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Factors limiting the success of groundwater remediations *

Bob Hockman

Amoco Corporation, Environmental Affairs and Safety Department, Groundwater Management Section, P.O. Box 3385, Tulsa, OK 74 102 (USA)

Abstract

Non-optimal treatment technologies such as excavation and disposal of petroleum hydrocarbon contaminated soil may result when remediation decisions are driven by political agendas, economic gains, and/or public perception as opposed to a sound, site specific technical analysis. Resultant misdirection of financial and technical resources could prevent remedial action at another contaminated site that poses a greater risk to public welfare. This paper discusses these problems and presents ideas to improve the situation. Technical considerations include (1) project management can take advantage of the asymptotic behavior of remediation technologies to re-evaluate and possibly modify components of the existing technology, and (2) most successful remediations result from additive affects of multiple, complementary technologies that have been customized for the site conditions.

Introduction

As of April, 1991, the U.S. Environmental Protection Agency (EPA) Office of Underground Storage Tanks had identified approximately 128,000 "confirmed releases" of petroleum hydrocarbons from underground storage tanks to the environment. Approximately 21,000 of these were considered "completed remediations". Most of the "completed remediations" were actually excavation of contaminated soils and disposal in a landfill [1]. Even though it is included in the U.S. EPA statistics as remediation, excavation and disposal may actually cause additional groundwater contamination.

Excavation and disposal simply moves the contaminated soils to another location. If the contamination from these soils reaches groundwater below the

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Correspondence to: B. Hockman, Amoco Corporation, Environmental Affairs and Safety Department, Groundwater Management Section, P.O. Box 3385, Tulsa, OK 74 102 (USA). Fax: (918) 660-4443.

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disposal location, a second remediation may result. Excavation and disposal may have actually caused more groundwater contamination than it prevented.

Few of the completed remediations factored into the U.S. EPA statistics include shutdown of groundwater pump-and-treat systems that had reached contaminant levels mandated by regulatory programs [1]. Groundwater remediations that have successfully reduced contaminants to permissible levels are rare even though pump-and-treat systems have been active for 5–10 years. Why? The following text discusses reasons for frequent use of excavation and disposal as a remediation method and the lack of pump-and-treat successes.

Forgetting the basics

When asked, most professionals conclude that the laws controlling groundwater remediations include RCRA, CERCLA, Clean Water Act, Safe Drinking Water Act, andthe state and/or local regulatory programs based on them. This assertion is only partly true. Three other laws actually have a more important role in controlling groundwater remediations.

The first, and most important technically, was written in 1856 and is known as Darcy's Law [2]. Darcy's Law states that the rate at which fluids will move through a porous media is limited by characteristics of the media, characteristics of the fluids, and the hydraulic gradient of the fluids within the media.

Darcy's Law, coupled with partitioning [2] of the contaminant present, will determine how the remediation should be performed, the rate it will progress, and if it will be successful in meeting the permissible contaminant levels. Professionals managing groundwater remediations often fail to consider Darcy's law limitations and engineer remediation systems that are inadequate for the physical conditions or fluids present. These flawed systems often result from attempting to satisfy regulatory requirements and/or lack of experience performing groundwater remediations.

The second, and most important practically, is "Murphy's Law". Anyone who has managed or even worked on a groundwater remediation knows that any possible complication that can cause difficulties will occur. These complications can include geologic surprises, technology malfunction, contractor malpractice, permit delays or combinations of all of these. As a result, remediation projects are infamous for being slow and/or over budget. The experienced remediation professional has usually learned this the hard way and factors the effects of Murphy's Law into projects accordingly.

The third, and most important pragmatically, is the "Law of the Squeaky Wheel". That is, the groundwater resource often is not the driving factor in a groundwater remediation. Groundwater remediations are often driven and prioritized by political agendas, economic gains, and/or related public perception. The resource and the effects of the contaminant(s) on it are often not the dominant consideration in developing groundwater remediations. Both regulatory officials and responsible parties may be forced to focus limited resources at locations more significant from a public perception standpoint than from a groundwater standpoint.

Technical decisions are often based on non-technical considerations thus limiting the potential success of a remediation. As a result, excavation and disposal of contaminated materials in landfills often result from the Law of the Squeaky Wheel. The professional managing and the regulatory official overseeing a groundwater remediation project may be forced, by non-technical factors, to use excavation and disposal even though there is no threat to groundwater on site. This may also prevent the professional from using better remediation techniques or simply monitoring the site for natural degradation and/or dispersion of the contaminants. A remediation technique is used, not because it is the best technically, but because it can be initiated rapidly to quell negative public perception.

Travis and Doty [3] in their evaluation of Superfund remediations concluded that "remediation decisions appear to be driven more by cost, EPA policy, compliance with state and federal environmental regulations and professional judgement rather than by current or future risk levels." Groundwater remediation requirements should be based on the risks posed by the contaminants present combined with the potential for the contaminants to reach groundwater.

Requiring remediation simply because a site has been contaminated limits the potential for groundwater protection in general due to misdirection of financial resources. Attempting to remediate all sites and the resultant workload precludes prioritization based on risk. Sites where groundwater is most at risk often are not addressed properly because regulatory officials, consultants, and responsible parties are "fighting fires".

Delays in remediation system start-up

Zhu et al. [4] evaluated the affects of delaying free-phase hydrocarbon recovery after a release. As shown in Fig. 1, delaying recovery significantly decreases the ratio of hydrocarbons recovered as free-phase vs. the quantity spilled.

As a result, significantly more of the hydrocarbon release migrates from the spill origin and is trapped in the geologic matrix as residual phase contamination (Fig. 2). Remediating residual phase hydrocarbons is significantly more difficult than recovering free-phase hydrocarbons. Thus, delaying free-phase recovery can limit the potential to successfully remediate the release to permissible levels.

In practice, groundwater remediations are often delayed due to the regulatory process and related public mistrust. The regulatory system often seems to work against the regulatory official and the responsible party attempting to

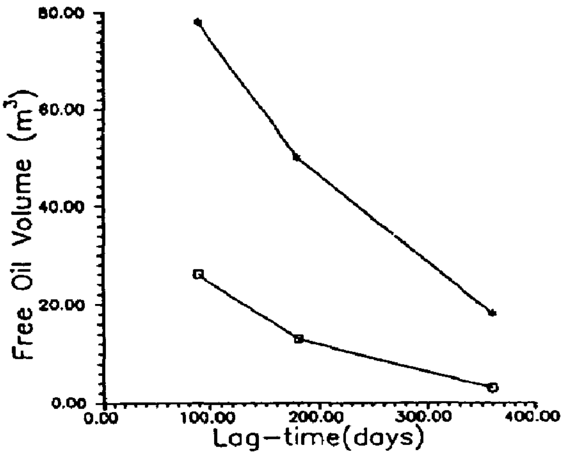

Fig. 1. Effects of delayed starting on free-phase hydrocarbon recovery (From Zhu et al., 1991). (*) Free oil before pumping, and (□) recovered hydrocarbon.

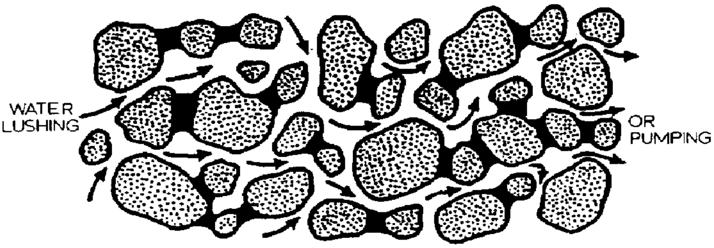

Fig. 2. Trapped oil at residual saturation (from API, 1989). Flushing will not remove all of the trapped product became of capillary attraction.

begin a remediation. Even when groundwater and/or people are threatened, the process is slowed by the number of approvals and/or permits required to install and operate a remediation system.

Nationwide, millions of dollars worth of remediation equipment is sitting idle or recovering contamination passively while awaiting air or water discharge permits. This is not a reflection of the lack of dedication or efforts by the responsible party or regulatory officials involved. It reflects the fact that the permitting processes were not designed or staffed to handle the number of permits resulting from groundwater remediations.

A single disgruntled neighbor, unaffected by the remediation, can delay a project resulting in increased exposure to others. This delay usually arises from the lack of trust by the general public in the regulatory process and/or the responsible party.

Groundwater remediation and asymptotic performance

While initially successful in rapidly decreasing contaminant concentrations in groundwater, remediation technologies respond asymptotically, as shown in

Fig. 3 [5], resulting in ineffective contaminant removal rates. During remediation, contaminant concentrations usually decline rapidly (Zone 1 on Fig. 3) and then level off, reaching the asymptotic phase (Zone 2 on Fig. 3). Asymptotic response is most often associated with pump-and-treat groundwater remediations (7–9) but it is also observed with aquifer venting [10] and can be expected with bioremediation.

Decreased effectiveness can result in increased time of remediation, increased costs relative to mass of contaminants removed, or loss of control of migration of the plume. Asymptotic performance often goes undetected or is misunderstood because of inadequate project management of ongoing remediations. Project management is usually focused on designing and installing remediation technology at the "new" site rather than operating existing sites.

Asymptotic performance can occur soon after system start-up. Figure 4 shows actual data from a remediation system that showed asymptotic performance

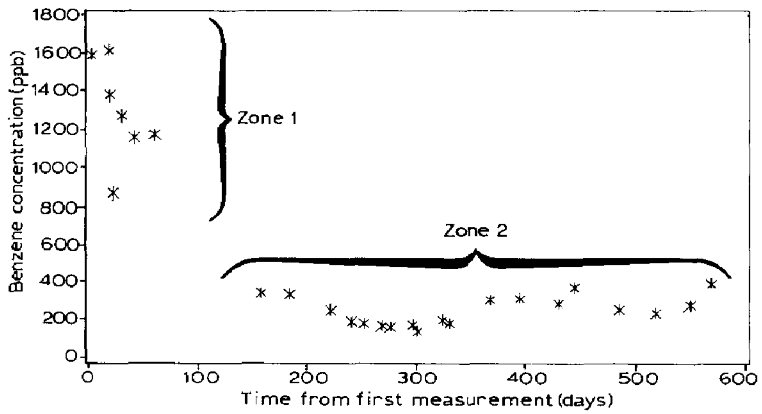

Fig. 3. Site 1 Data set - benzene concentration in a recovery well (from API, 1991).

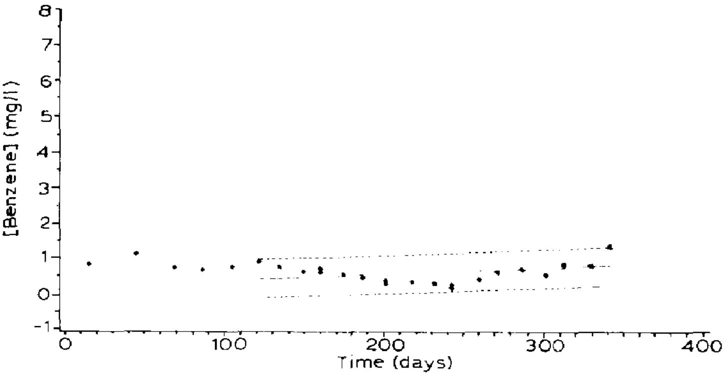

Fig. 4. Benzene concentration from a recovery well showing asymptotic response immediately after startup.

immediately after start-up. As shown in Fig. 5, a system also may operate for several years before showing asymptotic performance.

For materials less dense than water, such as petroleum hydrocarbons, Zone 1 reflects the removal of free-phase hydrocarbons and/or existing dissolved phase hydrocarbons. For inorganic contaminants, Zone 1 reflects removal of dissolved compounds. Zone 2 reflects residual soil contamination (Fig. 2) releasing contaminants at a rate nearly equal to that of removal by the remediation technique and entry of uncontaminated water into the zone of influence [5,6].

It is important to note that, even though a groundwater remediation has reached the asymptotic phase, contaminants are still removed and plume migration can be controlled. Continuing the existing remediation technology is acceptable at sites where there are no time constraints and/or risk due to exposure is controlled. Even if the existing technology is continued, the remediation can be optimized. The project manager should use the onset of Zone 2 as a benchmark to re-evaluate the components of the existing technology. For example, fluids pumped during Zone 1 may be treated most effectively and cheaply using air stripping with off-gas treatment. During Zone 2, the contaminant concentrations may decrease to levels that fluids are treated more effectively and cheaper using liquid phase carbon.

If time allocated is limited or exposure cannot be controlled, then the existing remediation technique may be modified to address residual soils contamination. The project manager can add aquifer venting, air sparging, or other technologies. An existing air sparging system can be modified to inject steam, nutrients, or oxygen to more effectively remove residual contamination. Re-

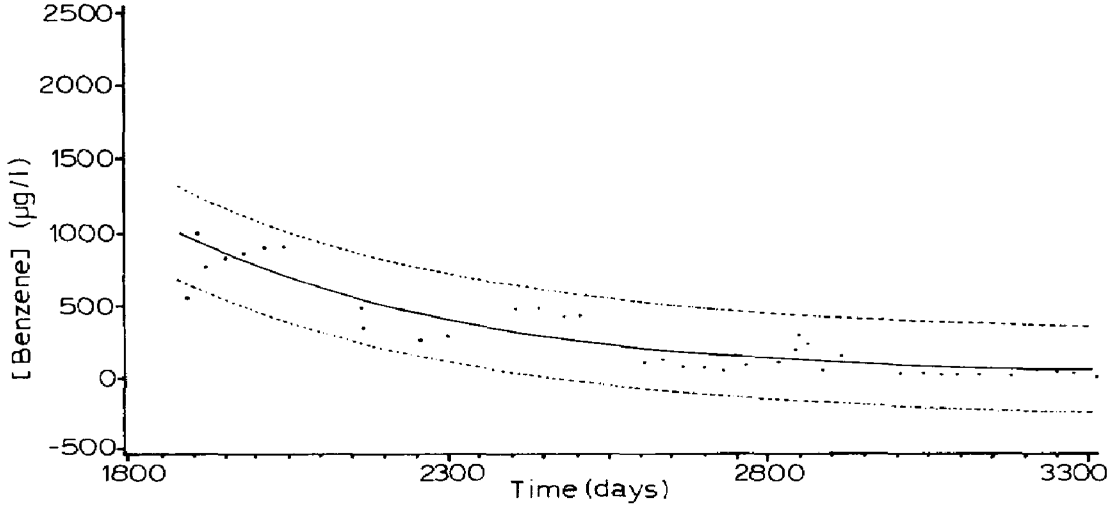

Fig. 5. Benzene concentration from a recovery well showing asymptotic response 3000 days after start-up.

mediation technologies are complementary and most successful remediations will results from the additive affects of multiple technologies customized for the contaminants present and the geological matrix underlying the site.

Technology modification may not always be the best alternative. In some situations, simply shutting the technology off and monitoring groundwater is the appropriate action. This approach is most applicable in locations where groundwater is not usable or where natural processes will render concentrations below permissible levels.

The average remediation system is not managed to assure optimum performance and effectiveness because asymptotic performance goes undetected. Due to workload, the effort expended during design cannot be maintained during operation. The system is monitored by a technician to assure that it is still operating. The professional who designed the remediation system is usually re-assigned to develop another and is not able to track the performance and adequacy of systems previously installed.

Conclusions

Groundwater remediation is an emerging science. Most ongoing remediations have only been operating for less than three years. More groundwater remediations will be designed and implemented within the next five years than the total installed to date. Professionals developing these groundwater remediation systems will not have the benefit of evaluating long term performance because of the lack of projects that have successfully reduced contaminants to permissible levels.

Ideally, the rate of installation of groundwater remediation systems should be slowed down to allow an assessment of the overall approach to groundwater remediation by both academics and field practitioners. This would allow intensive evaluation of both successful and unsuccessful remediations to develop both analytical and physical models to better manage and optimize.

Cooperation and communication are the most important components of any groundwater remediation. Each project must be viewed as a partnership between the responsible party, regulatory official, and affected neighbor. Each member of the partnership must be educated to fully understand just what can and cannot be accomplished with science of groundwater remediation. Without communication, groundwater remediation projects will not succeed.

Acknowledgments

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