result in high amounts of greenhouse gases.

DISCUSION OF IMPACTS

Natural resources are consumed and by-products are produced whenever investigation and remediation activities are conducted. Investigation related work includes soil boring drilling, monitoring well installation, investigative derived waste (IDW) management, and soil, sediment, and groundwater sampling. Remediation related work includes excavation, transportation, disposal, treatment, soil vapor extraction, soil washing, and groundwater pump and treat.

Direct and Indirect Environmental Impacts

Conducting investigation and remediation work causes both direct and indirect environmental impacts. The direct impacts relate to the performance of the work itself and include the consumption of water and fuel and the release of solid waste, wastewater, and air emissions. The indirect impacts relate to the manufacture and transportation of materials used in the environmental work. This includes the manufacture of PVC and stainless steel well materials, the manufacture of drilling and remediation equipment (prorated for the duration of the project or site use), the manufacture of disposable materials (gloves, drums, sampling supplies, etc.) and the impact from accidental fuel spills. Fuel loses usually occur during project work such loses should include both the on-site releases and also the reported national or regional fuel loses prorated based on the total fuel consumed by the site work.

An example of another indirect impact to the environment is the amount of paper consumed by reporting requirements. In the U.S. each MGP project requires the submittal of many hard copy documents. This is true for either federal or state led projects. A typical document will utilize between 50 to 200 pounds of paper (the equivalent of between 5,000 to 20,000 sheets of 8½ x 11 standard strength paper). It has been reported that each pound of paper requires approximately 8,000 BTUs of energy for its manufacture. Of course other natural resources are required for the production of paper such as water and trees. Once a document has been prepared, it then requires shipment to the interested parties. This involves the use of trucks and cargo aircraft. Similar to the direct impacts caused by conducting environmental work, the indirect impacts include the consumption of natural resources and the production of waste products. The indirect impacts may appear insignificant as compared to those caused from other activities however they are significant when one is attempting to justify an environmental project on the bases of its benefit to human health and the environment. Accurately quantifying the indirect impacts requires considerable time, specific industry knowledge, and the ability to filter politically or marketing derived figures but this work should be performed. Just as the analysis of soil and water samples is required for an MGP project, the total impact of the work performed should also be determined.

The direct impacts will be discussed below and the exposure concerns caused by the performance of environmental work is included in the paper “Comparison of Exposures for Conducting Environmental Work”.

Impact of Site Work

The environmental impact associated with an undisturbed or inactive MGP site is limited to the potential exposure of COCs. In comparison, the impact associated with a site in which investigation or remediation work is in progress, relates not only to potential exposure but also to the consumption of resources and production of waste streams caused by the work itself. To assist with the quantification of work related impacts, specific activities have been reduced to the number of gallons of water and fuel consumed and the amount of waste produced, primarily the amount of CO_2 emitted. Carbon dioxide emissions vary based on combustion efficiency and on the exact formulation of the fuel. A number of researchers, including those at the EPA and

California, use a rate of 22.2 lbs of CO_2 emitted for each gallon of diesel fuel burned. This is an average rate for the U.S. and may or may not take into account incomplete combustion and the production of particulate matter. According to Chevron Products Company, the CO_2 produced from end use combustion of diesel fuel is about 22 lbs of CO_2 per gallon. If the "upstream" CO_2 emissions for producing, transporting, and refining the crude oil is considered, then the total "well to wheels" emissions value is about 27 lbs of CO_2 per gallon. For the purposes of this discussion, 22 lbs of CO_2/gallon of diesel was selected as an approximate average emission rate. The other 5 pounds of CO_2 associated with the production of diesel fuel could be considered an indirect impact.

Other countries do not use CO_2 in calculating greenhouse gas equivalents or global warming potential (GWP); they use the mass of carbon within the CO_2. To convert to pounds of carbon, simply divide the pounds of CO_2 by 3.667 (the molecular ratio of 44/12 for CO_2 to carbon). Greenhouse gas emissions are a matter of international discussion. Many feel the U.S., who is the world's largest single contributor of greenhouse gases, is not doing its share to limit or address concerns over global warming. The U.S. claims that countries such as China are not being asked to limit there emissions. All this relates to economics, of course. Manufacturing and commerce generate CO_2 emissions and limiting these cost money. Recently, it has been proposed that construction projects, for example, be held to CO_2 budgets. If this were to occur, then municipalities and companies would be subject to carbon trading schemes. It would appear that such policies are not soon to be implemented but if they were considered, then the CO_2 emissions from environmental work should be considered first.

Investigation

The table below shows some of the direct impacts associated with conducting subsurface investigations at MGP sites. As indicated by the table, the type of drilling determines the associated impacts. Using direct push for soil and groundwater sampling for example has a relatively low environmental affect as compared with rotary wash (mud rotary) which has a higher affect. But it is important to understand that the different drilling methods are also dependent on the required depths of the investigation. Direct push and hollow stem auger are limited to relatively shallow work, mud rotary can go deeper, and rotosonic is the better method for the deepest work. An average MGP site will employ a variety of drilling and sampling methods and will result from 50 to 300 soil borings, 25 to 100 monitoring wells, and from 50 to 200 55-gallon drums of IDW. Conducting this work would require from 1,200 to over 6,000 gallons of fuel, 17,000 to over 190,000 gallons of water, and generate from 27,000 to 140,000 pounds of CO_2. These are only general ranges for typical MGP sites. Many sites require less work and many require more. For example, sites with long operational histories and large production capacities have had considerably more work than that listed above.

The amount of IDW generated also varies widely between projects depending on policies, work practices, and site conditions. The best practice is to limit IDW whenever possible. Soil and water generated from the investigation work should be returned to the subsurface when it is possible to do so without causing an additional or new exposure concern. Although well intentioned, the containerization of material into 55-gallon drums results in transportation and offsite disposal issues and this impacts the environment. Observations made from numerous MGP investigations indicate that a large amount of the IDW generated is unnecessary.

Drilling	Fuel gal/day	Water gal/day	Footage ft/day	CO2 lbs/day
CME-75 hollow stem auger	20	600	50 - 100	440
Failing (rotary wash)	25 - 40	1,200 - 30,000	50 - 100	550 - 880
GeoProbe 6620	3.5 - 5	50	150 - 250	77 - 110
Rotosonic	30 - 60	500 - 1,000	100 - 150	660 - 1320
Average fuel consumption for transportation (drill rig plus support vehicle)	100 gal/day			2200
Remediation equipment variables include horse power, bucket size, material, and hours of operation. Assume average site conditions and 9 hour days				
Excavation Equipment	Fuel gal/day	Water gal/day	Footage ft/day	CO2 lbs/day
small to mid-size front-end loader	30			660
large front-end loader	60 - 80			1320
small to mid-size excavator	30			660
larger excavator JD 200	80			1760
CAT 345	140			3080
CAT 320	106			2332

Remediation

The above table shows some of the typical fuel consumption and CO_2 emissions associated with certain remediation equipment. Because of the many variables, there is a large range in operational efficiency observed. For example, a single excavator and front-end loader are capable of loading out close to 1,000 tons per day under ideal conditions. Rarely are those conditions met. The availability of the trucks to transport the material is usually the limiting factor. The soil type, presence of debris, staging area, weather, sampling, documentation, and hauling distance to the landfill all tend to limit the amount of work that can be accomplished in a day. Most remedial actions greater than 20,000 tons will utilize two excavators, two front-end loaders, one bull dozer, and other miscellaneous equipment such as power screens, street sweepers, dewatering pumps, water treatment, and other support equipment such as smaller excavators, loaders, and a backhoe. None of these pieces of equipment are operated continuously during the course of a project. Depending on the available personnel and logistics, the excavation, staging, and load out are often alternated. A respectable throughput (requiring experience, planning and resources) can average a load out of 750 tons per day, not including non-working days of which there are many. The load out of this amount of soil will require between 300 to 400 gallons of diesel fuel and this will result in 6,600 to 8,800 lbs of CO_2 per day. The amount of fuel required to transport the soil to the disposal facility is of course strictly dependant on the travel distance and number of loads. A typical truck is capable of hauling 20 tons per load in the U.S. and a loaded truck will average between 5 to 6 miles per gallon. An empty truck will average only a little better than this.

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. Of all of these compounds, the most environmentally significant emission, from a global perspective, is CO_2. Although this greenhouse gas is not a toxicological concern, it is the major contributor to global warming.

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.

While DE represents an environmental concern, the more obvious impact associated with site work is from the exposure of COCs.

CONCLUSIONS

Site work can adversely affect the environment and also create exposure concerns beyond that associated with the original site itself. 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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