Evaluation of Adequacy of Site Remediation for Redevelopment: Site Assessment at Remediated-Redeveloped "Superfund" Sites

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Introduction

Several years ago, federal and state pollution control agencies initiated what will ultimately be a several hundred billion dollar hazardous chemical contaminated site remediation effort. These programs are being conducted in the US at federal and state "superfund" sites, Department of Energy (DOE) and Department of Defense (DOD) facilities. As part of recovering part of the cost of site remediation, some site owners are redeveloping the site. The redevelopment of some sites will involve a property transfer to new owners. This transfer should involve a hazardous chemical site assessment in order to ascertain the adequacy of site remediation compared to the proposed plans for redevelopment. Conducting an appropriate site assessment for such properties requires an understanding of the approaches being used today in remediating "superfund" type sites. This paper provides guidance on some of the factors that need to be considered in conducting site assessments associated with property transfers at remediated "superfund" sites.

This paper evolved out of the work conducted by the authors on behalf of the City of Sacramento, California where they served as third party reviewers for the remediation of the Southern Pacific Railyard site located in downtown Sacramento. The authors were asked to conduct an independent review of the adequacy of investigating the extent and degree of contamination of this property as well as the appropriateness of site remediation permitted by state and federal agencies of residual hazardous chemicals present in the site's soils and groundwaters compared to the redevelopment plans that were being developed for the site. The authors reported the results of this investigation to the Sacramento City Council, Planning Commission, Environmental Commission, and the Department of Planning and Development (Lee and Jones 1990a, 1990b).

Since the mid-1800s the Southern Pacific Transportation Company (SPTC) has conducted a variety of locomotive maintenance and repair operations at its Sacramento Railyard (SP site). The SP site covers 240 acres. SPTC is interested in selling the site property; its proximity to downtown Sacramento and its location on the Sacramento riverfront make it a desirable site for redevelopment. The Roma Design Group (1990) working with the City of Sacramento Department of Planning and Development has developed a plan for redevelopment of this site which would involve industrial, commercial, and residential uses. In the early-1980s, however, it was found that some areas of the Sacramento Railyard site were contaminated with a number of potentially hazardous chemicals. This site is now part of the California Bond Expenditure Plan

Requirements. It is not a federal Superfund site. For the purposes of this paper, it shall be considered a state "superfund" site. Any redevelopment of the site, therefore, will require that the existing chemical contamination be appropriately "cleaned up" to meet current regulatory agency requirements.

In June 1988, SPTC signed an enforceable agreement with the California Department of Health Services (DHS) covering the remediation of hazardous chemical contamination resulting from past industrial operations, under the supervision of the DHS and the Central Valley Regional Water Quality Control Board (CVRWQCB). While this site is not a federal Superfund site, the US EPA under its RCRA authority does exercise some control over the adequacy of remediation of some parts of the site where after those parts have been remediated to DHS specifications, the US EPA Region IX reviews and if appropriate approves the remediation. In general, US EPA and state of California DHS "superfund" site investigation and remediation requirements are similar. Further, based on the authors' experience working on "superfund" sites throughout the US, the site investigation and remediation being conducted at the SP site are typical of "superfund" site investigations and remediations conducted throughout the US. This paper uses the SP site as a point for discussion of factors that should be considered in conducting site assessments at remediated "superfund" type sites. This paper is based on part on a discussion of some of these topics by Lee and Jones (1991a).

Objectives of "Superfund" Site "Cleanup"

It is important to understand in conducting a site assessment associated with a property transfer of a remediated "superfund" site the general nature of the "superfund" site investigations and remediations that are being conducted today. The federal Superfund program began as a crash program out of the Love Canal, Niagara Falls, New York situation, to guide the definition of the hazards associated with industrial areas or areas in which industrial chemicals had been deposited such as landfills. It was also designed to guide the remediation of such contaminated areas so that they would not represent significant threats to uses of adjacent properties. In the beginning the focus of the Superfund program was not the protection for reuse of the site, itself, but rather for the protection of uses of adjacent properties.

For various reasons, only a few of the sites across the country at which significant amounts of hazardous chemicals are present, are listed as federal Superfund sites. States have the responsibility for managing contaminated industrial sites that are not included within the federal Superfund program. States' regulations for their own "superfund" sites are typically patterned after the federal regulations. The SP site is one of California's state "superfund" sites.

The "superfund" review and remediation process requires that the details of the evaluation of the type and degree of contamination, the amount of cleanup needed for subsequent use of the property, and other issues, be developed on a site-specific basis. Since the technical community has not come to the consensus about minimum requirements for these details, and since the degree of protection of public health and

environmental quality that should be assured is subjective, some degree of "negotiation" is involved in establishing what must be done at each particular location. In California, representatives of the site responsible party make a proposal to DHS to follow a particular approach in site investigation and/or remediation. The DHS reviewers comment on the proposal, indicating deficiencies they perceive in the approaches. The outcome of the "negotiations" is typically highly influenced by the responsible party trying to spend the least amount of money for investigation and remediation, and the state trying to develop appropriate levels of investigation and remediation based on the agency's current perception of what is "adequate" public health and environmental protection. The position of the state is based to a considerable extent on the understanding that the negotiator(s) has of the hazards that could be present at the site, and of the type and degree of remediation needed to protect future users of the property based on what the responsible party states is the intended use.

The members of the technical community - professionals developing and evaluating approaches - are far from coming to agreement on what is adequate for site investigation and about "how clean is clean?" especially for the public reuse of contaminated properties. Many of the details of the studies that need to be done are thus established somewhat arbitrarily. One example is how close together should samples be taken over the site to be satisfied that all of the contaminated areas are found. Another example is how many and which chemicals should be measured in samples of soil and groundwater at the site and away from the site. A third example is "how clean is clean" for the reuse of the property. Since the degree of public health protection that should be achieved is a subjective assessment, and since the investigation and remediation approaches necessary to achieve any given degree of public health protection are not well-defined, the comprehensiveness of a site investigation, the degree of remediation needed, and the degree of public health protection that is actually provided with the remediation can vary from site to site and within a given site.

There are significant pressures on the personnel of regulatory agencies that can cause less-than-optimum review of a particular site. Regulatory agencies are often significantly under-funded and under-staffed. There is a well recognized national shortage of adequately trained personnel to conduct the federal and state "superfund" programs. Further, because of the newness of "superfund" type investigations and high turnover rates among agency personnel, and the considerable legislative pressure to demonstrate completion of site remediation given the money being spent, there is opportunity for less-than-optimum site characterization and remediation. There is, therefore, justifiable concern about the adequacy of the state and federal "superfund" programs to produce appropriate evaluations of site hazards, and the remediation objectives and methodology.

There is also concern in the technical community about the appropriateness of intense public reuse of "superfund" sites. The authors have found through their work on evaluating the presence of contaminants, the approaches for remediation, and cleanup effected, that there is ample justification for the national concern about the adequacy of the "superfund" programs as they are being implemented to provide for long-term protection of public health and environmental quality where there is to be intense

redevelopment of the remediated property involving public access to the area. Just meeting the minimum requirements accepted by the regulatory agencies for site evaluation or remediation does not necessarily provide assurance that there will be long-term protection of public health or environmental quality associated with the planned redevelopment of the property.

One of the major controversies that has existed throughout the federal and state "superfund" programs is "how clean is clean?" For years, professionals in the field have been struggling with this issue and the answers are still evolving. As discussed above, the issue has two components, the degree of public health protection that can and should be afforded both on and adjacent to remediated "superfund" sites, and the nature and comprehensiveness of investigation and remediation needed to achieve a given degree of public health protection. There is still no general agreement on the degree of investigation necessary, appropriate treatment-remediation technology, and the appropriateness of redeveloping for intense public use so-called "remediated areas."

Generally, the principal responsible parties for "superfund" sites are trying to do the least possible investigation and remediation in order to save money. The public, on the other hand, who could be affected by residual chemicals left at a site after the "remediation" generally advocate a more comprehensive investigation, a more effective cleanup, and unequivocal protection from residual chemicals left at the site. The regulatory agencies try to develop compromises on these issues; what they adopt typically provides a high degree of protection of public health and environmental quality for off-site concerns. However, the introduction of intense public use of these sites after "remediation," adds another dimension to the concern about long-term protection of public health and environmental quality. Since redevelopment of the type being considered for the SP site where there could be intense use of the areas by the public is rare for "superfund" sites, that additional dimension has not had to have been addressed to the extent necessary to develop consensus on what should be done to provide "adequate" protection. Further, there is no long-term experience with such redevelopments from which to draw information on the adequacy of particular approaches to or degrees of remediation.

Some regulatory agency personnel object to the statement that they negotiate the degree of public health protection associated with a "superfund" site investigation and remediation. The bureaucratic response sometimes given by agency personnel is that the approach adopted by the agency "provides for public health and environmental protection." However, those familiar with this topic know that there is a wide latitude of ranges of protection that can be given in both investigating and remediating a site contaminated with hazardous chemicals. There can be little doubt that because of a lack of experience in this topic area what is considered today to be adequate public health and environmental protection associated with "superfund" sites will in the future be determined to be inappropriate. In some instances, less "protection" is justified. However, it is the authors opinion that in most instances more protection will be judged to be appropriate. For example, in the case of lead, Houk (1990) of the of the Public Health Service Centers for Disease Control in testimony before the Human Resources and Intergovernmental Relations Subcommittee of the US House of Representatives stated,

"Just last week, we began a process of reevaluating the 1985 CDC recommendations for the threshold level of concern with lead exposure. It is certain our recommended blood level will be decreased from 25 micrograms per deciliter to a lower value."

As noted above, there is a significant number of somewhat arbitrary decisions negotiated in establishing the overall remediation for "superfund" sites. An example of negotiated compromise that frequently occurs at "superfund" sites which has relevance to many sites is the issue of the spacing between soil samples over the site. At some sites, a 400-foot grid spacing is used for collection of soil samples to look for the presence of contaminants across much of the site where specific sources of contaminants are not known. That means that a distance greater than a football field would exist in any direction between one sampling point and the next. Soil sampling points using a 400-foot grid are generally considered too far apart for many "superfund" sites that are proposed for redevelopment involving public contact. The actual spacing that will be required will be negotiated; the shorter distance between sampling points, the lower the probability of not detecting a "hot spot" or contaminated area, the greater the assurance of public health and environmental protection, but the greater the cost to the responsible party for sampling and analysis.

Another concern is related to the policy adopted by regulatory agencies regarding which chemicals to measure at "superfund" sites. Of the many hundreds of chemicals that could be present at many "superfund" sites, regulatory agencies at the federal and state level only require that 150 or so - basically those on the list of Priority Pollutants, be determined. However, that list does not represent a comprehensive listing of all chemicals that could be present at many "superfund" sites that could be hazardous or detrimental to future uses of the site or on-site and off-site groundwaters; that list was not developed for that purpose.

The list of Priority Pollutants evolved out of the 1972 amendments of the Federal Water Pollution Control Act (PL 92-500). It was developed under court order and did not receive the scrutiny of the technical community due it. Further, the list was developed to include chemicals that had been reported in surface waters and to focus on contaminants discharged from industrial and domestic wastewater sources to surface waters. It was not developed based on chemicals that could be in soils or groundwaters at industrial and/or military sites. Nonetheless, the agency policy for state "superfund" site investigation, as well as the US EPA policy for federal Superfund sites, is to focus on Priority Pollutants. It is well known that there is a wide variety of chemicals that can be present at "superfund" sites, that can be readily measured by other techniques. At this time, neither the federal nor state programs are requiring such measurements.

Another significant deficiency in current approaches in assessing the hazard that chemicals present at a site represent to public health and the environment is the failure to use biological assessments. In the water pollution control field, bioassays-toxicity tests have become standard practice for judging whether a known chemical or combination of known chemicals as well as unknown chemicals are toxic to aquatic life in the receiving waters for the discharge. Such testing procedures integrate a wide variety of factors that

influence the toxicity-impact of contaminants. In addition to addressing toxicity due to unknown chemicals this type of testing also addresses synergistic and antagonistic impacts of known and unknown chemicals.

At this time, various types of biological response tests are being developed for use in "superfund" site evaluations. An example of the this type of test is the Ames test for mutagenicity. One of the reasons why such tests have not been used more extensively is the difficulty in interpreting the response of the test. It is likely that in the near future that tests of this type will become routinely used for assessing the hazards associated with "superfund" sites.

It is evident from the above discussions that those conducting site assessments of so-called remediated "superfund" or other sites must proceed cautiously with respect to assuming that because it is said that a site has been cleaned-up-remediated that there are no significant residual hazards due to chemicals at the site. It is possible that at some remediated sites that significant unknown hazards still exist because of inadequate investigations conducted as part of the original RI/FS. Further, the hazards associated with a particular contaminant or group of contaminants may be judged significantly different than they were at the time of remediation. Another area of concern is that there will almost certainly be a significant broadening of scope of the chemicals that are included within those that are considered hazardous beyond the Priority Pollutants which is the focus of today's remediation efforts. Further, some of the new biologically oriented tests that are at this time considered developmental will become standard protocol for judging the hazards that contaminated soils and water represent to public health and the environment. All of the above as well as other factors lead to the conclusion that those conducting property transfer site assessments in the future of remediated properties as well as properties near remediated properties and those that have received hazardous chemicals from remediated properties must proceed very cautiously in evaluating the adequacy of remediation compared to plans for future redevelopment of the property.

Relationship Between Presence of Residual Contamination and Redevelopment

DHS in its analysis of the safe concentrations of lead in surface soils that would be left in residential areas at the SP site has concluded that 174 mg/kg presents little risk to children. DHS has also established that 950 mg/kg lead in soil is a safe concentration for workers and other non-residential, non-children-related activities. The 950 mg/kg lead is a somewhat arbitrarily-established concentration which is not related to potential human health impacts. DHS concluded that workers can be exposed to soils containing on the order of 3,000 mg/kg lead with little risk of developing excessive blood concentrations of lead. However, 1,000 mg lead/kg is the arbitrarily established DHS Total Threshold Limit Concentration; soils containing higher concentrations of lead are classified as "hazardous waste." Therefore, DHS chose 950 mg lead/kg as the remediation level for lead in soils at the SP site except in those areas where children could come in contact with the lead-containing soil based on on-site exposure. Areas where such exposure is possible have to be remediated to 174 mg/kg lead.

SPTC and DHS are conducting a phased investigation and remediation of various parts of the site. At this time, this work has progressed to the point where there are DHS-approved hazardous chemical closure plans for several parts of the SPTC Railyard site. DHS has approved the closure of the Battery Shop Yard that was contaminated with lead. The remediation of that area included removal of all soil containing lead in concentrations greater than 950 mg/kg to a hazardous waste disposal site. Since SPTC has classified the Battery Shop Yard area as "commercial/industrial" future use, DHS has allowed SPTC to leave in the area soils that contain lead in concentrations up to 950 mg/kg. In order to minimize the possibility of those soils becoming scattered over the site by wind, DHS required that a 2-ft veneer of soil containing less than 174 mg/kg lead be placed above all soils in the Battery Shop Yard that contain lead concentrations greater than 174 mg/kg. DHS has also required that a deed restriction be placed on that area of the site that limits its use for residential, open-space, and other purposes that could result in the exposure of the public to elevated concentrations of lead.

The 2-tiered soil lead level remediation approach creates concern about the effectiveness of deed restrictions in intensively redeveloped areas, such as proposed for the Southern Pacific Railyard site, in which commercial, industrial and residential development will be side-by-side without any isolation (fencing or other barriers as proposed in the current redevelopment plans). Concern should be raised about the long-term public health implications of the remediation program that was undertaken and approved at the Battery Shop Yard area. There are areas within that region in which soils below the 2-ft depth have significantly elevated concentrations of lead which, if brought to the surface, could represent a hazard to children, based on DHS criteria.

There are a variety of activities that could cause lead-contaminated soils beneath the 2 ft low-lead soil veneer to be brought to the surface. Excavation in the area, such as that associated with digging holes for fence posts, shrubbery, large shade-trees, etc., and trenching could result in contamination of surface soils with lead and other contaminants. One of the lead transport processes of concern is the translocation of lead through plant roots that take up lead and, for that matter, other soil-associated contaminants and expel them through the leaves or fruit. Neither the US EPA nor DHS includes this mechanism of contaminant transport in their respective "superfund" guidance manuals; it is therefore not evaluated in the typical "superfund" site RI/FS. Translocation may be a relatively unimportant transport mechanism for the typical "superfund" site on which only shallow-rooted vegetation is planted, and at which there is little human contact after closure. However, it could be a significant transport mechanism at the SP site which will not only likely have more deeply rooted vegetation but also have intense human activity and long-term contact.

The basic issue that has to be resolved is whether the deed restriction for this area as developed in accord with DHS requirements provides for adequate public health protection of children to exposure to elevated concentrations of lead. While DHS is responsible for developing a deed restriction, according to the State Health and Safety Code, it is the City that is responsible for its administration. This situation should be of concern to the City since the adequacy of administration of the deed restriction by City

employees will be a major factor in determining the public health and environmental protection as well as protection of the City's interests and in particular its liabilities associated with the redeveloped property in those areas where a thin veneer of low-lead soil exists over soils that contain concentrations of lead currently considered by DHS as potentially hazardous to children.

A variety of scenarios exist in which 950 mg/kg lead in soils could be brought to the surface by individuals without their even being aware of the deed restriction or the fact that at one time the area was a "superfund" site and that the site has elevated levels of a variety of contaminants remaining in the soils. It is very important to note that the lead in the soils will be there forever. It has little tendency to migrate and while it is possible to control land uses associated with the initial property redevelopment, there will be considerably less consciousness about the residual contaminants, such as lead, left at the site by SPTC as part of the site remediation during re-redevelopment 50, 100, or more years hence. It appears that most of the focus of SPTC and DHS is on the initial redevelopment-associated hazards. Longer term hazards should also be considered, especially in light of the fact that SPTC is choosing, with the approval of DHS, not to remediate the site to levels of contaminants that are considered by DHS as safe for unlimited human exposure.

The City, through its administration of deed restrictions and permitting of various types of land use activities, including issuing of building permits, remodeling permits, business licenses, day-care facilities use permits, etc., could find itself with considerable liabilities for having approved a situation in which children become exposed to excessive amounts of lead or other contaminants at concentrations above those considered safe by DHS. As discussed above, there are a number of plausible scenarios where the safeguards that the City might impose as part of its regulatory functions could be circumvented through employee negligence in failing to implement deed restrictions, etc., where the City could be judged by the courts to have assumed some responsibility for the exposure of children to excessive concentrations of lead. It is important to emphasize that those problems will not likely occur as part of the initial redevelopment of the SPTC Railyard site, but could become important 50 or 100 years in the future when the fact that this was a former "superfund" site has long been forgotten.

A bottom line issue that must be considered is whether there are significant hazards to children that can arise from SPTC doing only a partial cleanup of the site. While the use of these areas with the elevated lead concentrations will initially be restricted to commercial and industrial purposes, a reasonable question to ask is whether there are plausible scenarios where leaving 950 mg/kg lead in the surface soils covered by a thin veneer of low-lead soil, would represent a hazardous situation at some time in the future. To construction workers or occasional users, passers-by, and so forth, this does not appear to represent a highly hazardous situation since as noted above concentrations of several thousand mg/kg would be allowed for adult exposure. However, is it possible that children could be exposed to the 950 mg/kg lead-containing surface soils in a commercial or industrial setting? Certainly with the increased day-care activities in commercial and industrial facilities it is fairly easy to envision a plausible scenario where 10, 20, 50, or so

years from now, a commercial or industrial establishment decides to or is forced to provide day-care facilities for employees' children. The building superintendent or supervisor could decide that this could be done by converting an existing office area and adjacent patio area into a day-care facility. While the establishment would likely have to get a permit for this purpose, it is possible that the day-care facility permit inspector would not be aware of or understand the deed restrictions on the property. Since little or no remodeling is being done, the establishment would not require a city building inspector's inspection and therefore it is possible that children could be exposed to 950 mg/kg lead-containing soils in the courtyard area of the commercial or industrial establishment under the condition where a thin veneer of low-lead soil covers soils containing up to 950 mg/kg lead. This type of situation is one of the reasons there is concern about only partial cleanup of the SP site, and the imposition of future-use restrictions.

Another plausible scenario for children exposure to excessive lead is one in which children from residential areas within the redeveloped site or from residential areas adjacent to the SPTC property could gain access to soils on "commercial/industrial" property that have lead at the surface that are potentially hazardous to children. This situation raises serious questions about any redevelopment plans for a "superfund" site where potentially significant amounts of residual hazardous chemicals exist at the site and there is not fencing or other adequate safeguards which could keep children from gaining access to "commercial/industrial" remediated property.

DHS has indicated to the authors that it would be their intent to require further cleanup of all areas, such as court-yards and other open spaces in order to significantly reduce the potential for the public to be exposed to elevated concentrations of lead in these areas. While currently DHS has indicated that it would be their policy to require additional remediation, there are no assurances that future and/or other DHS staff would address the situation in the same manner. Lee and Jones (1991a) have discussed a number of approaches that could be adopted at the SP site that would significantly reduce the hazard of the residual lead and other chemicals present at the site after remediation.

The use of 1 to 2-ft soil veneers of low known contaminant concentrations to cover elevated concentrations of the contaminants is commonly practiced at "superfund" sites. For example, the US EPA Edison, NJ, and the state of Missouri in closure of the Times Beach, MO, mobile incinerator test burn of dioxin-containing soils site used a 1-ft veneer of 1 ppb dioxin soil above soils containing 10 ppb dioxin. While obviously this site, and for that matter most "superfund" sites, is not now scheduled for intense public redevelopment, residual heavy metals such as lead and highly persistent non-migratory organics such as dioxins will be present in these soils forever or essentially forever. They will always, therefore, represent a potential hazard. It is appropriate, therefore, to question the long-term efficacy of the use of thin soil veneers as a means of reducing exposures to hazardous chemicals.

The SPTC soil lead situation is not atypical of what occurs at many remediated "superfund" sites. According to Laformara of the US EPA (1991), lead is an important

contaminant at over 50 percent of the "superfund" sites. Typically, based on a risk assessment, known contaminants are removed and/or remediated at the site to some selected level of risk. Some of the hazardous chemicals present at the site are left at the site unremediated and, therefore, represent potential hazards to future users of the property. Those conducting site assessments involving property transfer must carefully evaluate the potential hazards that the residual chemicals represent for future users of the property. Future uses and exposure should consider the latest information on what is known about the hazards that the known residual contaminants present at the site represent to public health and the environment. They also should consider the adequacy of the previous RI/FS in detecting identified areas of hazard as well as unknown hazards.

While in the future a remediated property may have presented no known public health or environmental problems since the time of remediation, there is no assurance that with re-redevelopment of the property that problems of the type discussed above will not be encountered in the future. Those conducting site assessments associated with property transactions should make their client fully aware of the potential problems and their potential liabilities associated with such problems. It is recommended that such assessments utilize plausible worst case scenarios for potential public health and environmental problems as a basis for conducting a proper site assessment. To the extent that this approach is appropriately fulfilled their client will be informed of the potential problems that should be considered associated with the property transaction. This plausible worst case scenario approach should be used in any property site assessment in which there is concern about the potential impacts of hazardous chemicals used or otherwise present at the site.

Groundwater Pollution

The studies that have been conducted thus far have shown that there is extensive pollution of groundwaters under the SP site and off-site to the south by chlorinated solvents and their transformation products (e.g., vinyl chloride). Some measurements of vinyl chloride in that area exceeded 100 ug/L; concentrations of some of the other transformation products of chlorinated solvents exceeded thousands of ug/L in that area. The US EPA's MCL for vinyl chloride is 2 ug/L (ppb); the state of California's MCL for vinyl chloride is 0.5 ug/L.

Since there are no known uses of the SPTC Railyard area groundwater today for domestic supply purposes, and since at least near the site it is highly unlikely that domestic water supply wells would be constructed, there is little immediate hazard to domestic water supply water quality associated with the groundwater pollution plume of VOC's (volatile organic compounds) from the site. The US EPA, DHS, and the Regional Water Quality Control Board will, however, likely require SPTC to clean up the contaminated groundwaters by reducing the VOC's and other known, potentially hazardous chemicals to some yet-undefined level. The cleanup levels will likely be the state MCL's since these are at least equal or lower than the US EPA MCL's.

If not cleaned up, the groundwater pollution plume of vinyl chloride represents a threat to down gradient groundwater domestic supplies that could be developed in the future. It also represents an as-yet undefined threat to public health through gas-phase migration of VOC's from the groundwater pollution plume to basements in the areas overlying the plume. The investigations that have been done on the groundwater pollution plume of VOC's from the SP site has shown that the potential for vapor-phase migration of VOC's from this plume into and through the air space in the aquifer above the water table (unsaturated zone) has not been adequately considered or investigated. It is well known that those chemicals, especially vinyl chloride, can readily move from contaminated groundwaters into the geological strata and soils above the groundwater table. There are some instances at "superfund" sites where sufficient releases of chemicals of this type have occurred to represent significant hazards to individuals occupying structures, such as homes, above the groundwater contamination plumes. This is particularly important in basements of homes or other buildings that do not have good ventilation.

Should there be significant vapor-phase migration of vinyl chloride or other chemicals of concern within the area that will be redeveloped, special precautions will have to be taken in constructing buildings above the groundwater plume to allow for proper ventilation of the areas to prevent hazardous chemical build-up in basements, etc. That technology is well known and can be readily applied at the time of construction. It is not likely that vinyl chloride or other gases in the groundwater plume would represent a hazard to workers during construction or to individuals walking through or otherwise using the open areas after redevelopment. The amount of chemical released to the air in open-air situations will almost certainly be small compared to the amount of air dilution typically available. As the polluted groundwater plume is cleaned up, the potential problem of soil gas migration will likely be significantly reduced.

Even after cleanup, there will be need to monitor the groundwaters essentially forever to ensure that other now-unknown sources of contaminants, such as buried containers of solvents, do not become important contaminants in the groundwater system at some time in the future. In a "superfund" site with as complex a history of activities as have been undertaken over the years at the SP site, it is possible that at some time in the past, containers of chlorinated solvent or other similar chemicals were buried on the site, which have not yet rusted out. A single 55-gallon container of TCE can pollute hundreds of millions of gallons of groundwater to levels above the drinking water MCL. Therefore, there will be need for very long-term, careful monitoring of the groundwaters at the site which should take place well after the groundwaters have been apparently cleaned up to the MCL's applicable at that time.

It would also be prudent public health policy to conduct monitoring of potentially hazardous gases in the basements of buildings that would be constructed at the site. As discussed above, an unknown buried container of TCE could, when it rusts out, contaminate groundwaters which could lead to the vapor-phase migration of VOC's that could contaminate the basements of certain buildings at some time in the future. Therefore, even though soil gas analysis does not now show excessive concentrations of

those chemicals there is a potential for these problems to develop in the future if a buried container for hazardous VOC's exists at the site and is breached.

Sulfate and other Groundwater Contaminants

It was standard practice for SPTC personnel in the Battery Shop Yard area of the SP site to dump sulfuric acid into what are called "dry wells" which were open areas of the soil in a concrete pad. That acid was also apparently allowed to run off the concrete pad onto the soil. Sulfuric acid could result in high concentrations of sulfate in the groundwater. Sulfate is of concern in domestic water supplies because of its laxative effect and its contribution to the total dissolved solids, which increase corrosion. The US EPA recently announced that it will establish an MCL for sulfate at 400 to 500 mg/L in the near future; DHS has a secondary MCL for sulfate of 250 mg/L.

The SP site sulfate groundwater situation brings out a potential problem that occurs at all "superfund" sites where federal and state "superfund" site evaluation and remediation guidelines focus on the limited number of hazardous chemicals that are identified as Priority Pollutants. As discussed above, this group of chemicals represent a small part of the wide variety of hazardous chemicals that can be present at "superfund" and other sites. Further, and most importantly, it is highly inappropriate as is done in federal and many states "superfund" programs to not include conventional and nonconventional pollutants as part of groundwater investigation and remediation.

With few exceptions, the purpose of groundwater remediation at "superfund" sites is to protect, and where possible enhance, the use of groundwaters for domestic water supply purposes. As discussed by Lee and Jones (1991b), domestic water supply water quality includes consideration of conventional, nonconventional, and hazardous chemicals. A conventional pollutant such as TDS present in excessive concentrations in groundwaters can be just as detrimental to the use of that water for domestic water supply purposes as a hazardous chemical such as TCE. In fact, in many situations conventional pollutants are more damaging to domestic water supplies than VOC's. Normally, VOC's are readily removable at a fairly low cost. The removal of conventional pollutants, however, is often very expensive and not normally practiced.

It is, therefore, important that those conducting site assessments for remediated "superfund" sites consider pollution of groundwaters by conventional, nonconventional, and hazardous chemicals by chemicals that have been used or otherwise present at the site. Further, even for sites at which the groundwater contamination has been "remediated" to below known contaminant MCL's, it is appropriate to conduct additional investigations of groundwaters at the site and under adjacent properties to be certain that the remediation was in fact properly conducted, the MCL's achieved are applicable to time of site assessment, and that no new sources of contaminants such as breached buried drums have caused additional groundwater contamination to occur. Further consideration must be given to the potential for soil-gas migration problems at the time of the site assessment even though there have been no previously known problems of this type.

Site Assessment Near Landfills

Some "superfund" site remediation approaches involve on-site containment of the hazardous chemicals in landfills. Further, the removal of hazardous chemicals from a site to a landfill for management creates potential problems for those conducting site assessment in the vicinity of the landfill because of the potential for long-term liability associated with the disposal of hazardous chemicals at that landfill. Those purchasing property that was a former "superfund" site may find that they inherit liability of not only the residual chemicals present at the site but also for any problems that may develop at the landfill where the chemicals have been taken for disposal. Therefore, it is appropriate that those who conduct site assessments of remediated "superfund" properties become familiar with the ability of on-site as well as off-site landfills to contain the hazardous chemicals associated with the site for as long as the chemicals represent a threat to public health, groundwater quality, and the environment. For many chemicals such as heavy metals, persistent organics, etc., the chemicals will be a threat to public health, groundwater quality, and the environment forever, i.e., as long as the wastes remain in the landfill.

While ordinarily hazardous chemicals removed from a "superfund" site are taken to RCRA Class C landfills, in some areas significant amounts of hazardous chemicals are taken to Class D (municipal) landfills as part of "superfund" site cleanup. As discussed above, in the state of California DHS has developed an arbitrary definition of a soil being classified as a hazardous waste whenever the lead content of the soil exceeds 1,000 mg/kg. Any lead-containing soils with lead above this amount must be treated on-site or be transported to a hazardous waste (Class C) landfill. The cost of disposal of such lead contaminated soils is on the order of \$300 per yd^3.

Soils with lead content above 174 mg/kg are judged by DHS to be unsafe for child exposure. Therefore, if the redevelopment of a "superfund" site property involves the potential for children exposure to the soil, the soils with lead above 174 mg/kg must be treated or removed from the site. The soils removed from the site can be taken to a municipal landfill for disposal with a cost of about \$20 to \$30 per yd^3. While municipal landfills already contain lead and other hazardous chemicals from a variety of sources, "superfund" site cleanup operations can readily increase the amount of lead and other hazardous chemicals deposited in the landfill.

Another source of contaminants for municipal landfills or for contaminants left on-site as part of remediation arises from the highly arbitrary approach that the US EPA adopted and continues to use for classification of wastes as hazardous wastes. One of the parameters used for this classification is a leaching test in which soil and a leaching solution are mixed together under standardized conditions and the amount of a few contaminants solubilized during this test is measured. With totally inadequate justification, the US EPA assumed and continues to assume that whenever the concentration of solubilized contaminant is equal to or exceeds 100 times the drinking water MCL, the material (waste) that was leached is classified as hazardous. While US EPA claims that this 100 times factor is justified based on typical attenuation factors that

occur in groundwaters near landfills, there are many situations, if not most, where such a level of attenuation does not occur. Under these conditions, contaminated soils and wastes can readily contaminate groundwaters with a variety of contaminants above drinking water MCL's and be classified as "nonhazardous" wastes.

The original testing procedure developed by the US EPA was the EP Tox test. This test was recognized as being grossly inadequate for use for this purpose. The federal Congress as part of the revision of RCRA ordered the US EPA to develop a more reliable test for waste classification. During the past year, the US EPA has adopted the use of the TCLP test for this purpose. While the TCLP is improved over the EP Tox test it is still grossly deficient as a reliable test for the classification of contaminated soils and other materials as hazardous wastes. Contaminated soils present at a site which passed a TCLP test by not having soluble components in them which are released under the conditions of the test can readily render groundwater unusable for domestic water supply purposes due to the release of contaminants. Such materials, however, would be considered safe to leave at the "superfund" site in an unremediated condition. This is one of the most significant deficiencies of the federal and state "superfund" site investigation and remediation programs.

Those conducting site assessments of remediated properties must be cognizant of this deficiency and inform their clients of it and the implications for property redevelopment. For further information on the type of site specific testing that should be done to properly classify a material as hazardous consult the review by Lee and Jones (1981).

The on-site as well as off-site landfilling of wastes in hazardous as well as so-called nonhazardous landfills typically takes place in plastic and clay lined tombs. These tombs are encased with flexible membrane liners (FML's) and compacted clay liners. The purpose of the tomb caps and liners is to prevent moisture from entering the landfill and leachate from leaving the landfill except through the leachate collection and removal system. It is now known that both FML's and soil liners leak at the time of installation and that over time the integrity of both types of liners deteriorates ultimately providing little or no barrier to moisture entering the landfill and leachate leaving the landfill. As discussed by Lee and Jones (1991b) such "dry tombs" should only be considered for use as temporary storage for hazardous and nonhazardous waste and other contaminated solids. The temporary nature of this storage arises from the fact that when the liners ultimately fail to prevent leachate migration from the landfill due to their deterioration, there is no possibility of repairing the liners without removal of the wastes. In some cases with the so-called nonhazardous wastes, the landfill can be hundreds of feet thick.

It is sometimes asserted by landfill owners and operators and consulting firms working on their behalf that the groundwater monitoring system that is typically used at landfills will detect liner failure and the associated groundwater pollution and thereby provide the opportunity for remediation of the groundwater before groundwaters under an adjacent property are polluted. The fact is that the typical groundwater monitoring program used today for hazardous and nonhazardous landfills in which one or so upgradient wells and several downgradient monitoring wells have very limited potential for detection of

groundwater pollution. The downgradient wells are spaced from hundreds to thousands of feet apart across the downgradient face of the landfill. The typical zone of capture for monitoring wells of the type being used today is a foot or so from each well. This means that there are hundreds to thousands of feet across the face of the landfill where there is no possibility of detecting landfill liner leakage with the monitoring well system being used.

It is now well known that leakage from specific point sources such as holes from landfill liners shows limited lateral dispersion in groundwater systems. This leakage can best be characterized as fingers rather than fan-shaped. This means that since the leakage from a flexible membrane lined landfill will initially be from point sources associated with holes in the liner that there is a very high probability that such leakage will not be detected with the monitoring well system used at both hazardous and "nonhazardous" landfills.

It is, therefore, evident that those conducting site assessments for remediated "superfund" sites as well as near other sites that have landfills containing municipal and/or industrial wastes including contaminated soils must give considerable attention to the eventual failure of the liner system to prevent groundwater pollution. It is totally inappropriate as is sometimes done for those conducting such assessments to state that since the landfill is lined there will be no groundwater pollution. The flexible membrane and clay soil liners used today only postpone the inevitable groundwater pollution that will occur at the site; they do not prevent it.

Conclusion and Recommendations

The current federal and state "superfund" guidelines allowing multiple tiers for site remediation have significant long-term potential public health and environmental problems associated with residual contaminants on the remediated property. The "piece meal" (phased investigation and remediation) approach used by some "superfund" regulatory agencies in evaluating the adequacy of a proposed remediation program can result in elevated potentially hazardous contaminant levels on the remediated property being immediately adjacent to "residential" contaminant level remediated properties or other residential areas without isolation of the two property uses. This situation could readily allow for children to "go across the street" and be exposed to excessive concentrations of residual hazardous chemicals.

Further, within remediated properties there are significant long-term potential problems with the ability of property owners and the administrators of deed restrictions to properly implement the deed restrictions ad infinitum to ensure high degrees of public health and environmental protection are achieved. It is clear that attention will need to be paid in conducting site assessments at "superfund" remediated properties to consider the potential long-term uses and the ability of regulatory agencies to administer property use restrictions ad infinitum.

Site assessments of remediated redeveloped properties must give particular attention for the potential for groundwater pollution by residual chemicals present at the site as well as

unidentified containers of chemicals that will ultimately leak contaminants to groundwaters. The groundwater plumes can be important sources of VOC's that can cause soil-gas migration problems in structures constructed above the plumes.

The ultimate failure of "dry tomb" landfill liners requires that careful consideration be given to groundwater pollution by on-site, near site, as well as off-site landfills. The groundwater quality monitoring programs associated with both hazardous and nonhazardous landfills typically have a low probability of detecting leakage from the landfill. They, therefore, provide little protection of groundwater quality from pollution by landfill leachate. The "dry tomb" landfills of the type being constructed today only postpone the eventual pollution of the groundwaters that can occur in the vicinity of the landfill. Such landfills should be considered as temporary storage for the wastes.

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