Perspective On Regulations for the Clean Up of Hazardous Waste Sites In the United States

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Introduction

The quantity and diversity of hazardous wastes have grown with the progression of technology. When released to the environment, many of these wastes persist for long periods of time and are harmful to public health and the environment characteristics that classify them as hazardous waste. For many of these compounds, a range of toxicities may be found in the literature and this data forms the bases for governmental regulations and the associated requirements for their safe treatment and disposal.

Most hazardous wastes disposed of on land migrate through surface and sub-surface soils to groundwater. Therefore, subsurface migration is a primary pathway for environmental contamination and exposure of receptors. A lack of understanding of the transport and behavior of chemicals in the environment lead to the early, improper disposal of hazardous wastes. Development of and understanding of the scientific concept that chemicals released to the environment enter a series of pathways that can transport the chemicals throughout the environment has provided the bases for present environmental regulations. The rate of waste transformation and transport can now be determined using chemodynamic and transport models supported by onsite sampling data. An understanding of sorption, volatilization, and transformation processes serves as the bases for the quantitative evaluation of hazardous waste sites because they control the release and transport of contaminants along with advective and dispersive processes.

A systematic evaluation of hazardous waste sites is usually approached using the conceptual theme of sources, pathways, and receptors. This approach aids in conceptualizing site assessments, evaluating treatment options, and determining risk and forms the bases for the regulation process used in the United states. The identification, assessment, and remediation of hazardous waste sites are processes that are evolving over time. The complexity and cost of remediation of hazardous waste sites has lead to the development of new efforts in the United States to reduce, at the source, the quantity of new waste generated and firm efforts to prevent new releases to the environment.

Regulation development

Hazards associated with the historical disposal of waste material were generally unknown until the 1970s. Wastes were commonly disposed of by unsafe methods for decades in pits, ponds, lagoons, on soil surfaces, and in poorly designed landfills. The various wastes were able to migrate through soils and groundwater and were detected throughout the environment. Large hazardous waste problems associated with disposal sites were subsequently discovered. By the mid 1970s in the United States, the potential for off site waste migration from disposal sites became apparent. Over 50,000 hazardous waste sites have now been identified under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), a law passed in the United States in 1980 to provide a mechanism for cleaning up past improper hazardous waste disposal sites. The regulation has driven the cleanup of widespread soil and groundwater contamination. It was reauthorize as the Superfund Amendments and Reauthorization Act of 1986 (SARA). Sara created an $8.5 Billion fund for cleanup.

The USEPA blueprint for site cleanup under CERCLA and SARA is the National Contingency Plan (NCP), which provides for site ranking, site assessment, engineering studies of the possible alternatives available for clean up of individual sites, and specific clean up actions. The NCP provides a critical pathway for site assessment, and the design, construction, and operation of remediation systems. Detailed plans are required because the cleanup of Superfund sifts is generally a lengthy, complicated process that requires years to complete.

Implementation of CERCLA

Under CERCLA, the USEPA has conducted more than 27,000 preliminary hazardous site assessments and conducted detailed investigations on over 9000 sites. Over 1200 of these hazardous waste sites have been places on the National Priority list (NPL), A system for ranking the waste sites for clean up.

More than 600 chemicals have been found at Superfund sites in the United States. The conpounds that are most frequently found are lead (43% of sites), trichloroethylene (42%), chromium (35%), benzene (34%), perchloroethylene (28%), arsenic (28%), and toluene (27%). The most common concern from the disposal of these compounds focuses on health effects such as cancer.

Protection of public health is a primary concern of CERCLA regulations and is generally the bases for ranking hazardous waste sites for cleanup. A site assessment is first undertaken to determination the extent of contamination of the soil and groundwater in order to determine how much, if any, of the soil and groundwater must be cleaned up. Once a site is assessed and the extent of the contamination determined, a risk assessment is developed to evaluate the potential threat to public health and the environment. The risk assessment serves as an effective decision tool by which the sites that pose the greatest threat to public health and the environment are cleaned up in relation to their potential danger.

Under the CERCLA regulations, potential human health effects are evaluated using quantitative risk assessment in which superfund sites are assessed on a site by site basis to determine the extent of cleanup required. It is important to understand that cleanup criteria are assessed on a site by site basis because of the unique hazards posed at each site as determined by the risk assessment for the site. The rational for this approach is that the hazard of a contaminate is a function of (1) its potential to reach a receptor, (2) the exposure of the receptor, (3) and the toxicity (type and extend of the damage) of the contaminate. The potential for a contaminate to migrate and degrade, as well as the distance to the receptor of concern is site specific. Only by assessing the risk for each site individually is it possible to rank the hazardous potential of sites and provide a cost effective and efficient cleanup for different sites.

Risk is defined as the probability of suffering harm or loss. Risk assessment, as performed under CERCLA, employs a risk assessment process in for stages: Hazard identification, exposure assessment, toxicity assessment and risk characterization. Risks from exposure are calculated for alternator remedial actions for comparison of their effectiveness to reduce risks. At present, the USEPA has defined acceptable risks for carcinogens as within the range of one in ten thousand to one in one million excess lifetime cancer risk. The one in a million risk is used as a departure level, meaning that a higher risk may be deemed acceptable only when there are special circumstances. Special circumstances may include such things as a small number of receptors located near the site, lack of available technology for control, or high cost for remediation (low cost effectiveness).

To make the cleanup of sites compatible with other environmental regulations, SARA also provides for the Applicable or Relevant and Appropriate Requirements (ARARs). The ARARs are usually derived from other environmental laws, such as the Safe Drinking Water Act (SDWA) and aid in determining the final cleanup requirements. One of the common ARARs is the use of the SDWA Maximum

Contaminate Levels (MCLs) as a cleanup level for contaminated groundwater. The level of cleanup specific by the ARARs may be required in order to protect drinking water supplies even if the site by site risk assessment allows a higher cleanup level.

Treatment Alternatives

Approaches to site cleanup are many and varied. In some cases contaminant may suffice. In others, on site treatment may be selected. In still others, removal may be the most effective solution. In all cases, current regulations require the question of risk to be addressed and the selection or remedial alternatives will be influenced by their ability to reduce risk as will as their cost effectiveness.

The remediation of hazardous wastes sites presents a number of special problems. First, all three media (water, soil, air) need to be treated and the concentration of hazardous compounds varies from very dilute concentrations in contaminated groundwater and soils to drums and tanks containing high concentrations of wastes. Finally, a single chemical is rarely found in soils, groundwater, or air emissions. Rather, chemicals are encountered as complex mixtures with varying chemical properties and toxicity. The wide variations in waste strength, waste properties, and multimedia composition results in a very complicated process for the conceptualization, selection, and design of hazardous waste treatment systems. Furthermore, the rate of subsurface transport of chemicals significantly influences the effectiveness of hazardous waste treatment processes.

It is generally necessary to minimize the rate of off site contamination migration from hazardous waste sites by employing technologies that minimize risk to the public health or the environment. A focused evaluation generally considers the question of source verses plume control. This is important because of the potential technologies that are applied. For plume control, recovery wells are generally employed while source control involves capping, removal of waste, and vertical and horizontal barriers. The purpose of passive source contaminate control systems in site remediation is to eliminate exposure pathways to minimize transport rates. Contaminated groundwater from recovery wells is generally treated for removal of contaminates in reactors. Some of the more common treatment processes and operations employed in the reactors include air stripping, granular activated carbon sorption, traditional biological processes, and thermal processes (such as incineration).

There are numerous soil and groundwater treatment methods available for the remediation of contaminated sites. Many of these are based on the natural pathways for the chemicals fate and transport in the environment. For example chemicals that tend to volatize from groundwater and soil can be effectively treated by use of engineering systems that promote their volatilization. Treatment processes can be used that involve in situ (in place) and ex situ (removal) processes. For example, a commonly used in situ volatilization process is soil vapor extraction in which vacuum is applied through wells placed in the contaminated site. Commonly used ex situ processes involve pump and treat in which groundwater is pumped to the surface for treatment in a reactor and then returned to the subsurface. Treatment processes can also be based on other natural occurring phenomena such as sorption, chemical oxidation, biodegradation, and thermal decomposition.

One of the least desirable options in the remediation of hazardous waste sites is disposal in hazardous waste landfills. This option involves long term containment with no treatment. The disposal of hazardous waste and residues from hazardous waste treatment processes in new landfills has a number of problems, the most prevalent of which is the potential for long term environmental release. This problem results in landfill disposals low priority as a waste management alternative. However, wastes such as incinerator fly ash, dioxin laden sludge, and metal sludge will continue to be disposed of in hazardous waste landfills because it is the only cost effective option for the management of these wastes. Landfill design technology has progressed in recent years, and although not a perfect option, represent a satisfactory means for the disposal of untreatable hazardous wastes. The hazardous waste landfill designs have a significant amount of redundancy to account for the potential release to the subsurface or the atmosphere. The designs include multiple liners, a cover system, leachate collection and waste segregation cells.

Because site conditions can be very complex at superfund sites and remediation alternatives not straightforward, experience often does not yet exist to show clearly how best to proceed. Because of these factors, the selection of a remedy often involves a great deal of judgement. Therefore, one of the most important considerations that requires careful attention is whether to treat or to contain. The tradeoff involves whether to implement preventive measures now to eliminate the possibility of a future, hypothetical problem, or implement then at a future date if and when monitoring data shows that without these measures the hypothetical problem would become real. The cleanup alternative selected must be sufficient to render the site and surrounding environment safe for the intended use. This objective will guide the selection of the appropriate remedial action. For some sites complete removal or extensive treatment of the waste will be required while in others containment (control of the contaminate migration pathway) will be adequate (and cost effective). In many cases, containment may be viewed as a final solution where the focus is on mitigation of risk associated with exposure to groundwater contamination between contaminated sources and potential receptors. Containment technologies may also be associated with other cleanup technologies (such as in situ remedial alternatives) to implement a long term cleanup strategy for a site.

Future Environmental Management based on past experience with CERCLA

Past industrial and waste management actives have contaminated soil and ground water at tens of thousands of sites in both the United States and other countries. It is clear, that a significant portion of the resources available for environmental management in the United States, have been, are, and will continue to be devoted to the assessment and clean up of existing hazardous waste sites. The thousands of hazardous waste sites resulting from preregulaory environmental disposal of hazardous wastes will require decades to assess and clean up.

A systematic evaluation of hazardous waste sites is usually approached using the conceptual theme of sources, pathways, and receptors. This type of approach aids in conceptualizing site assessments, evaluating treatment options, and determining risk and forms the bases for the regulation process used in the United States. However, the identification, assessment, and remediation of hazardous waste sites are processes that are evolving over time based on experience gained from past remediation efforts.

For complex superfund sites, the CERCLA and SARA regulatory processes requires a rigorous series of steps that require a detailed technical analysis to support the development and selection of a final remedial plan for a site. This is both costly and extents the clean up time. Because of this, the process of selecting a site remedy has evolved considerable since the passage of CERCLA in 1980. During the 1990s, regulator agencies developed and implemented regulations that establish different cleanup criteria based on different exposure assumptions. At the present time, the degree to which the evaluation/selection process of a remedy follows the rigorous approach dictated by CERCLA depends on the complexity of the technical and political issues of the site. For less complex sites, semiquantitative evaluation methods, experience at similar sites, phased implementation or interim corrective measures may be employed to reduce the time and cost for site remediation. The development of remediation criteria may now take into account the hazards posed by the site, the potential for exposure based on the future uses for the site, and the consequences if exposure were to occur.

For example, consider a site in the middle of a neighborhood where future land use may involve access to the site by residences. In this case it may be necessary to adopt strict cleanup standards for soil and groundwater. In contrast, for a site located in an industrial complex that can be fenced to prevent use, containment of the source to prevent migration of contaminates off site may be adequate. The application of this procedure can be seen in present regulations for the clean up of PCBs in soils which vary with the proposed use for the site after clean up. The starting point action level or preliminary remediation goal is 1 PPM for sites where unlimited exposure under residential land use is assumed and 10 to 25 PPM for sites where industrial use is assumed. In residential locations, soils with concentrations above 50 PPM must be removed and disposed off at a hazardous waste landfill. For concentrations between these levels and for other land uses, the site must be capped to prevent volatilization, fenced to prevent access and signs posted to indicate the present of hazardous material. The remediation level for groundwater that is potentially drinkable is 0.5 PPB, based on the SDWA maximum contaminate level.

Based on experience, sites considered relatively simple, such as a gasoline station with leaking underground storage tanks have a regulator evaluation/selection process that is much more focused based on experience gained in the field. Accordingly, the time and cost to develop and implement a remedy can be reduced. This is important because there are over 900,000 active petroleum storage tanks registered in the United States with over 350,000 confirmed releases since 1980. Site remediation has been completed at about 200,000 sites and there are about 30,000 new releases reported each year.

Public feedback has also indicated the desire to move rapidly toward evaluation of hazardous waste sites and use of interim corrective measures wherever possible. Experience at complex hazardous waste sites has also demonstrated that more cost effective approaches often unitize a phased implementation process. This is because interim processes often provide information to support a more cost effective expanded system than would have been selected without information gained with the interim process.

The complexity and cost of remediation of hazardous waste sites has lead to the development of new efforts in the United States to reduce, at the source, the quantity of new waste generated and firm efforts to prevent new releases to the environment. The 1990 Pollution Prevention Act in the United States is designed to reduce the generation of waste. The "cradle to grave" concept of hazardous wastes regulation requires development of means to reduce waste generation. This act requires industries to provide detailed annual reports on the effectiveness of source reduction for all chemicals under the community right to know prevision of SARA. Waste minimization efforts include process changes, changes in feedstock, use of new production processes or equipment, and housekeeping changes. Volume reduction is also possible by reuse and recycle of wastes. Another legal inducement to waste reduction is related to future liability, where an industry that generates a hazardous waste is responsible for that waste forever. Industries do not want to ship wastes to what may become a future Superfund site. At the present time, industry and government groups are attempting to identify a systematic means to evaluate and minimize the entire range of environmental impacts for all phases of industrial actives in what is termed life cycle analysis (LCA). This includes air emissions, wastewater, solids and hazardous wastes, renewable resources, and energy utilization.

Based on the experience obtained with hazardous waste site control in the United States, it is clear that developing countries need to undertake sound waste management practices in order to prevent disposal problems that are present in the United States and other developed countries. This is important because the cleanup of existing hazardous waste sites is an exceedingly tough engineering challenge and a significant amount of resources need to be devoted to the cleanup effort.