SITE REMEDIATION NEWS

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Variances Accepted to Reduce Quality Assurance/ Quality Control Deliverables for Cases with Long Term Ground Water Monitoring

By: Kevin F. Kratina, Chief, Bureau of Underground Storage Tanks

On November 20, 1995 Assistant Commissioner Gimello instructed Site Remediation Program staff to accept and\or initiate variances to reduce the amount of Quality Assurance\Quality Control deliverables submitted, resulting in reduced oversight cost to responsible parties and case management time, while still being provided with adequate information to make protective remedial decisions. This opportunity is a result of not requiring the submittal of the data deliverables specified in the "Technical Requirements for Site Remediation" for certain ground water sampling events for cases in long term ground water monitoring (i.e. natural attenuation and operation and maintenance (O&M) for active systems). In all long term monitoring situations, the same level of data deliverable package would be generated and certified by the lab (and available to the Department upon request), however, the actual data submitted to the Department would be reduced. This "variance" should be used based upon professional judgement in consultation with the Department case manager as follows:

1) For cases in long term ground water monitoring or O&M, the data deliverable package should consist of the information required under N.J.A.C. 7:26E-2.1(a)11.iii(1)-(7). The data deliverables requested under that citation are acceptable for delineation samples for known contaminants and should also be acceptable for long term ground water monitoring. Please note that a variance from N.J.A.C. 7:26E is not required (see 7:26E-2.1(a)11) for any NJPDES Permit monitoring since the permit will specify the QA\QC requirements.

2) Reduced or full data deliverable packages, as applicable, should continue to be required when contaminant identity is unknown, parameters are being eliminated from analysis or final case closeout decision is being made. Two rounds of adequate sampling data (whether historic or actual long term monitoring data) with the appropriate level of QA\QC shall be submitted, and accepted, prior to moving into this "variance".

The Department will continue to maintain the right to require increases in QA\QC if necessary. In addition, modifications to the Technical Requirements will be pursued in the future to incorporate this change.

Please contact your case manager if you have any questions regarding this matter.

Contents

General Information:

Please be sure to include the box number on all mail addressed to the Industrial Site Evaluation Element. Some mail has been received by the element many weeks past the date on the correspondence due to the omission of the box number. The proper way to address mail to the element is:

Section Name or Case Manager's Name
Industrial Site Evaluation Element
CN 028
Trenton, New Jersey 08625-0028

The Hazardous Waste Generator Seminar Series

The New Jersey Department of Environmental Protection, Division of Solid and Hazardous Waste Management is currently taking registrants for upcoming presentions of the Hazardous Waste Generator Seminar Series. The free one day seminars will be held on March 28, 1996 and May 23, 1996 at 401 East State Street in Trenton, NJ. The seminars will address the following topics:

- Definition of Solid Waste;
- Classification of Hazardous Waste;
- Manifesting Issues;
- Annual Reporting;
- Evaluation of Commercial Treatment, Storage, or Disposal Facilities (TSDFs);
- Exemptions from Hazardous Waste Facility Permit Requirements;
- Enforcement Issues; and
- Alternatives to the Off-site Disposal of Hazardous Waste.

Seating is limited therefore all participants must register to attend. For further information or to register to attend please contact Robin Heston at (609) 292-7081.

Evaluating Sites for Natural Remediation of Contaminated Aquifers

By: Franklin B. McLaughlin, Bureau of Ground Water Pollution Abatement

Introduction

In recent years, many researchers have found that natural remediation processes are an important mechanism in the containment or mitigation of groundwater contaminant plumes at a large number of polluted sites (USEPA, 1994). Natural remediation processes include biological, physical, and chemical mechanisms that can degrade, disperse, adsorb, volatilize, or transform groundwater contaminants (McAllister and Chiang, 1994). Over the last few years, New Jersey's environmental statutes and regulations, such as the Industrial Site Recovery Act and Technical Requirements for Site Remediation, have been modified to allow natural remediation to be utilized as a groundwater cleanup alternative. The objective of this article is to provide a quick method to evaluate the potential for natural remediation at sites exhibiting groundwater contamination by using a few groundwater quality indicator parameters.

The Hazardous Site Discharge Remediation Act (P.L. 1993 c.139, S-1070) better known as the Industrial Site Recovery Act, requires that remediation standards take into account site-specific characteristics such as location, surroundings, intended use of the property, and ambient conditions. The Ground Water Quality Standards (N.J.A.C. 7:9-6) allow the use of natural remediation through the establishment of a Classification Exception Area (CEA), an area were the designated uses and the constituent standards are suspended over a specified length of time. Proposed amendments to the Technical Requirements for Site Remediation (N.J.A.C. 7:26E-6.3) contain a set of guidelines for demonstrating natural remediation of groundwater, including (1) a groundwater monitoring program, (2) establishment of a CEA, and (3) documentation of the effectiveness. Overall, the combined intent of these above changes is to provide a mechanism to utilize site-specific risk assessments and institutional control measures to manage areas of groundwater contamination that do not threaten human health or environmental receptors.

Natural Remediation Processes

The processes that control the movement and fate of groundwater contaminants include volatilization, dispersion, adsorption, abiotic chemical reactions, and aerobic and anaerobic biodegradation (McAllister and Chiang, 1994). Of these processes, most authors report that adsorption and biodegradation are the most important factors affecting the movement and longevity of groundwater contaminants. Adsorption or sorption is the dissolved constituent's affinity for aquifer matrix solids, which tends to retard the movement of the dissolved constituents but does not degrade them (Olsen and Davis, 1990). While adsorption processes can limit the extent of the groundwater contaminant plume, these processes do not result in the destruction of the pollutants and can not restore degraded aquifers.

Natural or intrinsic bioremediation is the capacity of naturally occurring indigenous soil microorganisms to degrade organic contaminants that have been introduced into the subsurface environment. Microorganisms can utilize carbon-containing contaminants to obtain energy for survival, growth, and reproduction (Mobil, 1995). The remainder of the article will focus on bioremediation, the important natural remediation process which can restore aquifers that have been contaminated with organic constituents.

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Bioremediation of Organic Contaminants

Natural bioremediation of organic contaminants by indigenous microorganisms depends upon the type of aquifer environment and the nature of the contaminant. Aquifers can be generally classified into aerobic aquifers, those containing dissolved oxygen (DO) levels above 2.0 parts per million (ppm), and anaerobic aquifers containing little or no dissolved oxygen (<1.0 ppm). McAllister and Chiang (1994) divide aquifer environments into aerobic (DO>2ppm), hypoxic (DO=0.1-2.0ppm), and anaerobic (DO<0.1ppm) based on the election acceptors utilized by the indigenous microorganisms. Oxygen is the electron acceptor utilized in aerobic environments, oxygen and a secondary electron acceptor in hypoxic environments, and secondary electron acceptors are utilized exclusively in anaerobic environments. Microorganisms prefer oxygen as an electron acceptor because they derive much more energy from oxygen as compared to the secondary electron acceptors and biodegradation occurs at much greater rates in aerobic aquifers (Salanitro, 1993; Borden et al., 1995). The secondary electron acceptors used by indigenous microorganisms in order of the preference include nitrate, iron, sulfate, and carbon dioxide (Borden et al., 1995; Wiedemeier et al., 1994). 1995). Most aquifers in New Jersey are aerobic environments typically containing dissolved oxygen greater than 2 parts per million.

The nature of the organic contaminant also plays an important role in natural bioremediation. Halogenated organic compounds such as trichloroethylene have been found to degrade slowly in anaerobic aquifers, but results have been inconsistent and degradation processes may result in toxic daughter products, such as vinyl chloride (Olsen and Davis, 1990). Halogenated organic compounds have not been shown to appreciably degrade in aerobic environments (Wilson, 1992). However, virtually all petroleum hydrocarbons are biodegradable under aerobic conditions (Borden et al., 1995) and many field studies have shown that the more soluble petroleum components such as benzene, toluene, ethylbenzene, and xylene (BTEX) readily biodegrade in aerobic aquifer environments (Salanitro, 1993). Biodegradation of petroleum products in anaerobic aquifers have been well-documented for some constituents like toluene, but not clearly demonstrated for other components like benzene (Borden et al., 1995). While anaerobic degradation of BTEX compounds has been demonstrated in the laboratory, there are currently no field data demonstrating significant removal of petroleum hydrocarbons in anaerobic environments including iron- and sulfate-reducing, denitrifying, or methanogenic conditions (Salanitro, 1993). Biodegradation of higher molecular weight organic compounds and inorganic compounds has not been widely demonstrated in either aerobic or anaerobic environments, but these compounds typically adsorb strongly to the aquifer matrix, restricting the significant migration of these contaminants from source areas (Olsen and Davis, 1990).

Aerobic Biodegradation of Petroleum Hydrocarbons

Sites contaminated with petroleum hydrocarbons are best suited for natural remediation because they can intrinsically biodegrade in aerobic aquifer environments that predominate in New Jersey. Complete conversion of petroleum hydrocarbons to carbon dioxide and water requires approximately 3 ppm of dissolved oxygen for every 1 ppm of hydrocarbon (Salanitro, 1993), as represented by the mineralization of benzene:

$$C_6H_6 + 7.5\ O_2 \longrightarrow 6\ CO_2 + 3\ H_2O$$

Under aerobic conditions, most of the petroleum hydrocarbons are completely degraded to carbon dioxide and water as shown in the above equation. While field and laboratory studies have shown some variability, a typical pattern of aerobic biodegradation is followed at most sites, with toluene biodegrading at the fastest rate, followed by xylene, ethylbenzene, and finally benzene at the slowest rate (Salanitro, 1993). It should be noted that more limited studies of oxygenated fuel additives such as methyl tertiary butyl ether (MTBE) and tertiary butyl alcohol (TBA) have not indicated any appreciable or consistent biodegradation in aerobic aquifers (Sulfita and Mormile, 1993).

Elevated concentrations of non-aqueous phase liquids (NAPL) in excess of 1% of their respective aqueous solubility may be an indication of free or residual product in the source area (USEPA, 1992). Removal of free product is essential in any site remediation since it represents a constant source of reintroduced petroleum hydrocarbons to groundwater (Salanitro, 1993) and may be toxic to the microorganisms (Olsen and Davis, 1990). While the extent of a petroleum hydrocarbon plume may stabilize with a continuing source undergoing biodegradation, contraction of the plume size and restoration of groundwater quality will not occur until the non-aqueous phase liquids are removed from the aquifer (Salanitro, 1993). Therefore, removal of free product and, to the extent practicable, residual product should be included as part of a natural remediation program.

Overall, the extent of aerobic biodegradation is controlled by: (1) the volume of contamination released, (2) the rate of oxygen transfer to the subsurface, and (3) background oxygen content of the aquifer (Borden, 1994). The major limitation on aerobic biodegradation is the low solubility of oxygen in groundwater (Borden et al., 1995),

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with decreasing rates of biodegradation observed as oxygen levels decrease (Salanitro, 1993). At dissolved oxygen to total BTEX ratios of less than 3:1, aerobic biodegradation may be hindered or degradation may partially occur via considerably slower anaerobic processes (Borden et al., 1995). In anaerobic environments, Wilson et al. (1991) found that BTEX may be incompletely biotransformed to alkylbenzoate and alkyl phenol intermediates. Insufficient dissolved oxygen conditions may also be indicated by the presence of benzene but not the more degradable aromatics like toluene away from the source area. Therefore, when there is a significant source of petroleum products which exceed the available oxygen, incomplete biodegradation of the BTEX is evidenced by elevated levels of benzene in relation to the other components or by the intermediate breakdown products.

Most Appropriate Sites for Natural Remediation

The groundwater contamination sites that make the best candidates for natural remediation are sites where intrinsic biodegradation is actively occurring. Evidence for intrinsic bioremediation includes (1) depletion of dissolved oxygen, nitrate, and sulfate within the plume, (2) production of dissolved iron (Fe^{2+}) and carbon dioxide over background levels, (3) preferential removal of certain BTEX components (Borden et al., 1995), and (4) an inverse relationship between dissolved oxygen and BTEX concentrations (McAllister and Chiang, 1994). Dissolved oxygen, nitrate, and sulfate are utilized by microorganisms in the during the biodegradation of petroleum hydrocarbons within the plume, which causes a depletion of these indicator parameters in relation to background levels. Elevated dissolved iron (Fe^{2+}) levels within the plume in relation to background levels are indicative of a depletion of oxygen as microorganisms utilize iron as a secondary electron acceptor and convert insoluble Fe^{3+} to soluble Fe^{2+}. Carbon dioxide levels also increase in the plume relative to background levels as carbon dioxide is produced by bacterial respiration in aerobic environments. Intrinsic aerobic bioremediation can be most clearly evidenced by an inverse relationship between DO and BTEX concentrations as measured in background, source area, and downgradient locations.

Natural remediation is also evident when contaminant concentrations decrease over distance from the source area along the groundwater flow path (McAllister and Chiang, 1994). The overall shape of the groundwater contaminant plume also provides evidence of natural remediation, with a stable plume shape or a laterally-contracting plume shape typical of sites undergoing significant biodegradation (Salanitro, 1993). An expanding plume indicates that BTEX dissolution from the source area exceeds the biodegradation of BTEX; conversely, a contracting plume indicates that the dissolution of BTEX from the source area is exceeded by the biodegradation of BTEX (Mobil, 1995).

While aerobic biodegradation of petroleum hydrocarbons has been widely field-documented, biodegradation in anaerobic environments and of other organic contaminants has also been demonstrated. These degradation processes are typically much slower than aerobic biodegradation (Borden et al., 1995) and more difficult to demonstrate. Documentation of natural remediation of petroleum hydrocarbons in hypoxic or anaerobic environments is discussed in another article in this newsletter “Supporting a Ground Water and Soil Natural Remediation Proposal” by Sharon McLelland. Likewise, degradation of other organic contaminants, such as chlorinated solvents, requires a more intensive site-specific data collection and analysis effort. It should be noted that use of natural remediation for sites with other contaminants is consistent with the Industrial Site Recovery Act (ISRA), the proposed amendments to the Technical Requirements for Site Remediation, and the Ground Water Quality Standards.

Summary

Natural remediation processes influence the movement and fate of groundwater contaminants through biodegradation, dispersion, adsorption, volatilization, or transformation mechanisms. Bioremediation is the most important and only widely demonstrated process that can restore contaminated aquifers, especially aerobic aquifers that contain petroleum constituents. Due to the widespread occurrence of aerobic aquifers in New Jersey and the large number of sites contaminated with petroleum products, natural remediation is a viable cleanup alternative for many sites under investigation in the state. Table 1 lists several key ground water parameters which are indicative of actively-occurring bioremediation, which are the best candidates for a natural remediation cleanup alternative.

In summary, the following general criteria indicate natural bioremediation is currently occurring:

(1) inverse relationship between BTEX and DO levels;

(2) depletion of DO, NO_3, and SO_4 in plume; and,

(3) production of Fe^{2+} and CO_2 in plume.

Based on the Department’s experience, the sites with the following characteristics are the most appropriate for natural remediation:

(1) petroleum-contaminated sites;

(2) source removed;

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(3) aerobic aquifer (DO>2ppm); and,

(4) DO:BTEX ratio of 3:1 or greater.

Demonstration requirements for a natural remediation program are outlined in the proposed amendments to the Technical Requirements of Site Remediation, which includes (1) a monitoring program, (2) establishment of a CEA, and (3) documentation of the effectiveness. Ground-water sites contaminated with other constituents may also be amenable to natural remediation, but more detailed site-specific data collection may be required to document the existence of and effectiveness of natural remediation.

Table 1: Indicator parameters at target locations used to evaluate the whether intrinsic bioremediation is currently occurring at a site and whether the site is a good candidate for natural remediation.

Indicator / Location	Levels	Observation / Recommendation
DO / background	>2 ppm	aerobic aquifer / good candidate for natural remediation
	<1 ppm	hypoxic or anaerobic aquifer / site-specific data
DO / source area	>2 ppm	excellent candidate for natural remediation
	<1 ppm	active aerobic biodegradation
DO / downgradient	>2 ppm	active aerobic biodegradation at plume fringes
	<1 ppm	[DO]:[BTEX] > 3:1? / check for NAPL source
BTEX / source area	>1% sol.	check for free or residual product NAPL
	<1% sol.	rapid biodegradation if DO > 2ppm NOTE: Aqueous solubility (ppm) / 1% level: benzene = 1780 / 17.8 toluene = 542 / 5.42 ethylbenzene = 165 / 1.65 xylenes = 174-221 / 1.74-2.21
BTEX / downgradient	steady	check for NAPL source + [DO]
	decreasing	active biodegradation / monitor sentinel well
Dissolved Fe^{2+} / back	<0.3 ppm	aerobic aquifer / good candidate for natural remediation
	>0.3 ppm	hypoxic or anaerobic aquifer / site-specific data
Dissolved Fe^{2+} / source	<0.3 ppm	excellent candidate for natural remediation rate
	>0.3 ppm	active biodegradation
$C0_2$ levels	relative	biodegradation if source CO_2 > background CO_2

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Supporting A Ground Water and Soil Natural Remediation Proposal

By: Sharon P. McLelland, CPG, Bureau of Underground Storage Tanks

Natural Remediation can be a cost-effective remediation strategy that is presented frequently to the New Jersey Department of Environmental Protection (the Department). In many natural remediation proposals, requirements may be missing or not detailed enough for the Department to approve the proposal. Determining the geochemical environment of a site is often the part of the Remedial Action Workplan (RAW) which is not complete, yet is a critical aspect for RAW approval. Prior to proposing a natural remediation proposal, it is essential to determine the ability of the contaminants to naturally degrade given the site conditions (see Frank McLaughlin's article entitled "Evaluating Sites for Natural Remediation of Contaminated Aquifers", March 1996 *Site Remediation News*). The purpose of this article is to inform the regulated community about the site-specific parameters required in RAWs to support proposals for natural biodegradation of contaminants in the ground water and soil environments. This article discusses the secondary parameters which affect and/or control biodegradation in various environments.

How Natural Remediation Acts As a Remedial Strategy

Natural remediation is driven by the following five predominant factors: volatilization, adsorption to soil matrices, biodegradation, chemical (abiotic) transformation and dispersion (Crell and Garner, 1988; Chiang and McAllister, 1994; Testa, 1995). The most significant process supporting natural remediation for most gasoline discharges is biodegradation. However, many RAWs received by the Department propose natural remediation for gasoline discharges with a blanket statement that petroleum hydrocarbons are demonstrated in the literature as degradable, without site-specific data to support the proposal.

Literature reviews have documented biodegradation can occur for aromatic hydrocarbons, such as the benzene, toluene, ethylbenzene and xylene (BTEX) compounds of gasoline, especially under aerobic conditions; however, the ability of some aromatics, in particular, benzene, to degrade readily in anaerobic conditions is limited (Salanitro, 1993; Godsy, 1994). In addition, (limited) literature reviews conducted by the Department have not

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found support for either aerobic or anaerobic biodegradation of gasoline's oxygenated additives, such as methyl tertiary-butyl ether (MTBE) or tertiary-butyl alcohol (TBA) (Newman, 1995; Dominquez, 1987; Salanitro, 1993; USEPA, 1994; USEPA, 1995). The literature concludes that biodegradation is unlikely to occur in a significant manner for the tertiary-branched gasoline oxygenates (Suflita and Mormile, 1993; Jensen and Arvin, 1990). The ability of oxygenates, such as MTBE and TBA, to biodegrade is questionable (Borden et al, 1995; Newman, 1995; Suflita and Mormile, 1993); volatilization of dissolved gasoline from ground water is minimal (5% benzene mass transfer loss was calculated by McAllister and Chiang, 1994) although it is significant in soil (52%, Crell and Garner, 1988); chemical transformations have not been found to contribute to BTEX degradation (McAllister and Chiang, 1994) and no information on its effects on the oxygenates was found; and, adsorption to the soil is negligible due to the high solubility of the oxygenates in water. Thus dispersion becomes the driving factor for natural remediation in ground water for the oxygenate additives (Testa, 1995). Dispersion may be unacceptable in areas involving potable use or in the Pinelands where the limitation is to natural quality or the Practical Quantitation Limit, thereby eliminating natural remediation as a suitable remedial strategy.

The class of compounds (i.e., aromatic, halogenated alkenes, isoprenoids [branched-chained alkanes]) to be degraded and the specific geochemical environment at the site are the controlling influences over which compounds can biodegrade, how quickly the compounds are projected to biodegrade, and whether biodegradation is even a viable strategy for the site. Light to medium (C_{10}-C_{24}) range hydrocarbons, especially monoaromatics and straight (η-) chained alkanes, are generally more easily degradable, while the branched-chain distillates (such as the diesel isoprenoids of farnesane, norpristane, pristane and phytane) are more resistent to degradation (Borden et al, 1995; Testa, 1995; Christensen and Larsen, 1993). With diesel spills, use of concentration ratios of η-alkanes to isoprenoids (C_{17}/ pristane) can be used to evaluate if biodegradation is proceeding (the ratio decreases), and to determine the age of the spill (Christensen & Larsen, 1993). The gas chromatogram signature of a diesel spill can also tell you if biodegradation is occurring. Friedman and Bruya (1991) report that even η-alkanes (i.e., C_{10}, C_{12}) are removed in the oxidation process, leaving the odd η-alkanes (i.e., C_{11}, C_{13}). The presence of sufficient concentrations of Total Organic Carbon (TOC), nutrients and oxygen are all factors that contribute to the degradation of diesel. Volatilization in the early stages of a release is also a significant factor in the natural remediation of a diesel or jet fuel (Friedman and Bruya, 1991).

Evaluating the Site's Geochemical Indicators

RAWs proposing natural remediation need to include geochemical indicator parameter results that support natural biodegradation of the site compounds. A critical indicator parameter necessary to determine the type of microbial degradation is dissolved oxygen (DO). If low DO concentrations are exhibited, the site may be hypoxic (DO = 0.1 to 2 mg/L) or anaerobic (DO < 0.1 mg/L). This is important as some compounds do not readily degrade under low aerobic (hypoxic) or anaerobic conditions, and the rate of degradation is much slower in hypoxic or anaerobic environments than aerobic environments.

DO is the preferable electron acceptor for biodegradation of hydrocarbons. As the DO concentrations decrease, the primary electron acceptors change, resulting in the change from aerobic (oxygen-rich) to anaerobic (oxygen-depleted) degradation environment. The depletion of oxygen results in either nitrate, ferric iron, sulfate or methane serving as the primary electron acceptor and thus controlling the type of degradation, such as hypoxic degradation (denitrifying) or anaerobic degradation (iron-reducing, sulfate-reducing or methanogenic). Low dissolved oxygen levels may be representative of the interior of the contamination plume, whereas the downgradient or upgradient edges of the plume may demonstrate aerobic conditions (DO > 2 mg/L). It would be important to determine if a ground water recharge area exists upgradient to a low DO plume, providing a continuing source of dissolved oxygen to the upper aquifer. The availability of oxygen determines the ability of the plume to be remediated through biodegradation.

Site data supporting the type of degradation environment is critical information for the natural remediation proposal. For example, with gasoline, benzene has been found to be resistent to anaerobic degradation (Godsy, 1994), yet toluene, o-xylene, and potentially m-, and p-xylene have been field demonstrated as biodegradable under anaerobic conditions (McAllister and Chiang, 1994; Borden et al, 1995; Crell and Garner, 1988). Benzene degradation under anaerobic conditions remains disputed in the literature, with some support for benzene degradation under denitrifying conditions (Borden et al, 1995). As conditions become more anaerobic, the ability of the alkylbenzenes to degrade decreases. Toluene has been demonstrated to degrade in sulfate-reducing and methanogenic environments (Borden et al, 1995; Salanitro, 1993). However, both these environments are highly sensitive to changes in other secondary parameters such as temperature, nutrient levels and pH (Borden et al, 1995).

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The concentration of DO also determines the rate of degradation, as anaerobic degradation has been found to occur at significantly slower rates than aerobic degradation of gasolines (Crell and Garner, 1988; Salanitro, 1993). The rate of biodegradation is also enhanced with hydrocarbon concentrations lower than 1 ppm (Chiang et al, 1987). Conversely, hydrocarbon concentrations greater than 10 ppm present an inhibitory effect on the rate of degradation, potentially a result of toxicity effects (Testa, 1995). Jensen and Arvin (1990) found MTBE to have a minor inhibitory effect at elevated concentrations (200 ppm). Generally, as the concentrations increase, the concentration of DO required to degrade the compounds also increases.

After the initial field parameters of dissolved oxygen (DO), pH, temperature and Eh are obtained, the secondary indicator parameters need to be evaluated according to the potential degradation environment: aerobic, hypoxic, or anaerobic.

Aerobic Environments Sites demonstrating elevated DO (>2 ppm) across the site, including wells into the plume, should exhibit aerobic degradation. With aerobic degradation, the initial indicator parameters (DO, pH, Eh and temperature) are essentially all that are critical to confirm aerobic degradation is occurring, when combined with contaminant monitoring (i.e., BTEX). Aerobic environments have been shown in the literature to biodegrade monoaromatic hydrocarbons when sufficient DO is present in the environment. In the short-term (30 to 60 days), MTBE has not been found to degrade in aerobic environments (Jensen and Arvin, 1990).

The concentration of DO necessary to aerobically degrade BTEX varies in the literature. McAllister and Chiang (1994) found rapid degradation of BTEX in aerobic environments where DO was greater than 2 mg/L. Crell and Garner (1988) reported aerobic BTEX degradation when the ratio of DO to BTEX was 3.5 to 1. Chiang et al. (1987) and Salanitro (1993) provide a similar ratio of 3:1 for DO:BTEX for aerobic degradation.

Hypoxic Environments Sites that have exhibited DO readings in the low aerobic range of 0.1-2 ppm within and outside of the plume, require additional sampling for the secondary indicator parameters to determine the degradation processes occurring. Generally, after DO has been depleted, denitrification becomes the dominant degradation process when nitrate is present (Borden et al, 1995; McAllister and Chiang, 1994). To determine how the plume is degrading, sampling needs to be expanded to include nitrate (the electron acceptor). Benzene is not readily degraded, although ethylbenzene may degrade by denitrification processes (Borden et al, 1995; Salanitro, 1993). Continued monitoring of the BTEX compounds is important to evaluate that individual compounds are continuing to degrade as the process changes from an aerobic, high DO environment to a hypoxic, lower DO environment.

It is important to include upgradient and downgradient well points in the monitoring program for comparison with the interior plume data. Increased nitrate concentrations over background points, coupled with lower Eh and lower DO readings from the aerobic environments support denitrification as the active degradation process.

Anaerobic Environments Aerobic, hypoxic and anaerobic environments may all be exhibited across the site, as monitoring of the recharged upgradient wells, the plume edge wells and the plume interior wells is conducted. Often plume interior and deep wells will demonstrate anaerobic conditions, as the DO is used up preferentially by the microbes. Low aerobic/hypoxic conditions can often be demonstrated nearer to the plume edge, with aerobic conditions determined at the plume edge and outside of the plume (Crell and Garner, 1988).

Once DO is reduced, nitrate and ferric iron are generally the secondary electron acceptors. Following nitrate and ferric iron depletion, sulfate and then methane become the electron acceptors for biodegradation. Iron and sulfate reduction, and methanongenesis are anaerobic processes. In order to evaluate if the contamination is readily degrading under the varying aerobic to hypoxic to anaerobic conditions across the plume, it is important to determine through the secondary indicators which process is predominant. These secondary indicators include nitrate, dissolved ferrous iron, sulfate and if very low Eh is detected, methane and carbon dioxide (dissolved). Alkalinity is a geochemical parameter necessary to help determine if the dissolved carbon dioxide concentrations are a result of microbial respiration, a function of the geologic formation (aquifer matrix), or a result of the geochemistry of the ground water. Organic acids are produced as oxygen is reduced, creating a lower-pH area which could affect the alkalinity concentrations if within a carbonate aquifer (McAllister and Chiang, 1994).

Toluene, and o-, m- and p-xylene have been found to degrade in anaerobic environments with toluene consistently degrading even under methanogenesis (Borden et al, 1995; McAllister and Chiang, 1994; Salanitro, 1993). Sulfate-reducing environments appear to degrade even benzene, as do denitrifying conditions, according to reviews conducted by Salanitro (1993). Ethylbenzene was not found to be anaerobically degraded except under denitrifying conditions, in a review of 19 published BTEX degradation studies conducted by Salanitro (1993).

Measuring for the Secondary Indicators

Supporting A Ground Water and Soil Natural Remediation Proposal (continued)

The availability of electron substrates and nutrients are primary limitations in the rate of microbial degradation (Testa, 1995). Natural remediation proposals must be able to address the biodegradability of all the site specific compounds. It is assumed by the Department that the basic site information such as geology, depth to ground water, and extent of ground water and soil contamination is already known from the previous Remedial Investigation Reports. The primary site-specific factors which are required for natural remediation to be viable should be evaluated in the RAW, such as all components of and concentrations of the plume(s), geologic composition and hydraulic conductivities, all of which affect dispersion, volatilization and soil adsorption.

RAWs proposing natural remediation need to address the following geochemical parameters in the proposal: dissolved oxygen (DO), redox potential (Eh), pH (soil and ground water), alkalinity, ferrous/ferric iron (dissolved), carbon dioxide (soil and ground water), temperature, microbial counts, nitrogen, total organic carbon content, phosphorous, and soil moisture. Accurate results may require use of a flow-through cell or in-situ field measurements for some parameters, such as DO, Eh, pH and temperature. Laboratory analyses of these parameters are not encouraged, as changes in pressure and temperature following sample collection may significantly alter the laboratory sample results from the in-situ concentrations.

In sampling for **dissolved oxygen**, **Eh**, **ferrous iron** (dissolved), **pH**, **alkalinity**, **carbon dioxide** and **temperature**, the following need to be considered: samples should be collected from wells upgradient of the plume, within the plume and downgradient of the plume for comparative purposes. Eh of ground water generally ranges from -400 mV to 1000 mV. The contaminant plume water should have a lower Eh than the upgradient water quality (Weidemeier et al, 1994), if degradation is occurring. At 25°C and pH=7 S.U., aerobic degradation occurs around Eh=+820, denitrification occurs around Eh=+740, iron-reduction occurs around Eh=-50, sulfanogenesis occurs around Eh=-220, and methanogenesis occurs around Eh=-240 (Wiedemeier et al, 1994).

In anaerobic environments, ferric (Fe^{+3}) iron is reduced to soluble ferrous (Fe^{+2}) iron. It is important to know the background concentrations and site geology when using ferrous iron as an indicator of anaerobic conditions (Weidemeier et al, 1994). Naturally elevated iron levels may be present and thus using data from outside the plume is critical to demonstrate the interior anaerobic environment is iron-reducing as a result of biodegradation.

For most bacteria, temperature has an inhibitory effect on microbial degradation when soil/water temperatures are less than 5°C or exceed 25°C; however, microbial activity can be enhanced for ambient (5-25°C) temperature ranges, with bacterial metabolism doubling for every 10°C increase in temperature [the “Q”$_{10}$ rule] (Godsy, 1994; Weidemeier et al, 1994). Increases in temperature may also increase volatilization processes.

A **dehydrogenase enzyme activity** analysis (colorimetric determination, see Wiedemeier et al, 1994) can be conducted in the field to determine the presence of aerobic bacteria and if a sufficient population of microbes exists in the target (plume) areas. This may be necessary if acidic or alkaline pH values are exhibited at the site, to see if the microbial population has been affected by the pH levels.

Generally, for optimal microbial activity, the preferred range of pH is 6-8 S.U. However, it has been shown that indigenous microorganisms can adapt to lower pH environments (Weidemeier et al, 1994). When site pH levels are acidic, a plate count should be run. A low microorganism count may result from concentration toxicity, low nutrient levels, or from sudden changes in pH environment. Sufficient populations may demonstrate the microorganisms have adapted to the lower pH values.

In order for microbial degradation to operate successfully, it is important for an adequate level of nutrients to exist within the aquifer matrix. Nutrients (carbon, nitrogen, phosphorous, sulfate and iron) are used to build cell membranes in the bacteria. As such, it is important to evaluate the **Carbon:Nitrogen:Phosphorous** ratio for the site (applicable for both unsaturated and saturated zone). Sulfate and iron are generally present at sufficient quantities within an aquifer matrix. The C:N:P ratio is especially important if denitrifying conditions (hypoxic environments) exist, and nitrate becomes the electron acceptor and is reduced by biodegradation. Ideal C:N:P ratios are 100:10:1 for optimal microorganism growth (Testa, 1995).

Natural Remediation Evaluations for Soils

While most natural remediation strategies are proposed for ground water remediations, some proposals are presented as a soil remedial strategy. When soil is to be evaluated for natural remediation, additional parameters need to be considered to determine if the vadose environment is suitable for sustaining microbial degradation.

Important vadose zone soil indicator parameters include the **Total Organic Carbon (TOC)** content in the unsaturated zone, **soil moisture**, **soil pH**, **dissolved oxygen** and **dissolved carbon dioxide** (CO_2). To evaluate if soil conditions at a site are favorable for degradation, it is necessary to measure for Total Organic Carbon (TOC) content, soil moisture, soil pH, dissolved oxygen and

Supporting A Ground Water and Soil Natural Remediation Proposal (continued)

dissolved carbon dioxide. TOC content is used in determining the rate of desorbtion from the aquifer matrix into the ground water and is also a factor in determining retardation rates for migrating ground water plumes. Microbial growth is affected by very dry and very wet conditions (optimal conditions range between 40-70% moisture content; Testa, 1995). Microbial degradation is sensitive to pH, and populations can be threatened by acidic or alkaline conditions, especially if these changes occur rapidly. DO and CO_2 gas ratios are used to determine if aerobic or anaerobic processes are occurring (Weidemeier et al, 1994). Increasing amounts of CO_2 relative to DO demonstrate microbial respiration is occurring as DO is being depleted. Aerobic degradation in the vadose zone requires a minimum of 1% oxygen (Testa, 1995).

Summary

Literature reviews can assist in determining whether an aerobic, hypoxic or anaerobic condition is likely to exist; however, the literature review should not be the sole basis for proposing such a condition exists. The NJDEP's *March 1995 Guide For The Submission of Remedial Action Workplans*, p.14, requests that natural remediation proposals provide *site-specific* analytical data that support and demonstrate that this strategy is suitable for the site.

The following checklist is a general guidance for use in evaluating the site specific parameter results. This information was obtained from the limited review of the literature used in preparing this article.

Microbial Degradation Checklist

Parameter	**Low**	**Moderate**	**High**	**Comments**
__ Dissolved Oxygen (mg/l)	<0.1	0.1-2.0	>2.0	low DO environments use other electron acceptors such as NO_3^-, Fe^{2+}, SO_4^{2-}, and CH_4
__ Eh (Redox Potential, mV)	-200	0 - +400	+800	at -200 mV, sample for CH_4 and CO_2
__ Methane (mg/l)	—	—	—	1 mg/L BTEX degrades to produce 0.78 mg/L CH_4
__ CO_2 (dissolved, mg/l)	15-30	—	—	depends on aquifer matrix and geochemistry of the ground water
__ Alkalinity (as $CaCO_3$, mg/l)	~6	10-50	>50	carbonate aquifers may increase CO_2 levels by organic acids reducing pH
__ pH (S.U.)	<6	7	>8	microbes may adapt so need plate counts if low pH. Neutral is optimal.
__ Temperature (°C)	<5	—	>25	inhibited degradation at <5°C or >25°C
__ Moisture content (%)	<40	—	>70	wetness/dryness in soils affects microbial populations
__ Sulfate (SO_4^{2-}, mg/l)	<5	6-10	>10	1 mg/l SO_4^{2-} degrades 0.21 mg/l BTEX
__ Nitrate (NO_3^-, mg/l)	<1	1-6	10	1 mg/l NO_3^- degrades 0.21 mg/l BTEX
__ Phosphorous (P, mg/l)	<0.2	—	—	C:N:P ratio of 100:10:1 is optimal
__ Ferrous iron (Fe^{2+}, mg/l)	—	—	—	1 mg/l BTEX to produce 21.8 mg/l Fe^{2+}
__ Total Organic Carbon (mg/l)	—	—	—	use the average concentration from background samples obtained in the

Supporting A Ground Water and Soil Natural Remediation Proposal (continued)

most transmissive zone for R_f

(retardation) calculations

References:

The references the Department used in evaluating secondary indicator requirements for natural remediation are provided. Only a limited review of available literature was conducted. Comments and input from the public based on field studies are welcomed.

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Permit-by-Rule

By: Lois Arbegast, Bureau of Environmental Evaluation, Cleanup & Responsibility Assessment

On July 28, 1994, new rules and amendments were adopted regarding the New Jersey Pollutant Discharge Elimination System (N.J.A.C. 7:14A-6.14 and 22.4 and N.J.A.C. 7:14A-2.15 and 6.17).

The changes were an attempt by the department to make the New Jersey Pollutant Discharge Elimination System (NJPDES) more user-friendly by reducing paperwork and lessening administrative costs. These regulations should simplify the process for department approvals of certain aspects of groundwater investigations and remediations.

One of these aspects is the permit-by-rule authorization in N.J.A.C. 7:14A-2.15. Without a full NJPDES permit, the Site Remediation Program can authorize certain discharges back to the ground waters of the State related to: homeowner site remediations, pilot test activities, aquifer tests, or remedial design tests. However, be aware that termination of Department oversight terminates the permit-by-rule.

Issuance of a permit-by-rule requires that a remedial investigation of the site is being conducted pursuant to the Technical Requirements (N.J.A.C. 7:26E). The case manager in the lead program will decide if the discharge is feasible and if a permit-by-rule is appropriate for the proposed discharge.

The permit-by-rule discharge authorization will use the oversight document to establish effluent limits and require that the responsible party implement a monitoring program, appropriate for the discharge. The permit-by-rule will establish general system construction and operation requirements and a process to notify the department of any problems associated with the discharge. The oversight document will require the proper closure of any temporary reinjection unit after completion of the pilot test, biotreatability test, aquifer test, etc.

The period of time granted by the department is defined in the regulations and cannot be extended. N.J.A.C. 7:14-2.15 allows 180 days for pilot studies designed to evaluate biotreatability studies of groundwater pollutants. An extension beyond 180 days cannot be granted even though it may mean that the injected microbes will die. The rule allows 90 days for other discharges from pilot treatment plants for the purpose of obtaining engineering design data. The rule allows 30 days for discharges from wells to test aquifers for the purpose of measuring aquifer characteristics. The time period begins from the first date of discharge. Should longer investigative discharge timeframes be required, a full NJPDES permit must be approved by the department.

The only reasons for the issuance of a second permit-by-rule are if the purpose is to obtain different information omitted from the original work plan, or because conditions arose which precluded the completion of the test (i.e. system breakdown, delay of the date of discharge).

It is in the best interest of the person responsible for the remediation to pre-plan the pilot study carefully before requesting the permit-by-rule from the NJDEP. If it appears that a longer test period will be required, the person responsible for the remediation should be ready with an application for a NJPDES permit. Planning well ahead is necessary on this aspect of a case.

Freon/Infrared Petroleum Hydrocarbon Method (418.1) To Be Replaced

By: Greg Toffoli, Bureau of Environmental Measurements and Quality Assurance

Currently, aqueous and nonaqueous matrices suspected of petroleum product contamination are extracted and analyzed according to the procedures noted in USEPA Method 418.1 (aqueous) and 418.1-Modified (nonaqueous). The methods specify the sample is extracted with fluorocarbon-113 (freon-113).

As a result of an agreement among nations (including the U.S.) party to the *Montreal Protocol on Substances that Deplete the Ozone Layer*, chlorofluorocarbons (including freon-113) are banned from production effective January 1, 1996. An implication of this agreement is that the use of the existing freon-113 would be phased out by the environmental laboratory community and, subsequently, total petroleum hydrocarbon testing would require significant change.

Representatives from the NJDEP have met several times with the *Environmental Laboratory Advisory Committee for the Replacement of Freon Based Methods* (a group consisting of laboratory personnel and consultants) in order to elicit recommendations and discuss how best to proceed. The major issues/concerns raised at the meetings were:

1. Freon-113 was banned from production but not from use. Laboratories theoretically could continue using freon-113 if they had either stockpiled it or were willing to redistill it. However, it was determined that few laboratories had done or were willing to do either.

2. The cost of freon-113 had escalated. Freon, if available at all, could cost from $8,000 to $11,000 for a 55 gallon drum. The freon based method no longer made economic sense.

Freon/Infrared Petroleum Hydrocarbon Method (418.1) To Be Replaced (continued)

3. Analytically, infrared spectrometry could still be used. However, the alternate solvents available (due to the nature of the instrumentation) were not viewed favorably by the laboratory community nor by the NJDEP. The two other solvents that can be used are carbon disulfide (highly toxic) and carbon tetrachloride (carcinogenic).

4. The NJDEP has an obligation to promote methods that neither harm the environment nor pose an unacceptable human risk. As such, the continued long term use of freon-113 was determined to be unacceptable.

5. The situation provided an opportunity to improve the technical aspects of petroleum product testing by recommending and choosing alternate analytical methods.

After careful review of the issues raised at the meetings, the Site Remediation Program, with support from the NJDEP Office of Quality Assurance, has decided that matrices with suspected petroleum product contamination shall be extracted and then analyzed using gas chromatographic techniques. The new gas chromatography (GC) method has been based on USEPA method 8015B and the "Leaking Underground Fuel Tanks Field Manual" of the California State Water Resources Control Board and entails the following:

1. Samples are extracted with methylene chloride (water samples are extracted by either separatory funnel extraction or continuous liquid-liquid extraction; soils and sediments are extracted by either gyrotory shaker extraction or soxhlet extraction; and dissolved product is extracted by sealed extraction). Surrogate compounds are added to all samples prior to extraction. The methylene chloride extract is analyzed by a GC fitted with a capillary column and Flame Ionization Detector (FID).

2. Calibration of the GC is done using a synthetic C8 - C40 hydrocarbon standard, the components of which are defined. If the source of contamination is well documented orknown, actual product may be used as a standard in lieu of the synthetic standard. In either instance, the standard is used to establish the retention time boundaries to be used with sample integration/quantitation.

3. The petroleum product concentration is determined by integrating the appropriate area (previously defined during the standard calibration routine) under the chromatogram.

The method offers analytical options previously not available under method 418.1. For example, analytical results from both the existing IR method and the new GC method are given as total petroleum product numbers. However, the new GC method allows one to perform additional analyses (on the same extract used to obtain the total concentration value), using pattern recognition methods to determine product identity and potential source(s) of contamination. The method is appropriate for the analyses of matrices suspected of contamination from a wide variety of petroleum products, including diesel fuel, No 2-6 fuel oils, lubricating oils, crude oils, bunker fuels and processed oils. Anticipated costs are from $75 to $130 per sample.

The reproposal of the Technical Requirements for Site Remediation, N.J.A.C. 7:26E, allows the use of this method by laboratories performing analyses of water, soil and sediment samples for petroleum hydrocarbons. The new method is titled "Quantitation of Semi-Volatile Petroleum Products in Water, Soil, Sediment and Sludge" (method number OQA-QAM-025-10/91). Copies may be obtained by contacting, in writing, the:

New Jersey Department of Environmental Protection
Office of Quality Assurance
CN-424
Trenton, NJ 08625-0424
Attn: Petroleum Methods Coordinator

Online Resources for Public Access to DEP and SRP Info

By: John Abolins, Bureau of Planning and Systems

The New Jersey Department of Environmental Protection has set up a computer bulletin board system (BBS) to provide public access to information about the DEP and its programs. A BBS allows people using computers equipped for telephone communications to browse through the information on it. A BBS can provide information in various forms: online discussions, bulletin texts, files that can be "downloaded" (copied) to the callers' computers, etc.

The NJDEP BBS is the main computer bulletin board for the department. Besides providing general information about the DEP, several program areas of the DEP have their own sections on the BBS. SRP's section allows callers to leave messages with questions or comments about the SRP and its activities. The SRP File Libraries on the BBS allow callers to get copies of useful files, including several application forms and input spreadsheets for the HazSite database.

Online Resources for Public Access to DEP and SRP Info (continued)

SRP has also set up a computer bulletin board for its Chrome Project. Although this BBS is set up primarily for one project, it serves as a backup BBS for contacting the SRP. Many of the files from the SRP section on the NJDEP BBS are being duplicated onto the SRP Chrome BBS.

Here are the telephone numbers for the two BBSs:

DEP BBS	609-292-2006
SRP Chrome BBS	609-777-0004

To call these BBSs, you will need a computer equipped for telecommunications. Usually, this means that the computer has a modem and some kind of telecommunications software such as Qmodem, Procomm, or HyperAccess. The settings for both BBSs are 8-N-1 (8 bits, parity none, 1 stop bit). Both BBSs have fast 14.4K modems. The first time a person calls either of these BBSs, the systems will ask several questions to set up the free account.

In mid-January, the New Jersey state government opened up another online public access resource. The New Jersey State Home Page on the Internet's World-Wide Web (WWW) provides basic information about the state and its government. As this state WWW page develops, many agencies, including the DEP, will be expanding the amount of information available for that agency under the WWW page.

If you have Internet access that allows you to browse through the WWW, you can find the NJ State Home Page at http://www.state.nj.us.

If you have any questions about these resources, you can contact me at 609-633-0740 or by the Internet email to jabolins@dep.state.nj.us.

Division of Responsible Party Site Remediation Expedites Mailing Procedures

Five bureaus in the Division of Responsible Party Site Remediation have individual CN numbers. This change will now enable the Division to process its incoming and outgoing correspondence more efficiently. Correspondence which is sent to the following bureaus should now be addressed as follows:

For the **Bureau of Environmental Evaluation, Cleanup & Responsibility Assessment** :

New Jersey Department of Environmental Protection
Division of Responsible Party Site Remediation
Bureau of Environmental Evaluation, Cleanup &
Responsibility Assessment
401 East State Street, 5th Floor
CN 432
Trenton, New Jersey 08625-0432

For the **Bureau of Underground Storage Tanks**:

New Jersey Department of Environmental Protection
Division of Responsible Party Site Remediation
Bureau of Underground Storage Tanks
401 East State Street, 5th Floor
CN 433
Trenton, New Jersey 08625-0433

The **Bureau of Field Operations** has received individual CN Numbers for each of its two Sections. The new addresses are as follows:

For the **Case Assignment Section**:

New Jersey Department of Environmental Protection
Division of Responsible Party Site Remediation
Bureau of Field Operations - Case Assignment Section
401 East State Street, 5th Floor
CN 434
Trenton, New Jersey 08625-0434

For the **Initial Notice Section**:

New Jersey Department of Environmental Protection
Division of Responsible Party Site Remediation
Bureau of Field Operations- Initial Notice Section
401 East State Street, 5th Floor
CN 435
Trenton, New Jersey 08625-0435

For the **Bureau of Communications and Support Services**:

New Jersey Department of Environmental Protection
Division of Responsible Party Site Remediation
Bureau of Communications and Support Services
9 Ewing Street, Third Floor
CN 436
Trenton, New Jersey 08625-0436

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Division of Responsible Party Site Remediation Gets Voice Mail!

As part of its effort to provide a rapid response to inquiries concerning its cases, the Division of Responsible Party Site Remediation Bureau of Underground Storage Tanks, Bureau of Environmental Evaluation, Cleanup, and Responsibility Assessment, Bureau of Field Operations, Bureau of Federal Case Management, and Bureau of State Case Management), has begun using voice mail for all case managers. You may dial a specific case manager directly by using a touch tone telephone to call the case managers who are listed below. If the case manager is not available to speak with you, the voice mail system will be activated after approximately five rings. Please leave your message after the tone, and include a telephone number where you can be reached. Case managers will return your call as quickly as possible.

If you do not wish to listen to the case managers recorded message, please press the “#” key. This will eliminate the introduction, and you may leave your message after the tone. When you have completed your message, press the “#” key . You will hear a menu which will allow you to listen to your message, rerecord it, or leave the message. By pressing the “*” key, you can route your call to any other individual on the voice mail system.

If you wish to speak with the BUST Bureau Chief Kevin Kratina or BUST Section Chief James Duerbig, Mary Anne Kuserk or Joseph Miller, please call the Bureau secretary at (609) 292-8761.

If you wish to speak with the BEECRA Bureau Chief Steve Maybury or BEECRA Section Chief Maurice Migliarino, please call the Bureau secretary at (609) 777-0899.

If you wish to speak with the BFCM Bureau Chief Bruce Venner or BFCM Section Chief Pamela Lange, Roman Luzecky or Richard Yarsinsky, please call the Bureau secretary at (609) 633-1480.

If you wish to speak with the BSCM Bureau Chief Linda Grayson, or BSCM Section Chief Christopher Kanakis or Joseph Karpa, please call the Bureau secretary at (609) 633-1480.

If you have a question concerning a case that has not been assigned, call the Bureau of Field Operations, Case Assignment Section at (609) 633-0708.

If you have an inquiry concerning a file review, please call the Responsible Party Cleanup Element at (609) 633-1480.

Finally, please note that the listing for the Discharge Response Element contains not only voice mail telephone numbers for the BFO’s Case Assignment and Initial Notice sections, but also the numbers for the regional Field Offices as well. Listings for the Bureau of Emergency Response, (including the Hotline), and for the Bureau of Communications and Support Services, are also included for your reference.

Industrial Site Evaluation Element – Bureau of Underground Storage Tanks

Anderson, Dean	(609) 777-1949
Anderson, Sue	984-4791
Basavanhally, Jay	984-7830
Bauer, Paul	633-1202
Bayard, Judy	633-0836
Bello, Dan	984-1731
Blankenship, John	984-3071
Bowden, Karen	292-5184
Bruhl, Leslie	292-0912
Campion, Myrna	633-1337
Cramer, Don	292-1183
Dobry, Faith	292-5048
Eaker, Joe	633-1406
Eisenhauer, Nick	984-1733
Flesch, Erwin	633-1978
Flint, Linda	633-1473
Flite, Mike	633-2424
Foster, Ruth	292-0840
Gunoskey, Rich	777-0236
Hahn, Gerry	984-7844
Hall, Evelyn	633-0531
Halpern, Myroon	633-2975
Harper, Dave	633-1464
Hendricks, Lee	633-0745
Hicks, Patricia	984-4892
Honl, Sergio	984-7861
Hose, William	633-1330
Infanger, Mike	984-4430
Ingersoll, Ward	292-0568
Jones Rebecca	984-4423
Katz, Kathy	633-1438
Kinsel, Erick	292-8723
Lipman, Leonard	777-0126
Lough, Pam	984-4794
Majoras, Judy	777-0983
McGlynn, Eugene	633-0725
McKenzie, Jill	292-1993
McLelland, Sharon	633-1269
Meyer, Barney	633-2430
Miele, Dave	777-0900
Morrow, Judy	633-0710
Nickerson, Dave	633-1445
Nuss, Tim	633-1275
Patterson, William	292-6139
Pfleiderer, Cyndi	984-7906
Plummer, Donna	633-6839
Pupa, Diane	633-1270
Richter, Paul	984-9759
Rubin, Dave	633-1284
Sanderson, Gary	633-0544
Shanahan, Tom	292-6234
Spera, Jeff	292-7311
Stefanoni, Joe	633-1405
Steinhagen, Bob	633-1472
Tatar, Steve	633-0580
Urbanik, Steve	984-7909
Wallace, Erica	984-9891
Willinger, Allan	777-1403
Wright, Renee	984-5287
Zagorski, Ted	777-0124

Bureau of Environmental Evaluation Cleanup & Responsibility Assessment

Appezzato, Brian	(609) 292-4479
Arbegast, Lois	292-6296
Barnes, Ben	292-7274
Bean, Dave	633-7244
Bechtold, Bob	292-2545
Bevan, Wayne	292-0494
Bobko, Jackie	633-1410
Bono, Jim	633-1434
Bruder, Sharon	633-1449
Burgos, Richard	633-0721
Buriani, Mike	633-1425
Cao, Yang	633-0753
Cotter, Patrick	633-1427
Dillman, Andrew	633-1447
Estell, Lois	292-1871
Goldsworthy, Linda	633-1432
Goliszewski, Joe	984-1851
Graham, John	633-1451
Hadsell, William	633-1433
Hoch, Robert	633-1414
Inserra, Al	633-1413
Jacob, Grace	633-1422
Justiniano, Mike	633-1426
Kahora, Ken	292-2697
Kindervatter, Henry	633-1419
King, John	984-1854
Kosher, John	292-6943
Lafferty, Rosemary	292-4447
Ludovico, Joe	633-1423
Mandracchia, Mike	984-1845
Moore, Bryan	984-4077
Morrison, Murdo	984-1886
Myers, Steve	633-1392
Nickerson, Jay	633-1448
Nowak, Joe	292-0130
Schupak, Jacob	633-8170
Simpson, Robert	633-2466
Souders, Mark	292-1945
Wolf, Ann	633-1420
Yankauskas, Stan	292-9818

Responsible Party Cleanup Element – Bureau of Federal Case Management

Barunas, Gwen	(609) 633-7261
Berg, Jonathan	633-0737
Caulker, Comfort	633-1437
Curtis, Ian	633-7232
DeNoble, Jim	987-4101
Drake, Nadine	777-1912
Franca, Frank	984-4071
Gaffigan, Donna	633-1494
Graubart, Carol	633-0741
Harvey, Paul	633-0714
Kanjarpane, Dhruva	633-0709
Kaup, Edgar	633-1497
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Marton, Nick	633-1495
McGinty, Tom	633-0744
Outlaw, Riche	633-0747
Rogacki, Kathy	292-7253
Santos, Vicky	633-7233
Shah, Haiyesh	633-0718
Spiezio, Alex	633-1489
Weigand, Jerri	633-1498
Zalaskus, Greg	984-2065

Responsible Party Cleanup Element – Bureau of State Case Management

Beretsky, Bob	(609) 633-1165
Ciallella, Tony	984-4451
Cerino, Tina	984-4515
Crispi, Nancy	292-2827
Davis, Earl	984-4450
Doyon, John	633-0713
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Franco-Spera, Maria	633-0715
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Kall, Mary Ann	984-4485
Kanakis, Chris	633-1460
Kenney, Mike	633-0739
Layre, Tina	292-0989
Lipsius, Gary	984-0955
McClung, Anne-Marie	292-1973
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Normane, Todd	633-1439
Paterson, Dianne	292-1928
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Pinchuk, Sindy	984-4467
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Rago, Carol	292-6528
Ritter, Mark	984-4472
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Sklar, Bradi	633-1436
Sklar, Mike	984-4505
Smith, Paul	633-1485
Stankiewicz, Ed	633-1487
Turner, Matt	984-1742
Walters, Mark	633-1486

Discharge Response Element

5th Floor Receptionist	(609) 984-1688
Fax	633-1454

Assistant Director's Office

Bob Van Fossen, Asst. Director	(609) 633-1421
Robin Longmuir, Secretary	633-1421
Marlene Volper	633-1421
Lorie Guerieri	633-1421

Bureau of Emergency Response

Stan Delikat, Chief	(609) 633-2168
Olga Rodriguez, Secretary	633-2168
Fax	777-0985

ER I - 2 Babcock Place, West Orange

Gary Allen, Supervisor	(201) 669-3955
Gwen Battle, Secretary	669-3955
Fax	669-3993

Hayder Camargo
Bruce Doyle
Chris Gibbons
Joe Hoyle
Walt Janicek

ER II - 300 Horizon Center, Robbinsville, CN 407

Bruce Comfort, Supervisor	(609) 584-4130
Cindy Woods, Secretary	584-4130
Fax	584-4145

Pat DiGangi
Frank Gagliano
Chris Hagerman
Laura Hall
Jim Manuel
Galen McCreary
Rob Schrader
Rob Winterburn

Bureau of Field Operations

Mike Tompkins, Chief	(609) 633-0708
Debbie Gruzlovic, Secretary	633-0708
Fax	777-0985

Metro Field Office - 2 Babcock Place, West Orange

Yacoub E. Yacoub, Chief	(201) 669-3960
Pam Adelman, Secretary	669-3960
Mary Fulton, Secretary	669-3960
Eyllin Pombo, MIS Tech	669-3960
Fax	669-3987

Deborah Cowell
Rodger Fedak
Mary Fulton
Gloria Grant
Gary Greulich
Ellen Hutchinson
Steve Kehayes
Jamie MacBlane
Tom McClachrie
Dave Oster
Gary Pearson
Arnold Schiff
Jodie Stein
Anthony Wager
Harry Wertz

Central/Southern Field Office - 300 Horizon Center, Robbinsville, CN 407

Thomas Downey, Section Chief	(609) 584-4150
Debbie Filipowicz, Secretary	584-4150
Fax	584-4170

Al Anderson
Randy Bearce
Cindy Davis
Bill Dunfee
Chris Dwyer
Mark Gruzlovic
Kirstin Hahn (Pointin)
Linda Jordan
Karen Kloo
Jon Malkin
Vonnie McKeithen
Lynne Mitchell
Cheryl Priest
Linda Range
Bob Swanson

Case Assignment Section - 401 E. State St., Trenton

Mark Pedersen, Section Chief	(609) 292-2943
Kim Branin, Secretary	292-2943
Fax	292-2117

Nate Byrd	292-1073	Matt Coefer	292-3574
Janice DiClaudio	633-1466	Ralph Downs	292-2015
Jerry O'Donnell	292-2082	Janet Smolenski	292-3036
Clare Whittaker	633-9624		

Donna Conway
Dianna Gibson
Cathy Gross
Rehana Karamali

Initial Notice Section

Vince Krisak, Section Chief	(609) 633-1246
Sandy Kelly, Secretary	633-1246

Maria Brimat	633-8110	Jeannette Cleary	633-1428
Greg Cunningham	292-2769	Stuart Friedman	292-9208
Joshua Gradwohl	292-0408	Shiela Migliarino	292-1866
Hasmukh Patel	633-0735	Robert Posey	777-1911
Rafael Rivera	292-2461	Cheryl Rohrbacher	777-0428

Bureau of Communications and Support Services 9 Ewing Street, Trenton

Charles Krauss, Chief	(609) 633-0898
Rose Crawford, Secretary	633-0898
Fax	984-5536

Environmental Hotline (609)292-7172

Dave Kerr, Supervisor	(609) 633-0898

Roger Andrejco
Rich Barry
Julie Chobora
Joseph Gogan
James Hart
Kimberly James
Michael Paynes
Dianne Riggs
Joyce Sanderson
Robert Santello
Joseph Sell
James Simicsak
Patrick Sinwich
Joseph Stives
John Strong
Kimberly Young

Continuing Education Seminar on Hazardous Waste Permits

The New Jersey Department of Environmental Protection (NJDEP), Division of Solid and Hazardous Waste is sponsoring a free continuing education seminar on hazardous waste permits and approvals. The seminar will be held on May 2, 1996 in the NJDEP Public Hearing Room at 401 East State Street (1st floor), Trenton, New Jersey.

The seminar will include information on:

1. Hazardous Waste Facility Part B Permits, including Major and Minor Modifications
2. Hazardous Waste Facility Closure Plan Approvals
3. Generator Accumulation Tank Approvals
4. Treatability Study Approvals
5. Permit Exemptions for On-Site Recycling to Produce Fuel Approvals

Seating is limited therefore all participants must pre-register to attend the seminar. For further information on the seminar or to register to attend, contact Robin Heston at (609) 292-7081.

SITE REMEDIATION NEWS

State of New Jersey
Department of Environmental Protection
Division of Publicly Funded Site Remediation
CN 413
401 East State Street
Trenton, New Jersey 08625-0413

Senior Editor .... Donna Marie Zalis

Editorial Review Board .... Ron Corcory, Barry Frasco, Linda Grayson, Wayne Howitz, George King, George Klein, Kevin Kratina, Ed Putnam, Dave Sweeney, and Bob Van Fossen.

Graphics Support .... Kathy DiGregorio

Contributing Writers:
Kevin F. Kratina, Franklin B. McLaughlin, Sharon P. McLelland, Lois Arbegast, Greg Toffoli, John Abolins, and Kenneth F. Smith

General Information:

The *Site Remediation News* is published by the Program Support Element. If you want to receive the *Site Remediation News*, send a request containing your name and address to:

George H. Klein
Program Support Element
CN 413
Trenton, New Jersey 08625-0413

Site Remediation News Alphabetical Index

By: Kenneth F. Smith, Industrial Site Evaluation Element

Included with this edition of the Site Remediation News (SRN) is the annual update of the alphabetical index of articles found in the SRN (called ECRA UPDATE from Oct '89-Oct '91). The index is arranged using a key word or words from the title of the article. In some cases, an article title appears more than once. For example, an article dealing with soil cleanup was included under "Cleanup" and "Soil."

The index is updated once a year and included as an attachment to the edition published after the new year. If you have any suggestions for changes, please send them to Kenneth F. Smith, Industrial Site Evaluation Element, CN-028, Trenton, NJ 08625. If you would like to receive one or more back issues of the SRN or ECRA UPDATE, an order form has been included after the index. Although the most current issue of the SRN is distributed free of charge, a charge of $5.00 per back issue is being instituted for this special service.

Please send your order form, with a check made payable to "Treasurer, State of New Jersey", to George H. Klein, Assistant Director, Program Support Element, Attn: Site Remediation News, CN413, Trenton, NJ 08625-0413.

We regret that we cannot make copies of individual articles.

Site Remediation News
Alphabetical Index

(October 1989 – Summer 1995)

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NOTE: From October 1989 – October 1991, ***Site Remediation News*** was named ***ECRA Update***.

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Site Remediation News

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