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Soil Sediment & Groundwater June/July 2000
Biopiles: Overview of Construction, Operation, and Performance

Figure 1. Biopile at the 29 Palms Marine Corps Base in California. Pumps in the foreground are for the aeration and irrigation systems. The tank at the left is for irrigation water. This is a permanent facility that can treat in excess of 1000 yd3 of soil.

Figure 2. Heterotrophic and hydrocarbon degrading bacteria in five pristine soil samples were enumerated using nutrient broth and mineral salts with diesel fuel respectively.

Figure 3. Screening and shredding soil. Water and nutrients are sprayed on the soil as it exits the conveyor belt.

By Jeffery C. Heath and Frederick E. Goetz

Biopiles are a viable and cost-effective method for the cleanup of hydrocarbon contaminated soil excavated during the removal of underground storage tanks, repair of pipelines, treatment of refinery waste, and other sites with hydrocarbon contaminated soils. While similar to landfarming, biopiles are easily implemented at sites where it is necessary to treat contaminated soil in a limited area. Bioremediation of excavated soil is attractive because it reduces or eliminates toxic components, allows reuse of the soil, and eliminates long-term liability associated with excavation and reburial. Rapid bioremediation in biopiles is promoted by amending contaminated soil with nutrients and forming it into piles that are passively or actively aerated (Figure 1).

Since significant numbers of hydrocarbon degrading bacteria are often present in even pristine soil the objective of bioremediation in biopiles is to stimulate these bacteria and accelerate the rate of hydrocarbon degradation (Figure 2).

Table 2, summarizes factors that are known to affect the rate of degradation. More importantly, some of these parameters can be manipulated to optimize and accelerate microbial activity. However, it should be remembered that the indigenous bacteria in an old spill may be optimally adapted to the extant conditions including temperature and the availability of inorganic nutrients. Although this may not be critical in most applications, extreme alterations of soil properties may retard the degradation rate. For example, in Iceland the rate of degradation was only ~1% higher in a biopile supplied with heated air compared to a pile treated with ambient air. These results demonstrate that the
Contaminants are petroleum hydrocarbons
No or few recalcitrant compounds
Absence of or low concentrations of toxic metals
Total soil volume greater than 250 yd³; soil form different sources can be mixed
Remediation goal is 500 - 1000 ppm

Table 2. Prior to building a biopile.

Indigenous bacteria were optimally adapted to the ambient temperatures. Similar observations have been made in saline soils.

Biopile Construction

Prior to building a biopile, it is necessary to determine if the soil and contaminants are amenable to bioremediation. Criteria that can be used to determine if bioremediation is appropriate are summarized in Table 2. Prior to constructing the pile, it is recommended that the soil be shredded and screened (Figure 3). This homogenizes the soil and removes rocks and debris that may form preferential flow paths.

To supply nitrogen, phosphorous, and adequate soil moisture, it is convenient to spray soil exiting the shredder with water and fertilizer. Alternatively, solid fertilizer can be blended with the soil when the biopile is constructed. To promote the circulation of air and distribution of moisture, when using passive aeration or remediating high clay content soils, it may be necessary to add a bulking agent.

Examples of bulking agents are rice hulls and wood chips added to a final concentration of 20-30 % (w/v). However, natural products present in the bulking agent may artificially inflate the hydrocarbon concentration. The use of compost as a source of nutrients may have the same effect. Fuel range hydrocarbons contributed by these sources can be corrected by running and subtracting an appropriate amendment blank or using an immunoassay method. To minimize soil compaction, pile height is limited to 8-10 feet. Details of biopile construction are illustrated in Figure 4.

To prevent infiltration and capture runoff, biopiles are constructed on an impervious pad surrounded by a berm. The treatment pad can be either permanent or temporary. To prevent drying, control dust, prevent erosion, help retain heat, or capture volatiles, the soil can be covered with a tarp or geotextile.

Simple blowers attached to slotted PVC pipe laid in a clean gravel are used to either draw or push air into the soil. The latter is preferred, since it does not require a moisture knockout drum. However, if volatiles are a problem, air has to be drawn through the pile and recycled back through the pile or treated in carbon canisters or a biofilter. To reduce operation and maintenance, the blowers are operated at intervals or controlled by oxygen monitors which turn the aeration system on when the soil gas concentration of oxygen decreases to 5-10 % (v/v).

Biopile Operation

Following construction and placement of the soil, degradation is most easily monitored by measuring the rate of oxygen consumption. This is done by shutting off the aeration system, monitoring the decrease in oxygen concentration in the soil gas, and calculating the rate of oxygen consumption.

Typical results are shown in Figure 5. This figure illustrates the high rates of oxygen consumption and rapid rate of hydrocarbon degradation that occur during the first month. Experience has shown that hydrocarbon concentrations fall rapidly in the first month after which the rate of degradation declines. Within six months the concentration of residual hydrocarbons expressed as total extractable petroleum hydrocarbons (TEPH) will usually be <500-1000 ppm. Easily degraded priority pollutants, e.g., benzene, toluene, ethylbenzene, xylenes (BTEX) are often degraded to non-detect levels. However, it is important to negotiate the target concentration for residual hydrocarbons prior to remediating the soil.

An irrigation system can be used to maintain adequate moisture levels, usually 70-95 % of field capacity. If air is drawn through the pile, water recovered from a moisture knock out drum can be combined with leachate and used to irrigate the soil. Although it is usually not necessary to add either water or nutrients, additional nutrients can be added with the irrigation water.

Continues on page 10 →

Figure 4. Schematic illustration of biopile aeration system.
Copyright Battelle Press, used by permission.
Figure 6. Total heterotrophs and hydrocarbon degrading bacteria in a soil sample contaminated with diesel fuel were enumerated at 25°C and 45°C. No hydrocarbon degrading bacteria were detected at the higher temperature and the number of heterotrophs was significantly reduced.

Thermocouples placed in the soil are used to monitor the temperature which should be near or slightly above the ambient temperature. Temperatures higher than 50°C have been observed when there is rapid degradation and may also occur if immature compost is used as a source of nutrients. High temperatures should be avoided as the population of hydrocarbon degrading bacteria may be reduced (Figure 6).

To confirm that hydrocarbon degradation is occurring, it will be necessary to schedule three to four rounds of soil sampling. The number of samples, whether they are composited, and the analytical method will depend on the volume of soil, type of contamination, and regulatory requirements. Final disposition of the soil once the target concentration is reached will vary; examples include daily landfill cover and construction backfill.

Bioremediation of small quantities of soil in biopiles is an easily implemented and cost-effective method for remediating moderate quantities of petroleum contaminated soil. It has gained both regulatory and public acceptance. A number of Navy and Marine Corps activities have permanent biopile facilities which are used to treat contaminated soil that invariably occurs due to leaks, spills, and accidental releases. Table 3, summarizes major advantages of using biopiles.

Table 3. Advantages of using biopiles.

<table>
<thead>
<tr>
<th>Advantage</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>Contaminants are destroyed</td>
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<tr>
<td>Biopiles are easy to design and construct</td>
<td></td>
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<tr>
<td>Accepted by regulators and the public</td>
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<tr>
<td>Operators do not require extensive training</td>
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<tr>
<td>Target concentrations often achieved in 3-6 months</td>
<td></td>
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<tr>
<td>Cost-competitive with landfilling and thermal desorption</td>
<td></td>
</tr>
</tbody>
</table>

Table 4. Major conclusions of the Navy study of biopile performance.

**Case Study**

The Navy conducted a detailed study of biopile performance at the Port Hueneme National Environmental Technology Test Site (NETIS), Port Hueneme, Calif., funded by the Strategic Environmental Research and Development Program (SERDP). The soil was contaminated with weathered diesel fuel range and higher hydrocarbons and the project systematically investigated the effects of moisture, nutrients, and soil preparation on the rate of hydrocarbon degradation.
Figure 7. Effect of biopile reformation on the rate of hydrocarbon degradation. After 180 days, a test pile was broken down, run through a shredder, and reformed. The rate oxygen uptake expressed as hexane equivalents was used to monitor hydrocarbon degradation.

Methods for constructing and monitoring biopile performance were also formalized. Each pile was constructed with 500 yd³ of soil and a control pile was included in the study. In addition, compliance with air emissions and all regulatory and permit requirements were strictly adhered to. Some of the major conclusions are summarized in Table 4.

In an attempt to restore the initial high rates of hydrocarbon degradation that are observed immediately following biopile construction, one of the test piles was reformed. The results Figure 7, show a 4-7 fold increase in the rate of hydrocarbon degradation measured as oxygen consumption following pile reformation. This suggests that compaction of the soil and the formation of preferential flow paths create stagnant zones in which water, oxygen, and/or nutrients are depleted. As a result, there is a significant but reversible decrease in the overall rate of hydrocarbon degradation.

While the accumulation of more recalcitrant hydrocarbons may contribute to the slowdown, the resumption of hydrocarbon degradation following pile reformation suggests that this is not a major cause for the decrease in the degradation rate. This conclusion is reinforced by the observation that the degradation rate in the test piles was higher than the control pile which received no processing, nutrients, or additional moisture.

Because of the shallow water table at the test site, the treatment objective for on-site soil reuse was set at 250 mg/kg by the local regulators. To meet this requirement, it was necessary to operate the biopile for one year. At other sites, cleanup levels for industrial reuse have been set at 1000 ppm. The soil treated at NETIS would have met this target within one month. These results demonstrate the importance of negotiating reasonable clean-up targets based on the intended reuse.

Further Information. The NFESC website at erb.nfesc.navy.mil has several manuals available for download on the design, construction, operation, and cost of biopiles.
Tributyltin: A Unique Sediment Contaminant

By Allen D. Uhler, Scott A. Stout, Kevin J. McCarthy and Stephen D. Emsbo-Mattingly

To the environmental forensic investigator, many features distinguish the sedimentary environment from the terrestrial environment. Among the most obvious factors that differentiate a sediment site investigation from a terrestrial one are considerations regarding sediment composition, water column and pore water character, and sediment contamination transport and deposition mechanisms. At first blush, site investigators might assume that the spectrum of chemicals of potential concern (COPC) in contaminated sediments is the same faced at terrestrial sites. While there is tremendous overlap among COPC in the aquatic and terrestrial environs, there are some contaminants that are virtually unique to the aquatic-and hence sediment-environment.

Among the most important is the antifouling agent tributyltin (TBT). As discussed below, TBT is a significant contaminant in many urban sediments, and understanding its physical chemistry, environmental behavior, and fate is important for those investigators concerned with its occurrence, environmental impact, and fate in sediments.

**Background**

Tributyltin (TBT) has been used extensively since the 1960s in antifouling marine paint formulations which prevented or reduced the accumulation of barnacles and slime on boat hulls. In the early 1980s, analytical methods were developed that allowed extremely sensitive and compound-class-specific analysis of butyltin compounds in marine and fresh waters, sediments, and biological tissues. By the middle 1980s, investigators were reporting the presence of TBT, as well as its principal degradation products, dibutyltin (DBT) and monobutyltin (MBT), in marine, estuarine, and freshwater environments.

The major sources of TBT into the aquatic environment were found to be harbors, moored boats, and facilities that service recreational and commercial vessels. The major

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**Figure 1.**

Tin-specific gas chromatography with flame photometric detection analysis allows separation and measurement of individual organotin compounds in sediment, biota, and water.
route of TBT entry into the aquatic environment was discovered to be largely from slow leaching of the chemical from the hulls of vessels treated with TBT-containing bottom-paint formulations. Vessel repair and dry-dock facilities were found to be major TBT sources as well, and contributed TBT to the aquatic environment by releasing fugitive paint and paint chips into surrounding waters during and after boat-hull maintenance work.

**Ecotoxicology of TBT**

Low concentrations of TBT in water or sediment can cause measurable chronic and acute effects to a wide variety of aquatic species. For example, investigators in Europe and the United States discovered that very low concentrations of butyltins—typically well less than 0.1 mg/L—were causing growth and reproductive abnormalities to bivalve mollusks of important commercial value (e.g., mussels, oysters). Ultimately, findings such as these prompted a ban on the use of butyltins in Europe and the United States.

In the US, Congress issued the Organotin Paint Control Act of 1998. In this law, Congress greatly restricted the use of TBT-containing marine boat paints—particularly among smaller non-commercial vessels. Currently, the U.S. Environmental Protection Agency has established a chronic marine water quality criteria for TBT of 10 ng/L. The National Oceanic and Atmospheric Administration (NOAA) has recommended a chronic concentration of concern for TBT in freshwater of 63 ng/L. If present at a site, TBT obviously can be a significant chemical of concern and a forensic site investigator must be aware of its unique chemistry, behavior, and measurement requirements.

**Organotin compounds** are man-made organometallic chemicals comprised of organic side-chains covalently bonded to a tin central atom. Organotin compounds can exist as mono-, di-, tri- and tetra-substituted analogs; in turn, each of these analogs are trivalent, divalent, monovalent and neutrally charged, respectively. Organotin compounds have a variety of industrial uses as synthetic chemistry intermediates, stabilizers, and in some cases, as biocidal agents (e.g., pesticides, fungicides).

From an aquatic environmental chemistry perspective, these compounds are of concern because they have fate and transport properties similar to non-polar or moderately polar organic compounds (i.e., meaning they partition to sediments and particulates, and can be bioaccumulated and cross cell membranes rather easily), yet they exhibit toxicological properties that are largely derived from the tin central atom. The solubility of organotins, while low, are well within ecotoxicologically important concentration ranges in natural water. Typically, the solubility of organotins range from 10’s of milligrams per liter to low microgram per liter concentrations, with the mono-substituted organotins being more soluble than the di- and tri-substituted compounds, and much more soluble that the tetra-substituted analogs.

Water chemistry affects the solubility of these chemicals. For example, TBT’s solubility ranges from 750 to 31,000 mg/L over the pH range 2.6 to 8.1.

**Partitioning of Organotins from Sediment to Water**

The binding of organotin compounds to sediment is reasonably high-on par with many

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hydrophobic organic contaminants. The higher substituted analogs of organotins have much greater affinity for sediment than the more polar, lower substituted analogs (e.g., the affinity of the butyltin compounds for sediment is TTBTr > TBT > DBT > MBT). Organotin compounds are rather unique, in that their partition coefficients are highly influenced by ancillary factors, notably pH, ionic strength, and organic carbon content of sediment. Partition coefficients reported for TBT range from 340 to 390,000 L/kg, depending on these factors. Clearly, it is difficult to accurately predict a priori partitioning behavior of these chemicals without site-specific sediment-water distribution coefficients in hand. Such site-specific measurements are warranted if a quantitative fate model or if a risk assessment is needed at the site.

**Degradation Rates/Pathways**

Depending on ambient conditions, TBT has a half-life of about 1-3 weeks in natural waters. The principal degradation product of this process is toxicologically active DBT, which degrades more slowly than TBT to MBT. The degradation rate of TBT in sediments is varied, but appears to be on the order of several years. The pathways for degradation are both abiotic (hydrolysis) and microbiologically mediated.

Experiential evidence in the literature suggests that TBT’s principal degradation product, DBT, has a much longer half-life in sediment than its parent compound. The often relatively long half-lives in sediment, coupled with the large sediment:water partition coefficients sets up the classic situation where sediments act as long-term, chronic sources of butyltins to pore- and the overlying water column.

**Chemical Measurement Strategy is Critical**

Because of the unique chemistry of TBT and its analogs and the detection limit goals necessary for their measurement at environmentally relevant concentrations, the site investigator must use the proper laboratory methods to measure these chemicals in environmental media. None of the standard EPA methods of analysis-inorganic or organic-are suitable for measurement of butyltins. During the last decade, excellent methods have been developed for measurement of butyltins in environmental media.

The most widely used technique is cited in the 1993 National Oceanic and Atmospheric Administration Sampling and Analytical Methods of the National Status and Trends Program National Benthic Surveillance and Mussel Watch Project. (NOAA Technical Memorandum NOS ORCA 71). This performance-based method is a multi-residue technique capable of separating and quantifying individual butyltin by gas chromatography (Figure 1).

In this methodology, samples are extracted using an organic solvent and a tin-specific chelating agent to enhance extraction efficiency following by derivitization to neutral alkyl derivatives that, after suitable cleanup, are amenable to GC analysis using a tin-specific flame photometric detector.

It is important that the site investigator require analytical laboratories to achieve method detection limits that are commensurate with concentrations of environmental concern. For TBT, this translates to a detection limit goal of about 1 ng/L in water and 1 mg/kg in sediment and biological tissue. One word of caution regarding selection of a laboratory for measurement of TBT: organotins are ubiquitous contaminants in the laboratory; as such, most laboratories cannot achieve environmentally meaningful detection limits because of chronic background contamination from their facilities. Choose only a laboratory that can demonstrate it can meet the MDLs of environmental concern, and that can demonstrate a track record of reliably clean method blanks for the matrix you intend to have them analyze.

**Conclusion**

Tributyltin (TBT) is among a small group of truly unique sediment contaminants. In order to understand the occurrence, fate and effects of TBT, the site investigator must gain an appreciation of its unusual aquatic chemistry and ecotoxicology. Identifying an analytical laboratory familiar with butyltin residue chemistry and able to meet environmentally relevant method detection limits is among the first steps the site investigator must take in crafting a successful investigation in which TBT is a chemical of concern. Combining good chemistry with sound environmental behavior and fate data is the cornerstone to a successful TBT forensic investigation.
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Benchtop Composting Reactor for Remediation Studies

By Christopher E. Prigge, Robert G. Diener P.E., Stacy A. Gartin, Layle D. Lawrence, Douglas Hudson and Henry W. Hognire

The use of pesticides in the United States has increased from 200,000 pounds per year in the 1950s to more than one billion pounds per year by 1987. One of the major concerns of pesticide use by agriculture is the contamination of surface and ground water resources. Contaminated water sources may destroy wildlife such as aquatic species of animals, predators of these animals and the animals that depend on these aquatic environments for a source of water. Pesticide residues that contaminate the environment can come from spray tank wash water, pads where spray tanks are loaded and waste water.

Many methods have been used to eliminate pesticide contamination of both soils and water such as incineration, landfilling, land farming, chemical stripping and phytoremediation. These methods, however, are expensive and may contaminate the atmosphere and groundwater when contaminants escape from the treatment facility.

A more promising and cost effective way to eliminate these pesticides is by bioremediation which also changes the chemical makeup of the pesticide into a harmless state. Bioremediation is the process by which certain strains of microbes that are indigenous to site groundwater are identified for their ability to consume and digest contaminants of concern. Biodegradation has been defined as the process whereby a compound, for example a herbicide, is transformed structurally by photochemical, chemical, and biological means to CO\(_2\), water, and salts. This digestion leaves less toxic and more stable chemical forms of the contaminant, along with other inert byproducts such as water, carbon dioxide, methane, and hydrogen.

There are numerous materials that can be bioremediated which include chemical pesticides, pollutants such as sewage sludge, and petroleum products. Bioremediation benefits the environment because it not only removes the toxic chemical, but it does it in such a manner as to minimize additional environmental damage. However, there are several specific criteria that need to be met in order for bioremediation to be effective.

A large variety of microorganisms have been listed which can degrade the insecticides Asana, Guthion, Lannate, Lorsban, and Pennco- M, as well as the herbicides 2,4-D and Atrazine, 2,4-D and related halogenated compounds, as well as others that are similar, can be bioremediated with composting the same way as the above insecticides. Research has shown that mycorrhizal fungi can degrade lignin, also an aromatic plant compound. It is theorized that the plant host provides the fungi with carbohydrates while the fungi provides the plant host with minerals. Degradation of 2,4-D occurred both as mineralization (CO\(_2\)) and incorporated into tissue C, and that both mycorrhizal and non mycorrhizal fungi were able to degrade both 2,4-D and atrazine.

White-rot fungi are noted for their ability to degrade both lignin and aromatic hydrocarbons to CO\(_2\). These fungi secrete H\(_2\)O\(_2\) and a family of peroxidases that catalyze the free radical oxidation and depolymerization of lignin. The C-centered free radicals that are produced from this are responsible for the non-specific cleavage of the lignin polymer and probably the mineralization of other aromatic hydrocarbons as well. Herbicide degradation is directly related to microbial biomass.

In testing compost feasibility for bioremediation, a small scale reactor can often save the expense and time required to build a full static pile or in-vessel system. At West Virginia University, a bench top reactor design has evolved to duplicate the effects of a large reactor through its design, insulation and other features. Low cost construction materials and off-the-shelf instrumentation and fixtures were featured in this reactor so that others could easily duplicate it.

This reactor was used to determine the most effective procedure to bioremediate pesticide contaminated media. Since the process was done on a small scale the effectiveness of the reaction could be fine-tuned. This avoided the necessity of setting up a large scale windrow before it was known if composting pesticide residues would be worthwhile. With effective disposal methods for pesticides required, it is important to determine both a cost efficient and effective method of disposal.

Christopher E. Prigge, Robert G. Diener P.E., Stacy A. Gartin, Layle D. Lawrence, Douglas Hudson and Henry W. Hognire are with West Virginia University, Morgantown, W.Va.

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Consideration of Surface Area to Volume Ratios

The smaller an object is, the greater the surface area to volume ratio it will have. Smaller objects will have a greater heat loss because of this increased surface area to volume ratio. This is why only large animals such as polar bears survive in the Arctic regions. Therefore, smaller composting vessels will need additional insulation to compensate for this heat loss in order to maintain the same temperature as the larger systems. The following computations were used to determine the additional insulation required for the small reactors to compensate for their reduced size.

Consider a commercial vessel 10 feet wide, 3 feet high, and 10 feet long,

\[
\frac{\text{Surface Area}}{\text{Volume}} = \frac{2(10 \times 10) + 4(10 \times 3)}{10 \times 10 \times 3} = \frac{320}{300} = 1.067
\]

as opposed to a small bench top reactor: 1 foot wide, 1 foot long, and 1.5 feet high,

\[
\frac{\text{Surface Area}}{\text{Volume}} = \frac{4(1 \times 1.5) + 2(1)}{1 \times 1 \times 1.5} = \frac{8}{1.5} = 5.33
\]

Thus, the small reactor has a larger surface area to volume ratio by a factor of $5.33/1.067 = 5$, and therefore must also have an insulation factor of five times that of the larger vessel to equalize heat loss.

Consider an 8" cement block wall used in a commercial in-vessel reactor which has an R of 1.10. Then consider a benchtop reactor with a 1/2" plywood wall with an R value of 0.65 and foam insulation with an R value of 5.4 per inch. Thus, we must add a calculated value of foam insulation to achieve an R value of five times that of a commercial reactor.

\[
5 \times R \text{ of an 8" cement block} = \frac{R \text{ of 1/2" plywood}}{R \text{ foam (thickness)}}
\]

where:
- R (8" block) = 1.10
- R (1/2" plywood) = 0.65
- R (1" foam insulation) = 5.4

Thus:

\[
5 \times 1.10 = 0.65 + 5.4 \cdot \text{(inches of thickness)}
\]

From the this relation it is determined that 0.898 inches of foam insulation is specified. Therefore, one inch of insulation is selected because it is the closest commercially available size.

Assembly of the Compost Reactor

The compost reactor shown in Figures 1 and 2 had outside dimensions of 13"x 13"x 24" high before the...
insulation was applied. The reactor was constructed from 0.50" thick plywood and had a plenum board to equalize the air flow located at a distance of 5" from the bottom. The function of the plenum was to provide uniform airflow through the reactor. The plenums used had multiple 0.25" holes on a 1" spacing to allow uniform airflow.

Three coats of polyurethane were applied to the insides of the reactor and to both sides of the plenum to protect the wood from moisture and decomposition. Foam insulation of 1" thickness was glued to each exterior surface of the reactor to prevent heat loss. Duct tape was placed around the four corners and bottom to protect the insulation.

**Reactor Cover**

The reactor cover shown in Figures 1 and 2 was constructed of 0.50" thick plywood. It was used to prevent heat from escaping through the top of the reactor and consisted of a plywood cover with a plenum board inside it placed 5" below the top of the cover. The plenum board rested on top of the reactor and consisted of a sheet of 0.50" plywood with 5/16" holes drilled through it at a 1 1/2" spacing.

A plenum board was used to evenly distribute airflow to the top compost media. Two coats of polyurethane were applied to the inside to protect the wood from moisture. On the top of the cover a 4" hole was cut in the center to allow the insertion of an adapter that would allow 3" schedule 40 PVC pipe and two 90° elbows. Figures 1 and 2 illustrate the correct placement of the pipes and elbows.

<table>
<thead>
<tr>
<th>% Nitrogen</th>
<th>C/N</th>
<th>MC WB %</th>
<th>Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poultry Manure</td>
<td>8</td>
<td>6</td>
<td>40.5</td>
</tr>
<tr>
<td>Newsprint</td>
<td>.10</td>
<td>625</td>
<td>5.5</td>
</tr>
<tr>
<td>Peat Moss</td>
<td>-</td>
<td>-</td>
<td>86</td>
</tr>
</tbody>
</table>

Table 1. Chemical and physical values of materials used.

<table>
<thead>
<tr>
<th>Lb Dm/Lb</th>
<th>Lb N/Lb Dm</th>
<th>Lb C/Lb Dm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poultry Manure</td>
<td>.595</td>
<td>0.0476</td>
</tr>
<tr>
<td>News Print</td>
<td>.945</td>
<td>0.000945</td>
</tr>
<tr>
<td>Peat moss</td>
<td>.14</td>
<td>(1)</td>
</tr>
</tbody>
</table>

Table 2. Pounds of nitrogen and carbon for materials listed calculated from values in Table 1.

**Water Trap**

The water trap shown in Figures 1 and 2 was used to collect condensation from hot exhaust gases leaving the reactor. It consisted of a 1' section of 4.5" schedule 40 PVC pipe with caps glued on both ends. A 1.5" hole was threaded into the lower side of the water trap pipe and a second hole was cut near the top to prevent moisture from escaping with hot exhaust air. These holes were then threaded with a 1.25" NPT pipe tap to enable the installation of 1.25" flexible hose connectors to the sides.

**Biofilter**

The biofilter (Figures 1 and 2) was used to remove odors and pesticide residues from exhaust gases. The biofilter was constructed from 0.50" class AC plywood. Outside dimensions of the biofilter were 6.5" x 7" x 24" before insulation was applied. An air plenum board placed 3" above the bottom of the biofilter with 0.25" holes drilled on 1" centers was used to enable air to flow evenly through the media.

Three coats of polyurethane were applied to the insides of the biofilter and both sides of the plenum to protect the plywood surface. A 1.25" NPT hose connector was installed on the lower face of the biofilter to allow exhaust gases from the plenum chamber to enter under a positive pressure.

Insulation of 0.75" thickness was used outside of the biofilter to retain heat. The insulation was protected with 1 1/2" duct tape placed around the four corners and at the top and bottom of each biofilter. The biofilter media was composed of a mixture of half finished compost and half wood chips which passed through a 3/4" screen.

![Schematic diagram of the compost reactor system](image)

**Figure 3. Wiring schematic showing temperature and aeration controls.**

![Airflow readings from Seneca Way Farms](image)

**Figure 4. Airflow readings from Seneca Way Farms which were recorded at chimney on the biofilter of the WVU Compost Reactor.**
Operation of the Benchtop Reactor

Theoretical relations for carbon and moisture balance.

Calculation of C/N Balance. The C/N ratio equation was used to calculate the amount of newsprint (carbon source) added to one pound poultry manure to give a C/N value of 30:1. Values of Carbon to achieve a 30:1 C/N ratio are now calculated below using values from Table 2.

where: \( C/N = \frac{C_{\text{Poultry Manure}} + X \times C_{\text{Newsprint}}}{N_{\text{Poultry Manure}} + X \times N_{\text{Newsprint}}} \)

\( C/N = 30 \times \frac{0.286 + X \times 0.591}{0.0476 + X \times 0.000945} \)

thus \( X = 2.03 \) pounds of newsprint per pound of poultry manure to produce necessary carbon for a C/N ratio of 30.

Calculations of moisture balance of poultry manure and newsprint. The moisture balance can now be calculated based on values derived from the C/N ratio determination.

where: \( MC\% = \frac{(\text{Water in poultry manure} + \text{Water in newsprint}) \times 100}{\text{Total weight}} \)

and using values for moisture content from Table 1 and 2.03 lbs. of newsprint from the previous equation, we have:

\[ MC\% = \frac{(1 \text{ lb} \times 40.5) + (2.03 \text{ lb} \times 5.5)}{1 \text{ lb} + 2.03 \text{ lb}} \]

thus \( MC = 17.05\% \)

Determination of final mix with addition of peat moss. Peat moss at 86% moisture content was added to the above mix to obtain a resulting recipe of 60% moisture content (Wet Basis). It was assumed there was no nitrogen value in peat moss and carbon was only slightly available, thus:

\[ MC = 60\% = \frac{100 \times (\text{Mix lbs} \times \text{Moisture content of mix}) + (Y \times \text{Moisture content of peat moss})}{\text{Total Weight}} \]

and \( 60\% = \frac{100 \times (1 \text{ lb} \times 0.17) + (Y \times 0.86)}{1 + Y} \)

where \( Y \) is lbs. peat moss added per lb. of mix, and \( Y = 1.66 \) lbs. peat moss per 1 pound of mix

Mixing Relations

Based on above calculations the mix values in Table 3 were determined.

Reactor Aeration and Controls.

Air was evacuated in a negative manner down through the compost mix, through the plenum board and into the plenum chamber. The air was then drawn out of the plenum chamber by a Dayton Model 2C782 squirrel cage blower shown in Figures 1 and 2.

<table>
<thead>
<tr>
<th>Reactor Used in Experiment</th>
<th>Condensate</th>
</tr>
</thead>
<tbody>
<tr>
<td>150° F</td>
<td></td>
</tr>
<tr>
<td>128.4° F</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td></td>
</tr>
<tr>
<td>61.35 ppm</td>
<td>0</td>
</tr>
<tr>
<td>19.53 ppm</td>
<td>N/D</td>
</tr>
<tr>
<td>%Reduction of Methyl Parathion</td>
<td>68%</td>
</tr>
</tbody>
</table>

Table 4. Pesticide bioremediation data with pesticide levels, temperatures, and condensate.
Operation of the fan was controlled by a Paragon Model # JW10-00 percentage timer and a Honeywell Type T675A insertion thermostat wired parallel as shown in Figure 3.

The percentage timer was set to run at the minimum of 15 seconds per 10 minutes to prevent the reaction from going anaerobic. The insertion thermostat was set at 140°F Fahrenheit to prevent overheating.

Fan Calibration

In order for the WVU Compost Reactor to work effectively, the fan was calibrated to run for a specified length of time. Time was based on the amount of air that could flow through the complete compost apparatus. As airflow decreased and/or temperature increased the fan was calibrated to run for a longer duration.

To insure that there were no restrictions from compaction and that the exhaust air was adequately flowing through the reactor, water trap, and biofilter airflow readings were recorded daily with an airflow anemometer. These readings as illustrated in Figure 4 were taken from a horse manure compost study done for Seneca Way Farms.

Figures 4 and 5 show that airflow through the WVU Compost Reactor was operating near the cutoff of airflow at a range of 0.21 to 0.215” of water. Any additional restrictions, such as water blockage in the exhaust hose, would completely block airflow causing the reaction to overheat and crash from the death of bacterial colonies.

Also note the compaction phase as indicated in Figure 4 during the first day of the reaction. This shows that as the compost reacted, began to settle, and then compress, airflow was significantly reduced. This was because the porosity was decreased as the mixture compressed. Although this was not a problem, more severe compaction could have blocked the airflow if the blower cutout point had been reached.

Temperature Curve

Daily temperatures were recorded for the compost reaction shown in Figure 6. The reactor shows a sudden rise in temperature the first two days and then a gradual decrease in temperature as nitrogen is used up over the next several days. At day twelve of the reaction the temperature began to rise. This temperature increase was probably due to increased fungal populations which generated additional heat.

Overall this curve was normal and rose and dipped according to the typical compost temperature curve. There were no sudden decreases in temperature which was good. Two curves shown are based on the temperature readings from the top and bottom thermometers. The thermometer at the bottom of the reactor was hotter because less heat loss occurred at its location.

Pesticide Bioremediation

As indicated in Table 4 there was a significant reduction of 68% in Methyl Parathion concentration as a result of composting. This media could have been recomposted a few more times which would cause the media to be almost completely bioremediated making it safe for land application. Condensation was collected from the water trap and the amount of pesticide residue found in the condensate was undetectable making disposal methods safe and simple. If the water collected was contaminated it could be added to the reactor for additional remediation.

Conclusions

- This study developed a successful benchtop compost reactor to bioremediate pesticide contaminated media which duplicates the airflow and heat loss properties of a large scale reactor.
- Different compost recipes were developed to determine ideal quantities of poultry manure, newspaper clippings, and wood chips.
- No pesticides were detected in the water trap condensate exiting the reactor.
- This reactor successfully remediated 68% of Methyl Parathion in the first cycle which lasted 16 days.
- Further remediation could be done by additional composting cycles.
Selection of Off-Gas Treatment for Petroleum Releases

By Michael J. Pierdinock, Joseph B. O’Brien and John C. Mesheau

Two of the most common forms of vapor phase treatment utilized in the remediation of petroleum impacted soil and groundwater are vapor phase carbon (VPC) adsorption and catalytic/thermal oxidation. This article provides an overview of these off-gas treatment technologies and describes how to assess the technologic and economic feasibility of each technology.

Activated Vapor Phase Carbon

VPC is often utilized in the adsorption of vapor phase volatile organic compounds (VOCs) extracted from soil and/or groundwater through remediation technologies such as soil vapor extraction, air sparging and groundwater air stripping. Typically, VPC is placed at the end of these process streams to treat off-gases prior to discharge. Many states have air pollution control regulations or guidelines which provide discharge limits for off gas. The designer of a remediation system should be familiar with the relevant regulations or guidelines prior to selection of an off-gas treatment technology.

VPC is typically placed in a series of low pressure vessels, which the off-gas process stream passes through to provide the necessary contact time for the adsorption of VOCs from the off-gas onto the VPC, as indicated in Figure 1.

Typical Vapor Phase Carbon Layout Detail

Many factors can impact the VOC adsorption rate, including, but not limited to; inlet off-gas concentration, relative humidity, temperature, pressure and/or vacuum, age of carbon, number of previous regeneration cycles of carbon and contact time. Carbon manufacturers can supply carbon adsorption isotherms for their carbon products which may aid in predicting carbon efficiency. For the purposes of this article, and based on experience operating remediation systems, an adsorption efficiency of 10% (10 pounds of carbon to treat 1 pound of petroleum) will be utilized in the cost estimate examples set forth below.

The successful operation of a VPC adsorption system requires the ability to predict the “breakthrough” of off-gas constituents through the VPC, to prevent the discharge of off-gas emissions above applicable air pollution limits. One simple method to predict the “breakthrough” of the entire VPC system is to use multiple VPC vessels in series, screening for VOCs between vessels, to document “breakthrough” in primary VPC vessels prior to “breakthrough” in secondary VPC vessels. The initial frequency of screening is predicted by calculating the mass of VOCs in the inlet process stream versus the mass of VPC within the vessels.

One common phenomenon occurs when off-gas with low concentrations of VOCs passes through VPC that previously treated off-gas with higher VOC concentrations, VOCs can desorb from the VPC back into the off-gas (reversing the concentration gradient). By changing out primary vessels and rotating secondary vessels into the primary position, this desorption can be avoided and the efficiency of the VPC can be increased, reducing the potential for exceeding the applicable air emission standards and decreasing carbon costs.

Catalytic and Thermal Oxidation

Thermal oxidation is a process in which organic compounds are oxidized through combustion. The general expression for the combustion of hydrocarbons is set forth in the equation below.

\[
C_{x}H_{y} + \frac{4x + y}{2} \text{O}_2 \rightarrow x\text{CO}_2 + \frac{y}{2} \text{H}_2\text{O}
\]

Continues on page 22 →

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Equation No. 1 - General Expression for Combustion of Hydrocarbons where:

\[ x = \text{number of carbon atoms in the hydrocarbon, ie... methane (CH}_4, \text{C}_x = 1 \]
\[ y = \text{number of hydrogen atoms in the hydrocarbon, ie... methane (CH}_4, \text{H}_x = 4 \]

Petroleum hydrocarbons are oxidized to carbon dioxide and water in the combustion process. The key factors of a thermal or catalytic treatment system are the combustion temperature, residence time and turbulence (mixing). The normal operating temperature for the combustion of petroleum related VOCs (thermal oxidation) ranges from 550°C (1,022°F) to 850°C (1,562°F).

A catalyst (usually a precious metal based) can be placed within the combustion chamber to accelerate the rate of the oxidation reactions and enable the reactions to proceed at temperatures ranging from 375°C (707°F) to 500°C (932°F), reducing energy costs. Auxiliary energy, in the form of electricity, propane and/or natural gas, is required to maintain the reaction temperature within the combustion temperature.

Some caloric benefit can be gained from the combustion of petroleum VOCs within the off-gas, consequently, higher off-gas concentrations actually decrease auxiliary fuel demands and costs. Many catalytic and thermal oxidizers have heat exchangers to preheat influent off-gas which also decreases auxiliary energy demands and costs.

**Catalytic/Thermal Oxidizer Detail**

Catalytic and thermal oxidizers are usually placed at the end of an off-gas process stream prior to discharge to the atmosphere, as indicated in Figure 2. If properly designed, catalytic and thermal oxidizers provide a higher confidence level of off-gas treatment than VPC treatment. Factors that can effect the destruction removal efficiency of catalytic and thermal oxidizers include, but are not limited to; air flow greater than design flows, low combustion temperatures and off-gas concentrations greater than design parameters.

In order for a manufacturer to design a catalytic or thermal oxidizer for a particular site, the off-gas process stream must be adequately characterized and quantified. Off-gas concentrations of a properly designed remediation system decrease over time and therefore the catalytic or thermal oxidizer should be designed to operate at 100% capacity at some time after the initial start-up (e.g. 3 to 6 months).

Using this design approach, the introduction of dilution air into the off-gas process stream may be required to reduce concentrations at startup and avoid overheating. Over time, as inlet off-gas concentrations decrease the dilution air can be reduced until no dilution air is required (100% capacity.)

As the remediation project approaches "closure" off-gas concentrations will decrease and additional auxiliary energy will be required to maintain the combustion chamber temperatures. By using this design approach, a smaller catalytic or thermal oxidizer can be utilized, reducing capital and energy costs.

**Calculating Off-Gas Mass Loading**

The most important factor to determine which off-gas treatment is appropriate for a soil and/or groundwater remediation system is the "mass loading" of VOCs in the off-gas. Off-gas mass loading is a function of the off-gas concentration and flow rate. Off-gas concentrations are expressed in a volume/volume basis (e.g. parts per million by volume (ppmv)). A pilot test should be conducted to establish site specific empirical data including off-gas concentrations and optimum flow rates.

The conversion of volume/volume to mass/volume of gases involves applying the Ideal Gas Law, including multiple site specific variables and constants used to derived the mass loading for each individual constituents of the off-gas. More often than not, soil and/or groundwater remediation systems are

<table>
<thead>
<tr>
<th>Petroleum Coefficients for Mass Loading</th>
<th>Average Molecular Weight (g/mol)*</th>
<th>Petroleum Coefficient (lbs./day/SCFM/ppmv)**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline</td>
<td>607 x 10^-4</td>
<td>3.86 x 10^-4</td>
</tr>
<tr>
<td>Jet Fuel 165</td>
<td>607 x 10^-4</td>
<td>3.86 x 10^-4</td>
</tr>
<tr>
<td>Diesel Fuel</td>
<td>230</td>
<td>8.46 x 10^-4</td>
</tr>
</tbody>
</table>

** Mass loading a 25 C, anc 1 atm assumes continuous operation.

** Mass loading a 25 C, and 1 atm assumes continuous operation.
designed to address a mixture of compounds, such as gasoline, jet fuel, or diesel fuel.

For the purposes of this article, and based on experience operating remediation systems, we have provided simple equations to estimate the mass loading of petroleum-related compounds based on volume/volume concentration measurements that have proven to be accurate at many petroleum remediation sites as set forth below. Mass Loading (lbs./day) = (CoF) x (QoF) x (PC) where: CoF = Concentration of Off-Gas (ppmv) QoF = Off-Gas Flow Rate in standard cubic feet per minute ("SCFM") PC = Petroleum Coefficient (lbs./day/SCFM/ppmv)(See Table 1)

Table 2. Hypothetical site No. 1. Estimated mass loading.

<table>
<thead>
<tr>
<th>Hypothetical Site No. 1 - Estimated Mass Loading</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Operational Period (months)</td>
<td>Off-Gas Concentration (ppmv)</td>
<td>Predicted Mass Loading (lbs./day)*</td>
</tr>
<tr>
<td>Month (1)</td>
<td>1,000</td>
<td>115</td>
</tr>
<tr>
<td>Months (2-3)</td>
<td>500</td>
<td>58</td>
</tr>
<tr>
<td>Months (3-6)</td>
<td>200</td>
<td>23</td>
</tr>
<tr>
<td>Months (6-12)**</td>
<td>50</td>
<td>6</td>
</tr>
<tr>
<td>* Off-gas flow rate of 300 SCFM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>** 12 month remediation life cycle</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Example: A soil vapor extraction system is remediating a release of gasoline 24 hours per day and discharging 300 SCFM of off-gas at a concentration of 1,000 ppmv as benzene. Therefore: Mass Loading (lbs./day) = (1,000 ppmv x (300 SCFM) x (3.86x10^-4) = 115 lbs./day

Selection of Vapor Phase Carbon Vs. Catalytic and Thermal Oxidation

The appropriate off-gas treatment can be selected based on a cost benefit analysis. Catalytic or thermal oxidizers typically have higher initial capital and installation costs than VPC but VPC may have higher operational costs based on mass loading.

In the following examples, assumptions have been made based on experience and to provide simplicity. We strongly suggest that designers determine their specific design and equipment specifications and costs prior to selecting the appropriate off-gas treatment technology.

Off-Gas Characteristics

- Off-gas air flow rate = 300 SCFM
- Caloric Benefit of Petroleum = 17,500 BTUs per pound

Continues on page 24 →

Option -1A. Estimated Vapor Phase Carbon Treatment Costs of Hypothetical Site No.1

<table>
<thead>
<tr>
<th>Operational Period</th>
<th>Predicted Mass Loading*</th>
<th>Number of Months in Operational Period</th>
<th>Predicted Mass Loading</th>
<th>Carbon Required at 10% Efficiency</th>
<th>Operational Period Costs @ $1.78/lb.</th>
</tr>
</thead>
<tbody>
<tr>
<td>months</td>
<td>lbs./month</td>
<td>months</td>
<td>lbs./period</td>
<td>lbs./period</td>
<td>Dollars</td>
</tr>
<tr>
<td>Installation</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>$6,000</td>
</tr>
<tr>
<td>Month (1)</td>
<td>3,450</td>
<td>1</td>
<td>3,450</td>
<td>34,500</td>
<td>$61,410</td>
</tr>
<tr>
<td>Months (2-3)</td>
<td>1,750</td>
<td>2</td>
<td>3,450</td>
<td>34,500</td>
<td>$61,410</td>
</tr>
<tr>
<td>Months (3-6)</td>
<td>690</td>
<td>3</td>
<td>2,070</td>
<td>20,700</td>
<td>$36,846</td>
</tr>
<tr>
<td>Months (6-12)</td>
<td>180</td>
<td>6</td>
<td>1,080</td>
<td>10,800</td>
<td>$19,224</td>
</tr>
<tr>
<td>TOTAL</td>
<td>-</td>
<td>12</td>
<td>10,050</td>
<td>100,500</td>
<td>$184,890</td>
</tr>
</tbody>
</table>

* assumes 30 days per month

Option - 2A. Estimated Propane Fired Catalytic Oxidization Treatment Costs of Hypothetical Site No.1

<table>
<thead>
<tr>
<th>Operational Period</th>
<th>Predicted Mass Loading</th>
<th>Number of Months in Period</th>
<th>Predicted Mass Loading</th>
<th>Catalytic Oxidizer Firing Rate</th>
<th>Net Auxiliary Energy (Propane) Required</th>
<th>Operational Period Costs @ $5.00/MBTu</th>
</tr>
</thead>
<tbody>
<tr>
<td>months</td>
<td>lbs./month</td>
<td>months</td>
<td>lbs./period</td>
<td>MBTUs per period</td>
<td>MBTUs per period</td>
<td>Dollars</td>
</tr>
<tr>
<td>Installation</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>$44,000</td>
</tr>
<tr>
<td>Month (1)</td>
<td>3,450</td>
<td>1</td>
<td>3,450</td>
<td>60</td>
<td>126</td>
<td>$330</td>
</tr>
<tr>
<td>Months (2-3)</td>
<td>1,750</td>
<td>2</td>
<td>3,450</td>
<td>60</td>
<td>252</td>
<td>$960</td>
</tr>
<tr>
<td>Months (3-6)</td>
<td>690</td>
<td>3</td>
<td>2,070</td>
<td>36</td>
<td>378</td>
<td>$1,710</td>
</tr>
<tr>
<td>Months (6-12)</td>
<td>180</td>
<td>6</td>
<td>1,080</td>
<td>19</td>
<td>756</td>
<td>$3,685</td>
</tr>
<tr>
<td>TOTAL</td>
<td>-</td>
<td>12</td>
<td>10,050</td>
<td>175</td>
<td>1,312</td>
<td>$50,685</td>
</tr>
</tbody>
</table>

C = Mass loading pounds per period multiplied by caloric benefit of 17,500 BTUs/lb./1,000,000
D = Firing rate of 175,000 BTUs/hr.x 24 hrs/day x 30 days/month x months in period./1,000,000

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**Option -1B. Estimated Vapor Phase Carbon Treatment Costs of Hypothetical Site No.2**

<table>
<thead>
<tr>
<th>Operational Period</th>
<th>Predicted Mass Loading*</th>
<th>Number of Months in Operational Period</th>
<th>Predicted Mass Loading</th>
<th>Carbon Required at 10% Efficiency</th>
<th>Operational Period Costs @$ 1.78/lb.</th>
</tr>
</thead>
<tbody>
<tr>
<td>months</td>
<td>lbs./month</td>
<td>months</td>
<td>lbs./period</td>
<td>lbs./period</td>
<td>Dollars</td>
</tr>
<tr>
<td>Installation</td>
<td>A</td>
<td>B</td>
<td>AxB</td>
<td>AxBx10</td>
<td>AxBx10x$1.78</td>
</tr>
<tr>
<td>Month (1)</td>
<td>345</td>
<td>1</td>
<td>345</td>
<td>3450</td>
<td>$ 6,000</td>
</tr>
<tr>
<td>Months (2-3)</td>
<td>175</td>
<td>2</td>
<td>345</td>
<td>3450</td>
<td>$ 6,141</td>
</tr>
<tr>
<td>Months (3-6)</td>
<td>69</td>
<td>3</td>
<td>207</td>
<td>2070</td>
<td>$ 3,684</td>
</tr>
<tr>
<td>Months (6-12)</td>
<td>18</td>
<td>6</td>
<td>108</td>
<td>1080</td>
<td>$ 1,922</td>
</tr>
<tr>
<td>TOTAL</td>
<td>-</td>
<td>12</td>
<td>1,005</td>
<td>10,050</td>
<td>$ 23,888</td>
</tr>
</tbody>
</table>

* assumes 30 days per month

---

**Option - 2B. Estimated Propane Fired Catalytic Oxidation Treatment Costs of Hypothetical Site No.2**

<table>
<thead>
<tr>
<th>Operational Period</th>
<th>Predicted Mass Loading</th>
<th>Number of Months in Period</th>
<th>Predicted Mass Loading</th>
<th>Caloric Benefit from Mass Loading</th>
<th>Catalytic Oxidizer Firing Rate</th>
<th>Net Auxiliary Energy (Propane) Required</th>
<th>Operational Period Costs @$ 5.00/MBTU</th>
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<td>1,512</td>
<td>1,494</td>
<td>$ 51,470</td>
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C = Mass loading pounds per period multiplied by caloric benefit of 17,500 BTUs/lb./1,000,000
D = Firing rate of 1/5,000 BTUs/hr.x 24 hrs/day x 30 days/month x months in period./1,000,000

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**Off-Gas Treatment Costs**

- Carbon Vessels (2 - 1,000 lb. vessels @$ 3,000/ea.) $6,000.00
- Carbon Costs (10% efficiency) includes change out labor $1.78/lb.
- Catalytic Oxidizer (175,000 BTU/hr. rating) includes installation $44,000.00.
- Catalytic Oxidizer auxiliary energy costs per million BTUs $5.00/Million BTUs.

**Hypothetical Sites**

At hypothetical Site No.1, the designer has performed a soil vapor extraction pilot test within the source area of a gasoline spill. During the pilot test, off-gas concentrations of 1,000 ppmv were measured with a photo-ionization detector (PID) and/or flame ionization detector (FID) and an air flow rate of 50 SCFM was extracted from one pilot test well. Based on the pilot test data, six soil vapor extraction wells would be required to properly cover the proposed remediation area, therefore, the total proposed off-gas emission would be 300 SCFM. The estimated mass loadings are set forth in Table 2 and based on the mass loading the estimated cost for each off-gas treatment option is set forth below.

At hypothetical Site No. 2, off-gas concentrations are an order of magnitude less than hypothetical Site No.1, with the same air flow rate of 300 SCFM as set forth below.

As set forth in the tables, the cost to furnish and operate a catalytic oxidizer did not vary significantly from hypothetical Site No.1 to No.2, where as VPC varied significantly. The cost to operate a catalytic oxidizer remains fairly constant regardless of changes in off-gas concentration, where VPC usage is directly linked to off-gas mass loading. As set forth in Hypothetical Site No.1, the VPC costs ended up approximately three times greater than amount to treat off-gas over Catalytic Oxidation.

**Conclusions**

Although the remediation of no two sites is the same, by applying site specific variables to the guidelines set forth above, a meaningful cost analysis can aid in deciding whether VPC or catalytic/thermal oxidation treatment of off-gas is appropriate for petroleum impacted sites. In conclusion, by completing a thorough evaluation of capital, installation, energy and operational costs, combined with an accurate prediction of project mass loading, a successful and efficient off-gas treatment program can be selected and achieved.
Innovative Abatement and Remediation of Perchlorate At McGregor, Texas Weapons Plant Site

By Dan Cowan

Innovative perchlorate abatement and remediation efforts by the U.S. Navy and its environmental contractor, Ensafe, Inc., Memphis, Tenn., have shown exceptional results at the McGregor, Texas Naval Weapons Industrial Reserve Plant. Details are being reported jointly this spring at conferences sponsored by the National Defense Industrial Association, the Air and Waste Management Association, and the Battelle Institute.

In particular, an innovative, in-situ, biological "permeable reactive barrier" has shown capability for abatement of perchlorate in groundwater migrating off-site, from 27,000 µg/L to below detection limits, thus eliminating the need for a previously planned ex-situ system. It has also proved effective for biodegrading trichloroethene(TCE) that is present as a co-contaminant among other low-level chlorinated hydrocarbons. In addition, ex-situ bench- and pilot-scale studies evaluating a biodegradation remediation method showed reduction of perchlorate concentrations in collected water from 23,000 µg/L to below detection limits, while a bench-scale study of excavated soil showed concentration reduced from 580,000 µg/kg to below detection limits.

The project represented a significant advance in the relatively new field of perchlorate remediation. It is believed to represent the first successful in-situ bioremediation of perchlorate. It also demonstrated substantially simplified ex-situ bioremediation.

Perchlorate

Perchlorate contamination of groundwater and soil at the site, as well as surface water via exfiltration primarily during rainy periods, resulted from the use of ammonium perchlorate as an oxidizing agent and thrust-booster for solid rocket fuel that was manufactured, used, stored, and disposed of at the now inactive plant. Large volumes of the chemical were also disposed of at other U.S. plant sites where solid fuel rocket motors were manufactured and tested.

Perchlorate salts have also been widely used elsewhere in the manufacture of munitions, matches, air bag inflators, fertilizers, photocatalysts, and pharmaceuticals. Perchlorate, an inorganic ionic breakdown product, is highly soluble and extremely mobile in surface water and groundwater, and can persist for decades under oxygenated or aerobic conditions. However, it is biodegradable under anaerobic conditions.

The EPA has investigated inhibitory effects of perchlorate on human thyroid hormone function, and

Dan Cowan, is a remediation engineer with Ensafe, Inc., Memphis, Tenn.

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further health risk assessments have been conducted by the National Center for Environmental Assessment (NCEA). Perchlorate is now undergoing intensive study by an Interagency Perchlorate Steering Committee (IPSC). Thyroid hormone deficiencies can affect normal metabolism, growth, and development.

**McGregor Site Background**

Perchlorate abatement and remediation efforts at the McGregor site originated in 1998 when the Texas Natural Resource Conservation Commission added perchlorate to its already established RCRA Facility Investigation. On-site and off-site surface water sampling began when the nearby city of Waco detected perchlorate in surface water upstream of the city’s drinking water reservoir. No perchlorate was detected in private well sampling. Perchlorate concentrations of 5600 µg/L were detected in tributary surface water at a site boundary, with detection in groundwater wells in that area ranging from <4.0 µg/L to 91,000 µg/L. It was also measured at 22,000 µg/L in a wet weather spring connected to the boundary tributary. About one mile downstream from the tributary’s junction with a creek, concentration was 200 µg/L, and three miles downstream, near the confluence of the creek with a river, perchlorate was detected at 56 µg/L. Detection in soil underneath the foundations of former propellant mixing facilities ranged from 23 to 1,800,000 µg/kg.

The Texas Natural Resource Conservation Commission has adopted 22 µg/L as its provisional action level for perchlorate in drinking water, and 270 µg/kg for soil. Its action level for groundwater under an industrial site is 66 µg/L, while under residential sites the 22 µg/L drinking water standard applies. In June, 1999, Interim Stabilization Measures originally proposed at the McGregor site included installation of groundwater interception trenches; pumping and treatment of collected groundwater; discharge of treated water to site surface water; and excavation and management of contaminated soil.

**In-Situ Abatement Of Off-Site Migration**

Abatement of off-site migration has been addressed with an innovative, prototype biological “permeable reactive barrier” system. It consists of trenches that have been excavated and backfilled with highly permeable reactive material. This included gravel, as well as carbon sources from organic materials such as compost, vegetable oil and cottonseed, that were needed to induce anaerobic conditions required for perchlorate biodegradation.

Early success of bench-scale reactors provided the opportunity for low-cost modifications to the trench design that allowed for pilot-scale in-situ testing without interfering with interception and collection of groundwater. The success of the in-situ pilot test provided for a cost effective option in the remedial strategy, which includes an alternative ex-situ system. Analytical results from this in-situ pilot system, and the concurrent bench-scale study featuring extensive evaluation of alternative organic materials, have indicated capability for biodegrading perchlorate from 27,000 µg/L and higher to below laboratory detection limits (4 µg/L). In addition, initial results indicate that trichloroethene (TCE), a site co-contaminant, can be biodegraded to below detection levels concurrently with perchlorate in the specially designed trenches.

**Ex-Situ Remediation Of Groundwater And Soil**

Consideration of available and commercially developed remedial technologies for treatment of collected perchlorate-contaminated groundwater included ion exchange as well as biological techniques. However, ion exchange treatment was deemed cost-prohibitive for intermediate-to-high concentrations of perchlorate, or in the presence of substantial concentrations of other ions such as nitrates or sulfates. In addition, it was regarded as generating process waste that required additional management.

Accordingly, technology selection research for water at the McGregor site focused on biological treatment systems, including consideration of successful installations in California, Nevada, and Utah. For soil treatment, both in situ landfarming and ex-situ prepared beds (treatment cells) were considered.

A 5 ft. diameter, 18 ft. tall, 2600-gal. carbon steel pilot-scale bioreactor for water treatment was designed based on the results of a bench-scale study. At an influent flow rate of 45 gpm, perchlorate concentrations were reduced from 23,000 µg/L to below detection limits, which translates to a removal capacity of about 12 lbs. of perchlorate/day.

In the first bench-scale study for soil remediation, perchlorate concentrations were reduced from 580,000 µg/kg to below detection limits (600-1700 µg/kg) after 28 days. Results also indicated that both fructose and citric acid were effective as carbon sources to induce anaerobic conditions necessary for the functioning of perchlorate-reducing microorganisms. They also showed indigenous microorganisms to be as effective as treatment with microbial enhancements.

A second bench-scale soil study was conducted to calculate the rate constant for perchlorate biodegradation.

The soil remediation studies concluded that given carbon and nutrient augmentation of the soil to create an anaerobic environment, perchlorate contamination could be treated to the required cleanup levels. Pilot-scale evaluation has begun with a sample of 1500 cubic yards. Based on specific site conditions, in situ soil treatment is considered preferable to treatment in an engineered system, by yielding significant cost savings and reducing the need for handling contaminated material.
Oil companies are facing tightened regulatory and economical constraints that restrict the disposal of oily wastes from drilling projects. In the U.S., Gulf Coast operators operate under zero discharge regulations in inland waters, and an EPA proposal would eliminate all non-water based mud discharges, including synthetic-based fluids, from all coastal and offshore waters. Worldwide, the trend is similar.

North Sea regulations are especially stringent. Since 1996, operators in this area have been required to reduce oil on cuttings (OOC) discharged to the sea by 20% per year, and by January 2001, they must reduce OOC to less than 1% by weight.

This requirement has forced operators to consider alternative drilling fluids and treatment/disposal methods. Water-based mud (WBM) is one option, but it may not allow proper borehole integrity on directional wells or on some difficult straight holes. Synthetic-based fluids provide good wellbore stability, but are extremely costly and oil recovery is a factor.

**Treatement and Disposal Methods**

Common treatment and disposal methods for oil based drill cuttings include cuttings injection, bioremediation, encapsulation, and land-farming. Each of these methods has inherent advantages and disadvantages.

Injection involves slurrying the cuttings and pumping them into a “safe” formation. While injection often appears to be the most-cost effective solution, it may not be feasible because of well location, formation constraints, or local regulations. Also, there is the risk of future contamination of the surface or water source if the injection process is poorly designed or executed.

Bioremediation involves dilution of the contaminated cuttings with some amount of clean soil; spreading and mixing the cuttings to introduce oxygen, nitrogen, and phosphorus nutrients into the material; and controlling moisture levels to promote the growth of bacteria. This action bio-chemically breaks down hydrocarbons over time. Bioremediation requires large land treatment cells and long periods of time, often up to a year or longer.

Landfarming is similar to bioremediation, but it involves mixing large amounts of clean soil with the contaminated cuttings until the composite mix has a Total Petroleum Hydrocarbon (TPH) level below local regulatory requirements. As with bioremediation, landfarming requires large areas of land and time.

Encapsulation, or fixation, involves a chemical bonding of the oil in the form into a “shell”, or matrix, around the cuttings particle, with subsequent burial or land-farming disposal. Common encapsulation materials are cement dust (lime) and liquid sodium silicate. When properly done, encapsulation forms a stable matrix with little risk of oil escape.

However, the procedure is dependent on complete blending of the cuttings and stabilizing agent and is susceptible to poor mixing, weak matrix formation, and eventual leaching of the oil. In this sense, oil is introduced to the environment in a “time-capsule”, and most likely, will eventually leach out. For this reason, encapsulation is sometimes considered to be an extended form of bioremediation.

**Thermal Desorption**

A relatively new method to treat drilled cuttings is thermal desorption. This method substantially reduces exposure to liability for future contamination of the environment, the time, and eliminates the need for large waste treatment cells associated with other methods. Thermal desorption involves heating the cuttings in an oven-like device until the oil and water vaporize. The gaseous oil and water are then processed in an oxidizer that destroys the contaminants.

Alternatively, the contaminants can be condensed and recycled for other uses such as fuel or as a component of drilling muds. In theory, this approach sounds solid, but companies have tried unsuccessfully for many years to adapt older thermal technology - such as cement or lime kilns, and thermal (hot oil) screws - to process oilfield wastes.

Typical “direct fired” systems (somewhat similar to an asphalt plant), where the flame actually comes in contact with the material being processed, can only handle soils with up to about 1.5% by weight oil contamination. Hot oil screws cannot achieve the

*Brad Wood is Latin America operations manager with Brandt, Houston, Texas. Juan Carlos Rojas P.E. is fluids environmental team leader, BP/AMOCO, Bogota, Colombia.*

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temperatures required to vaporize the hydrocarbon chains found in these oil based mud cuttings, and typically there is inherent plugging and maintenance problems associated with rotating equipment in hot abrasive material. Most of these systems are also limited to around two tons per hour maximum.

Rotating augers within an indirect fired drum have been found to be limited due to solids caking between the auger and drum surface, forming a layer of insulation, and again high maintenance. Indirect fired rotating drum (batch or continual feed) type systems typically cannot handle the high liquid contents in drilled cuttings, are made from carbon steel or alloys which cannot reach the temperatures required for complete vaporization (processed material leaves with high TPH). Water discharged from these systems must be sent to an auxiliary water treatment system, and if oil is recovered, it has typically in the range of 5-10% solids contents.

Non-rotary batch type systems provide good temperature control, but are limited due to continual caking of solids, excessive handling of material (feed and discharge), time to process small quantities, warm-up and cool down time. Without the proper safety controls in place, all of these systems have the potential for rapid uncontrolled expansion of hot gases, and thermal excursions.

Since these oilfield waste streams are variable and more difficult to process than the wastes for which the units were originally designed, throughput has been limited and the results have been less than satisfactory. The machines used in other industries are not normally designed to handle the high oil content, sticky clays, or abrasive materials found in oil based drilled cuttings. Likewise, the materials used in the construction of these systems do not always withstand the high temperatures necessary to process longer chain hydrocarbons that may be found in diesel based mud cuttings or crude oil.

A new "second-generation thermal desorption process" is currently operating in Colombia, South America for a major multi-national oil company. This system was designed and developed specifically to process oil-based drilled cuttings and provides several advantages over earlier designs. Most important, it has proved successful in allowing the operator to comply with strict environmental regulations and recover valuable diesel oil that would normally be lost with the cuttings. This recovered diesel is used to fuel the thermal desorption process and is also returned to the drilling rigs as base oil for new drilling mud.

The operator has estimated that savings in Colombia of approximately $2,000,000(US) per well are achievable with this new thermal desorption technology because of:

- Better wellbore stability inherent with OBM (compared to water based mud)
- Lower drilling time required per well

### Diesel OBM Drilled Cuttings Test Results

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<td>Feed Rate</td>
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<tr>
<td>Feed Solids (Water Content)</td>
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<tr>
<td>Recovered Oil - Water Content</td>
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<td>(Vol) to 0.02%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Non detectable</td>
</tr>
</tbody>
</table>

![Figure 1.](image1)

- Process cost savings compared to other disposal alternatives
- Use of recovered diesel as fuel and base fluid for drilling mud

### Recent Results

The thermal desorption unit (TDU) in Colombia is currently processing 7,600 to 8,000 metric tons per month of diesel-based mud cuttings contaminated with 25-30% oil and 20-25% water (by volume), without using dilution prior to treatment. A water treatment system is not necessary, as the water produced during the process (from the drill cuttings),
Figure 3. The thermal desorption unit.

is utilized in the desorption process for cooling, rehydration of discharge dirt, and dust elimination, thus avoiding any water discharge to the environment. The end product processed material is typically below 10 ppm TPH, and independent lab testing has shown that the system can achieve TPH levels of <5 ppm if required - dependant on heating and retention time within the system. The processed material in Colombia is typically back-filled on site, but can also be used for road base, or cover for a sanitary landfill. Bricks made with the processed drilled cuttings have shown very

Continues on page 30 ➞
high tensile strength, and have been deemed suitable for construction projects.

The solids content of the recovered oil is between non-detectable and 0.02% by volume (Figure 1). Compared to other recovered oils, this is very favorable.

Gas Chromatograph tests have shown no significant degradation of the base oil during the thermal treatment. Therefore, it is considered safe and suitable for new mud makeup (Figure 2). The fuel required for the burners that heat the thermal process has been recovered from cuttings, with the excess oil produced being returned to the operator.

Testing is currently underway to check the suitability of the long-term use of recovered oil for fuel in diesel engines, and preliminary tests at the project site are promising. The thermal unit operators have already successfully run a diesel driven pump with the recovered oil with no apparent damage to the engine or plugging of fuel filters.

How It Works

The TDU (Figure 3) removes most all of the hydrocarbon contaminants from the cuttings, including fuel oils to heavy oils. The system has been uniquely designed and specifically customized for both short and long chain hydrocarbons that may be present in drilled cuttings by using a multiple shell dryer made of a stainless steel alloy for higher soil discharge temperatures. The equipment can process a wide range of soil sizes from clay to 4" rock.

Before processing, the contaminated cuttings are weighed, then placed into a holding hopper equipped with a variable speed auger-feeder that meters the material fed into the rotary dryer at a rate up to 25 metric tons (wet) per hour (typical average in Colombia is 15-20 tons per hour). The dryer unit is designed to dry and heat the contaminated cuttings indirectly so that burner combustion gases do not come in contact with the cuttings or the hydrocarbon/water gas stream.

The externally heated rotary dryer is sealed on either end to limit oxygen entering the system, and vapor exiting the system. The dryer shell heats the cuttings to between 600 and 900°F Fahrenheit by conductive heat transfer. A special cleaning system in the dryer shell eliminates caking of solids and keeps the material agitated to allow for even heat transfer.

In order to guarantee vaporization of the water and hydrocarbons from the cuttings within the dryer, the cuttings stream must be thoroughly heated to the minimum temperatures required for complete vaporization of all liquid constituents. These temperatures are continuously monitored, regulated, and recorded within the UL-approved control room. Retention time within the dryer varies between 15-30 minutes depending on specific clean-up levels required.

Processed inert soil leaving the dryer is mixed with recovered water for dust control, cooling, and added moisture. After the water and hydrocarbons are suspended in the gas air stream, the gas is passed through a specially designed, high temperature, fabric filter baghouse at 8,000 to 12,000 ACFM, for ultra-fine particulate removal. This particulate is then combined with the discharged processed cuttings by means of a screw conveyor.

The cleaned gases are subsequently condensed by means of a fin-tube condenser and cooling tower. The recovered liquid is then passed through an oil/water separator and coalescer, and the water is passed through an Ultra-Filtration Membrane system to ensure minimum oil content.

The recovered water is used for rehydration of the processed cuttings, and for make-up water in the cooling tower. The recovered oil is returned to the client for future use, or it can be used in the 40 MM BTU primary burners to heat the process. Processed inert solids discharged from the system can be utilized as road base, fill dirt, or used in brick or construction projects.

Air emissions from the system meet or are well below the standards set by EPA 1990 Clean Air Act for Particulate Matter, SOx, NOx, and VOC's. In fact, the EPA is designating this type of system as Best Demonstrated Available Technology (BDAT) for cleanup of hydrocarbon contaminated soils. For each ton of cuttings processed in Colombia, the system recovers approximately 0.6 barrels of diesel fuel valued locally at $42 Bbl. At an average 260 tons per day process rate, this equals $6,552.00 per day savings to the operator. Using a value of $350 Bbl for a synthetic base fluid or mineral oil, the savings would extrapolate to around $54,600.00 per day.

Operating costs for thermal desorption vary greatly depending on the amount of cuttings available and logistics of the operation. Figure 4 shows a cost comparison between competing technologies within Latin America. Thermal desorption net cost to the operator is shown using $42 Bbl for diesel recovered, based on 8,000 metric tons per month. Cuttings injection is not shown, as actual cost information is limited. Injection is not allowed or used in most areas of Latin America. Likewise, landfilling is not generally performed in this region.

As shown in Figure 5, the continuous process TDU is designed to operate 24 hrs per day with scheduled maintenance one day per month. The footprint of this particular installation is approximately 100'x100'. Units are also sized for single drilling rig or multi-rig operations, in mobile or permanent configurations. In Colombia, the TDU system has solved a particularly stubborn problem. It provides an alternative whereby operators can comply with environmental regulations and maximize recycling and waste reduction, cost-effectively.
Utilizing a Watershed Approach

By Bill Kucharski and Susan Sylvester

One of the great opportunities available to me as the editor of this column is the number of good programs and approaches that I am able to get acquainted to through this endeavor. Following is an article that I have drawn from the Spring 2000 issue of ECOSTATES, published by The Environmental Council of the States. The issue of utilizing a Watershed approach first became important to me as the Secretary of the Louisiana DEQ. Since more than half of the US drains into the Mississippi, and THE RIVER ends in Louisiana, everything upstream can impact the state and the Gulf of Mexico. This article, like many of the ECOS issues, focuses on an individual state. However, the approach could be applied to the major watersheds instead of the state by state focus.

My special thanks to Robbie Roberts and the author of this article, Susan Sylvester with the Wisconsin Department of Natural Resources for allowing us to share this article.

by Susan Sylvester

"There are two ways to apply conservation to land. One is to superimpose some particular practice upon the pre-existing system of land use, without regard to how it fits or what it does to, or for, other interests involved. The other is to reorganize and gear up the farming, forestry, game cropping, erosion control, scenery, or whatever values may be involved so that they collectively comprise a harmonious balanced system of land use." -Aldo Leopold, Coon Valley: An Adventure in Cooperative Conservation, 1935

The Clean Water Action Plan (CWAP) charts a course towards reaching the original goals of the more than 25-year-old Clean Water Act "fishable and swimmable" waters for all Americans. Growing out of the first Earth Day, the Clean Water Act spawned tremendous efforts and achieved substantial progress towards cleaning up our nation's waterways. Substantial further progress cannot be made, however, using the program-by-program approach of the last 25 years. The CWAP-spearheaded by the EPA and Department of Agriculture with the participation of other agencies and the States recognizes that the nation is at a crossroads and that we need to reorganize and redirect our efforts around a watershed approach as the path of further progress.

The concept of a watershed approach is not new. Aldo Leopold found in the fledgling Soil Erosion Service of the 1930's a champion of the complex, difficult task of reorganizing land use. In its first erosion control project, the agency offered farmers in Wisconsin's Coon Valley the technical know-how, labor and supplies to help stabilize their watershed and the farming community it supported, and to return to health the trout streams that once ran clear, deep and full through their coulee country.

According to Leopold, who advised the project, nearly half of the watershed's farmers accepted the offer. The 315 farmers and their government partners removed all cows and crops from the steep, eroding hillsides and used them instead for timber and wildlife. They intensively cultivated the flatlands, terraced or strip cropped sloping fields, and introduced contour farming and crop rotations. They repaired eroding gullies and the stream banks.

Today, states must find the courage and will to "reorganize" land management as the CWAP envisions, and as the Soil Erosion Service did successfully more than 60 years ago. Federal agencies must be willing to make the necessary changes to turn CWAP's vision into reality. If they don't, the country will continue down a path that cannot fully safeguard human health, restore to health the 40% of our nation's waterways still unsafe for fishing and swimming and protect watersheds vulnerable to future problems.

"People love their lake, stream or bay, but they don't love their permit." Jim Baumann, the Wisconsin Department of Natural Resources' DNR's water policy analyst, displays this saying in his office to remind him that the resource's needs, not the programs', must drive water pollution control efforts in the 21st century. For the last 25 years, states have planned their year's work in terms of permits to issue, grants to get

Bill Kucharski is the former Secretary of the Louisiana Department of Environmental Quality, and is now located in Bronxville, N.Y. Susan Sylvester is administrator of the Water Division of the Wisconsin Department of Natural Resources and serves as vice chair of the ECOS Water Committee.

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out and facilities to inspect. These are worthwhile things to do, but by themselves they can't take us to the next step.

States should concede to a watershed-based approach because it focuses stakeholders on what a particular lake, river, wetland or aquifer needs and what they can do collectively to meet that need.

This focus helps better integrate and coordinate the myriad of state, federal and local programs and efforts by groups and citizens. It helps leverage financial and other resources to stretch protection and restoration efforts farther. It decreases duplication, and it allows projects to draw on the different strengths, authorities and ideas that different governmental units and partners possess.

States should also consider pursuing a watershed approach because it provides ownership to those people most affected by the resource-and most responsible for its condition. Such ownership of problems and solutions will ultimately determine success in protecting or restoring the watershed, as researchers are documenting in Wisconsin and elsewhere.

For instance, University of Wisconsin researcher Jim Cavaye found that when he studied four DNR Interactions with communities, "the community oriented approach increased local accountability, improved internal and external coordination and increased the importance of DNR’s expertise," he reported in his 1997 dissertation thesis. "In a paradox for traditional public administrators, community orientation allowed the DNR to fulfill its delegated responsibility, and may have enhanced it."

The watershed approach helps stakeholders understand the benefits their community receives from their water resources, how they affect these resources and how changing their habitats or practices can help. That’s particularly valuable because the collective impact of individuals’ actions contribute significantly to polluted runoff, degraded shorelines and other problems, and because individuals own 70% of American land, excluding Alaska, with the proportion much higher in Wisconsin and many other states.

Understanding such connections is increasingly important for the fate of natural resources as many Americans become increasingly removed from the land in their vocations, avocations and where they live. A watershed approach helps involve citizens in their resources so that the resources are no longer an abstraction but something they can see, feel, touch and love, to paraphrase Aldo Leopold.

The CWAP articulates better than any other document in a long time why America needs to take a watershed approach, and broadly, what that will look like. For the first time, multiple federal agencies have committed to that same common vision instead of operating independently. And the plan speaks of pursuing efforts to assure the health of the American people and the environment. But federal agencies need to fine-tune how they put CWAP into practice. Specifically:

• States must take the lead role. They have the authority to address challenges that cut across federal agencies and are more connected to local landscapes. Federal agencies must remove or reduce hurdles created by the multitude of new programmatic requirements and create the flexibility to integrate these programs into a watershed approach. With each new program claiming to be a high priority and containing its own implementation schedules, the flexibility is missing to set priorities based on water quality needs. EPA, other federal agencies and states need to creatively think about how programs can best fit into a watershed. The Storm Water Phase 2 regulations, for example, have great Potential to be integrated into a watershed approach.

• Protection needs to receive equal billing with restoration. One in 14 of the nation’s watersheds is vulnerable to future problems, according to the CWAP. States realize that an ounce of prevention is worth a pound of cure, not only in financial but functional terms. Research is increasingly suggesting, for instance, that mitigated wetlands lack the range of beneficial uses and diversity a natural wetland supports. EPA has taken an important step by recently providing funding for Source Water Assessment Plans to protect drinking water supplies, but that is only a first step, and a baby step at that.

• States must have flexibility and at the same time be held accountable for carrying out CWAP’s goals. In Wisconsin, efforts by a single farmer to keep his cows out of a stream is improving water quality to the degree that the DNR is likely to be able to remove that stream from the 303(d) list of impaired waters without having to create a Total Daily Maximum Load (TMDL) for it. This should be encouraged. Forestry Best Management Practices that Wisconsin and other states have advocated have taken hold and are achieving the erosion reductions called for under EPA’s TMDL requirements. Such good-faith, fruitful efforts also should be encouraged.

• Efforts must build on the past 25 years’ progress, not start from scratch, and they must be inclusive. States and other partners must be included in federal planning to implement watershed management on federal properties. Rivers, lakes and aquifers on these lands run through, and are affected by, activities on state and privately-owned lands. Accordingly, States and others must be active participants in the discussions.

The CWAP holds great promise, but that promise will remain unfulfilled if states do not take up Leopold’s challenge to reorganize land management and if the federal government does not support and complement these efforts.
Density-Driven Convection Wells Used at North Carolina MTBE Site

By Les Pennington

As the furor over MTBE (methyl tertiary-butyl ether) contamination continues to grow, the deepest concerns among many U.S. citizens and legislative groups are focused on the widespread presence of the controversial fuel additive in the nation's water table. In addition to general concerns about public health, homeowners in MTBE plume areas are worried about property values and environmentalists are intensely troubled by prospective damage to wildlife. Cleaning up this mess, without costing an arm and a leg, is the highest priority of many state, federal and private interests.

Used as an octane enhancer in gasoline since the 1970s to promote more complete burning (thereby reducing carbon monoxide and ozone emissions), MTBE has leaked from fuel storage tanks and migrated into soil and water throughout the country. And whether or not MTBE is a carcinogen or otherwise a serious health hazard, the consequences of our misadventure with it are widespread and promise to be a very costly.

A recent “60 Minutes” report states that 49 states have now detected MTBE in groundwater at some levels. The environmental sanctuary of Lake Tahoe has been tainted, with 12 of 34 wells in the city of South Lake Tahoe shut down due to MTBE contamination.

In Maine, a statewide survey found that as many as 5,200 domestic wells contain MTBE levels above the state's drinking water standard of 35 ppb. Three percent of shallow urban wells tested in a U.S. Geological Survey exceeded the EPA draft health advisory level (20 μg/L).

State regulatory bodies are increasingly mandating that MTBE contamination be cleaned up. The big questions are how soon and at what cost? Although many cleanup estimates run into the billions of dollars over many years, the real answer depends on what methods are used.

One of the most promising remediation methods - not only from MTBE contamination, but also "traditional" toxic gasoline constituents such as benzene and toluene - is a recently developed sparging technology known as Density-Driven Convection.

In August, 1994 the Wilmington Office of the North Carolina Division of Waste Management (NCDWM) Underground Storage Tank (UST) Section tested samples collected at UST excavations from the site of a former Fast Fare service station where several gasoline tanks had been removed. Due to the presence of MTBE and other contaminants, Coastal Environmental Services Company (CESC) of Wilmington was contracted to install six shallow groundwater wells to monitor the contaminants at the site. A potable water well on an adjacent residential property was also tested for contaminants.

Although no dissolved petroleum hydrocarbons were detected in the potable water well, dissolved contaminant plumes were present at the former service station property, and the plumes were migrating. The plume migration was relatively slow, but the amount of MTBE and other contaminants warranted that the site be cleaned up.

In 1997 CESC contacted Wasatch Environmental, Salt Lake City, Utah, about their proprietary aeration technology called Density-Driven Convection (DDC). A remediation system consisting of 10 DDC wells and two soil vapor extraction components was installed. There was a very substantial drop in the petroleum contaminant levels, including MTBE and benzene, within a month of the system going into operation.

After 30 months of operation, average total BTEX was reduced from 7.15 mg/L to 0.78 mg/L (an 89% reduction). MTBE was reduced from 0.70 mg/L to 0.002 mg/L (nearly 100% reduction).

Generally known as groundwater recirculation (GWR) systems, DDC wells are constructed with a lower screen near the bottom of the contaminated aquifer and an upper screen near the water table surface. The installer connects an air injection tube to an air compressor at ground level, and drops the nozzle down to the bottom of the well casing.

As air is injected into groundwater at the bottom of the casing, it forms bubbles that flow upwards, aerating the groundwater and producing a vertical gradient within the casing. This draws water in through the lower perforations and pushes it out the upper ones.

Volatile water-borne contaminants are stripped from the groundwater within the wellbore. Aerated compounds emitted from wells in the form of gases may be released to the atmosphere or collected at the wellhead for treatment. Groundwater remediation is achieved by airtipping with the DDC well and by circulating dissolved oxygen, which stimulates microbial growth.

Well systems using the DDC technology are simple to install and require very little maintenance. Systems can be incorporated into a complete grid of wells for aggressive treatment of an entire plume area. Or, a line of wells may be installed across a plume to act as a barrier to plume migration by removing contaminants as they pass.

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Leslie H. Pennington is founder and principal engineer with Wasatch Environmental, Salt Lake City, Utah.
The Southern Maryland Wood Treating Superfund Site, located in Hollywood, MD, plans to hold a sealed bid auction of surplus government equipment. The sale will be open to the public. United States Army Corps of Engineers anticipates equipment available for bid will consist of the following:

- Two- (2) (to be sold individually) indirect fire thermal desorption units and major treatment components, used for treatment of contaminated soils. (Major Components such as: scrubber, hot cyclone, wet electrostatic precipitator, flameless thermal oxidizer, and associated soil handling components.) Spare parts for thermal desorption units and associated equipment such as motors, bearings, pumps, etc. will also be made available for bid. Finally, water treatment equipment used for the processing will be available for bid. Some of the water treatment equipment consists of the following: sand filter, small filter press, clarifier/lamella, carbon vessels, Ultraviolet — oxidation system, etc.

There is a reserve placed on the two above listed thermal desorption units, therefore the government may opt to refuse all bids for these two units if an equitable bid has not been submitted.

A bid package, containing technical information, flow diagrams, listings of equipment, and bid instructions is available upon request. The bid package can be obtained by calling the U.S. Army Corps of Engineers, at Hollywood, MD at (301) 373-5954. Please ask for Bob Messie and have your mailing address available (no PO boxes). Requests for bid packages can be via fax: (301) 373-5965 or e-mail Robert.Messie@nab02.usace.army.mil. Whether requesting via fax or e-mail, a mailing address must be provided (no PO boxes). The bid package will be mailed to prospective bidders and will define a time for inspecting the equipment while it is still in operation including dates for bids. Bidders should tentatively anticipate inspecting the equipment on 15 June, 2000, between 2pm and 3pm, and a bid deadline of early July, 2000.

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ASTM Committee D18 on Soil and Rock. Sheraton Hotel, Toronto, Canada. Call Bob Morgan, 610-832-9732.

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West Coast Energy Management Congress. San Jose Convention Center, San Jose, Calif. Information, call 770-279-4390.

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Environmental Site Assessments from A to Z. ABS Group, Crowne Plaza Resort, Hilton Head, N.C. Call 301-921-2345.

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ISO 9000 Executive Briefing. ABS Group, Regal Knickerbocker Hotel, Chicago, Ill. Call 301-921-2345.

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Writing Effective Operating Procedures. ABS Group, GI Training Center, Rockville, Md. Call 301-921-2362.

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ISO 9000 Year 2000 Revision and Implementation. ABS Group, Regal Knickerbocker Hotel, Chicago, Ill. Call 301-921-2345.

July 5-7, 2000
Jacketed Tubing

Clean Environmental Equipment, Oakland, Calif., has introduced Jacketed Tubing as a unique bundle of tubes, encased in a strong, resilient plastic sheath. Jacketed Tubing provides the largest ID combinations of tubing on the market, in coil lengths up to 500’. Write in 604

Railroad Spill Containment

UltraTech Intl., Jacksonville, Fla., offers Ultra-TrackPans to provide spill containment at industrial rail sidings and locomotive maintenance facilities. The modular TrackPans will collect incidental or catastrophic spills. Write in 601

Oxygen Consumption of Bacterial Cultures

N-CON Systems, Crawford, Ga., offers the AV4R Respirometer to measure and record oxygen consumption of solid or liquid bacterial cultures. A computer senses, controls and records oxygen delivery. Write in 602

Clean Sample Containers

Environmental Sampling Supply, Oakland, Calif., offers clean sample containers for EPA soil method 5035. Tare weighted 40 mL glass vials are available with Sodium Bisulfate or Methanol preservative. Teflon® coated disposable stir bars are also included. Write in 603

MTBE Remediation

Surface Technology, Riverside, Calif., has developed CLEANWATER for the remediation of MTBE from water. Tests show that one gallon of CLEANWATER will treat 25,000 gallons of water. Write in 609

MTBE Destruction

NEEP Systems, West Lebanon, N.H., has introduced technology that adsorbs and destroys MTBE. The system called ADDOX™ achieves 99% destruction at a cost near 5% of GAC. Write in 600

Mini Bladder Pump

Durham Geo-Enterprises, Stone Mountain, Ga., offers the MBP Mini Bladder Pump as an economical system purging and low flow sampling. The pump offers and excellent solution to collection in micro wells installed using direct push or conventional monitoring. Write in 605

Chemical Oxygen Demand Reagent Vials

Chemetrics, Calverton, Va., has introduced an economical new line of reagent vials for the lab currently using the micro-COD reactor digestive method. Write in 606

Backreamer for Soft Soil

Ditch Witch, Perry, Okla., offers the new MX Mixer. A combination backreamer that mixes cownhole fluid slurry while enlarging pilot holes made with horizontal directional drilling equipment. Write in 607

Wide Belt Oil Skimmer

Wayne Products, Malvern, Penn., has announced the Model MSX belt oil skimmer for use in wastewater pits, water treatment equipment and coolant tanks. Write in 608
Terrain Mapping System
Vermeer Mfg., Pela, Iowa, has introduced the Terrain Mapping System. This is a laser topography program designed for planning horizontal directional drilling jobs.

Low Profile Air Stripper
Carbonair, Minneapolis, Minn., has announced the STAT 720 low profile air stripper. The STAT 720 is capable of treating up to 1,000 gallons per minute. The device can achieve a removal efficiency of up to 99.99% from a long list of volatile organic compounds, including MTBE.

Small Area Oil Skimmer
Turnkey Solutions, Mahwah, N.J., offers the MopClear oil skimming system for use in any small area where oil accumulates. A polypropylene mop drops from the unit and across the oil contaminated surface.

24 Bag Sampler
Global Water, Gold River, Calif., has introduced a new 24 bag sampler for wastewater and environmental sampling. The device collects up to 24 samples in standard laboratory bags. Samples can be scheduled on a timed or flow proportional basis.

Software Program Extends Power of Turbochrom
Perkin Elmer, Norwalk, Conn., has announced an agreement with Mantra Software, Westborough, Mass., to develop and market a NuGenesis® ARCHIVE™ software application for the Perkin Elmer Turbochrom™ Chromatography Software. Workflow and compliance practices are improved.

World’s Largest Infrared Spectral Collection
Bio-Rad Laboratories, Philadelphia, has announced the launch of HaveltAll™ IR. This subscription based service provides more than 90,000 spectra of pure compounds and over 80,000 commercial spectra on one CD.

New Toxic Sensors Available
GasTech, Newark, Calif., has announced the Genesis Multi-Gas Monitor now has new toxic sensors. The Genesis monitors combustible gases, oxygen and up to two toxic gases.

Data Acquisition
AMS, American Falls, Idaho, has partnered with ENVI, Alingsas, Sweden, as distributor of the cone penetrometer testing equipment known as MemoCone II and GeoPrinter.

Extracting Solvents for Infrared Analysis
Wilks Enterprise, South Norwalk, Conn., offers the Infracal TOG/TPH Analyzer and Solvent Selection Guide. The chart describes potential candidates for Freon replacement.

Oil Leak and Spill Sensors
Ionics Agar Environmental, Watertown, Mass., offers the new Leakwise® Model No. ID-221. The device uses a patented high frequency electromagnetic energy transmitter and antenna to monitor the liquid surface.

Bag Filter With Four Way Opening
Hayward Industrial Products, Elizabeth, N.J., offers the Loeffer Flowline bag filter. The product features a specially designed cover that can be easily oriented in the field to open and close in any of four different directions.

Dual Pressure Recorders for PRVs
Telog Instruments, Victor, N.Y., has announced the DPR-21 dual pressure recorder. The DPR uses two sensors, one installed in the fitting on the input and one installed on the output of the PRV.
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Please FAX to 913-897-4685
DNAPL Consortium Hosts Successful Demonstration Site Tour at Cape Canaveral

By Interagency DNAPL Consortium (DOE, DOD, EPA and NASA)

Nearly 300 technology end users, regulators, lawyers, and other stakeholders attended a tour at Cape Canaveral Air Station in Florida hosted by the Interagency Dense Non-Aqueous Phase Liquids (DNAPL) Consortium in late January, to learn more about the issues associated with side-by-side technology deployment demonstrations designed to effectively clean up DNAPLs.

The Interagency DNAPL Consortium includes the U.S. Department of Energy, U.S. Department of Defense, National Aeronautics and Space Administration, and U.S. Environmental Protection Agency (EPA). For nearly two years, the Consortium’s participants have worked together to tackle this shared environmental problem. Their mission is to accelerate the deployment of DNAPL technologies. This has been achieved at Cape Canaveral by involving regulators up front in the discussion of the demonstration, providing the opportunities to test new sensors designed to support in situ characterization and remediation of contamination problems, and cost-sharing of the demonstration and the comparison of the technologies.

DNAPLs pose serious, long-term groundwater contamination problems due to their toxicity, limited solubility in groundwater, and significant migration potential in soil gas, groundwater, and as separate phase liquids. DNAPL chemicals, particularly chlorinated solvents, are among the most common of environmental contamination problems in the United States as well as for most industrialized countries.

Launch Complex 34 at Cape Canaveral, Fla. was selected as the technology demonstration site after extensive evaluation of some 20 sites. The decision was based on screening criteria and evidence of high concentrations of trichloroethylene in soils and groundwater at the site. The cost and performance data collected from the side-by-side demonstrations will be used to evaluate other applications of the technologies.

Tour attendees also learned about innovative DNAPL characterization tools that have been tested at the site, and about the pre- and post-demonstration performance assessment of the three technologies. Performance assessments are being conducted in accordance with the EPA Superfund Innovative Technology Evaluation (SITE) program. Cost and performance information will be available later this year.

The nature and extent of DNAPL contamination were confirmed by Savannah River Technology Center in December 1998 by source contamination delineation through chemical analysis of collected sediment and groundwater samples and by using several innovative characterization schools including the Ribbon NAPL Sampler. Battelle and EPA, who collected pre-demonstration coring samples, led characterization activities in support of the performance assessment.

Several statistical approaches were evaluated for determining the number and locations of soil cores to be collected from each treatment cell. Based on this evaluation, coring locations were systematically determined and results of the coring were used to determine the total mass of the trichloroethylene present in each test cell. Both pre- and post-demonstration coring results will be used to evaluate the performance of the technologies.

During the tour, site regulators from the Florida Department of Environmental Protection and EPA Region 4 described the issues that were successfully resolved so the demonstration could be approved. Members of the Interstate Technology Regulatory Cooperation DNAPL Team, who are involved in the review of the Consortium’s project, also shared insights on issues regarding deployment of the technologies in other states.

The tour included vendors’ presentations of their technology installations and operating strategies at the demonstration sites at Launch Complex 34. Current Environmental Solutions (CES) reviewed the six-phase soil heating system; IT Corporation explained the chemical oxidation system (two permanganate injections have been completed and a third is planned shortly); and Integrated Water Technologies, Inc. (IWT) reviewed the steam injection system, which is expected to go into operation later this spring after the other two demonstrations are completed.

Chemical Oxidation (IT Corporation)

In Situ oxidation using potassium permanganate is a potentially fast and low cost solution for the destruction of chlorinated ethylenes (trichloroethylene, perchloroethylene, etc.), BTEX (benzene, toluene, ethylbenzene, and xylene), and simple polycyclic
aromatic hydrocarbons. Specifically, potassium permanganate reacts effectively with the double bonds in chlorinated ethylenes such as trichloroethylene, perchloroethylene, dichloroethylene isomers, and vinyl chloride. It is effective for remediation of absorbed phase and dissolved phase contaminants and produces innocuous breakdown products such as carbon dioxide, chloride ions, and manganese dioxide. The permanganate typically is applied as an aqueous solution at concentrations of one to three percent via injections wells.

**Six-Phase Heating**  
(Current Environmental Solutions)

The six-phase soil heating technology removes contaminants from soil and groundwater through thermal treatment by passing an electrical current through the soil matrix. The current generates heat due to electrical resistance within the soil. As the temperature of soil and groundwater in the remediation area increases to the boiling point of water, vaporized contaminants are transported to vapor recovery wells for removal and ex situ treatment.

**Steam Injection**  
(Integrated Water Technologies, Inc.)

Thermal remediation by steam injection and recovery is accomplished using a combination of Dynamic Underground Stripping to recover volatile contaminants for ex situ treatment, and Hydrous Pyrolysis/Oxidation to destroy some of the contaminants in situ. The Dynamic Underground Stripping System uses boilers to generate steam, which is pumped into injection wells that surround the contaminants. The steam front volatilizes and mobilizes the contaminants and pushes them toward a central network of extraction wells where they are vacuumed to the surface. In some cases, direct electrical heating of clays and fine-grained sediments can be used to vaporize water and contaminants not readily available to the steam and force them into steam zones where vacuum extraction removes them. Electrical Resistance Tomography is used as a process control method to measure changes in the electrical resistance of soils in the treatment zone as the temperatures rise. This permits real-time modifications in the amount and location of steam injection to optimize the process.

DOE's Subsurface Contaminants Focus Area plans to distribute quarterly e-mail updates on the side-by-side demonstrations to tour attendees and other interested parties. To receive updates, contact Emily Charoglu, Envirolissues, (206) 269-5041 or by e-mail at echaroglu@enviroissues.com.
We are happy to invite you to exhibit at the 16th Annual International Conference on Contaminated Soils, Sediments and Water at the University of Massachusetts, Amherst. The Contaminated Soils Conference has become a leading national/international conference in this important environmental area. The conference attracted over 800 attendees last year including a wide variety of representation from state and federal agencies; the military; various industries including railroad, petroleum, transportation and utilities; the environmental engineering and consulting community; and academia.

The exhibit area is located in the center of the conference activity to assure maximum contact and exposure with interested conference participants and potential customers. Exhibition space is limited to 38 booths to insure a high ratio of attendees to exhibitors. The rental fee for an 8’ by 10’ exhibit booth space is $995.00. Outdoor areas are available for equipment demonstrations at an additional cost.

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- environmental fate and modeling
- soil chemistry
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- contamination at military installations
- contamination at shipping ports
- chlorinated hydrocarbons, pesticides and heavy metals
- jet fuel contamination
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Using Remote Sensing in Soil and Ground Water Remediation

By B. M. Kariaga and A. R. Conklin, Jr.

How much pollution is spread over how much area? This is the question that often faces remediation teams. One way of answering this question is to walk over the area. If the area is not too big and the location is accessible this may be feasible. However, if the area is large or in a remote area this may not be feasible. In Zimbabwe one might have to drive 5 or 6 hours over deeply eroded and rutted areas to get to a polluted site. In other cases the affected area may be more readily accessed by viewing from overhead.

For this type of situation satellites are valuable. The process of obtaining information about the earth’s surface using satellites is called remote sensing. Remote sensing can provide a great deal of information about the extent of pollution and its effects. The information can be mapped using GIS systems. Sometimes this information can be more accurate than that obtained by on site visual inspection. The reason is that remote sensing can pick up effects on plant life, and water, which may not be readily visible on the ground.

To understand how remote sensing can give detailed information about what is occurring on the ground one needs to understand the multispectral nature of light. In addition one needs to know how each plant, soil or object on the earth’s surface behaves in various spectral bands. That is what bands (a band is a group of wavelengths which are accessed at the same time, for example band 2 is between 520 and 620 nanometers(nm)) are adsorbed and which are reflected along with how much of each band is reflected. The accompanying table shows the range of each band and its application.

When the sun’s radiation strikes the earth’s atmosphere a great deal of its radiation is absorbed. However, certain portions pass through the atmosphere, through so called windows, and strike the earth’s surface i.e. soil, plants, buildings, bodies of water. The windows allow the transmission of light with wavelengths between 0.4 and 3 micrometers (m). These wavelengths are from the blue to the mid infrared region of the spectrum. Depending on the characteristics of the component of the earth’s surface some wavelengths will be adsorbed and some will be reflected back into space. Thus, for each wavelength there is a ratio of amount absorbed to the amount reflected.

Sensors in satellites can be designed to record the wavelengths and the amount of each adsorbed and reflected. The signals are then converted to numbers that correspond to the amount of light reflected in each of the spectral bands. These numbers can be stored in digital format so that they can be processed by computer. If information is stored in an eight bit format the digital

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number 255 represents 100% reflectance and 0 stands for complete absorption.

In addition to spectral differences due to the material that light strikes there are also differences due to the conditions of the material. Thus, wet soil will be distinguishable from dry soil. Dry vegetation from healthy vegetation. The reflectance may be specific enough to allow for the identification of the specific vegetative cover. In the accompanying imagery of the Mhondoro area of Zimbabwe white shows bare dry soil where vegetation has recently been cleared while purple or blue indicates water or wet soil.

To understand and interpret satellite imagery properly one needs to understand color and color-coding. Visible light is composed of three primary colors; blue, green and red. The rest of the colors are derived from these three. For instance the secondary colors yellow, magenta and cyan are formed by mixing the primary colors. Each can be darker or lighter depending on saturation. In our daily lives we see thousands of colors which are basically combinations of the three primary colors each with a varying degree of saturation. Absence of the primary colors results in black or no color. The combination of all three colors with maximum saturation gives white.

Spectral information stored in the computer can be assigned colors and thus represented as a spectral composite. Each individual band can be assigned one of the three primary colors: red, green or blue. When the colors representing each band are combined different colors are produced depending on the colors combined and their saturation. There can also be different combinations of bands which will result in different colors.

A specific example of a combination of bands used to create a color composite image is the so-called False Color Composite (FCC). In FCC red is assigned the near-infrared band, green the red visible band and blue to the green visible band. With this assignment green vegetation will appear reddish, water bluish and bare soil will have shades of brown and gray. When using FCC, if a known body has an unexpected color it can be said to be contaminated. If water has a color of say yellow instead of blue then it is contaminated. Likewise if a known bare soil area is purple soil contamination would be indicated.

There are other bands and other ways of representing the specific band by a specific color. Bands 1, 2 and 3 can be represented in blue, green and red respectively. This is done in SPOT (Système Pour L’Observation de la Terre a French satellite) multispectral imagery. Band 1 is wavelengths of light between 0.45 and .52 nm which is in the blue region of the visible spectrum. These wavelengths are capable of penetrating water and so are used to observe shallow water and sediments. Band 2 is wavelengths between 0.52 and 0.62 nm and is the green region of the visible spectrum. This band is used to capture the reflection from green vegetation. Bands go up to 7 which is between 2.08 and 2.35 nm. This is in the mid-infrared region of the spectrum. Each band is thus used to observe a specific part or component of the earth’s surface (see the table for specifics).

The combination of red, green and blue can also be used for other bands and combinations of bands. For instance they are commonly used for bands 5, 4 and 3 in the Thematic Mapper (a highly advanced sensor incorporating a number of spectral radiometric and geometric design improvements over previous multispectral scanners). Other combinations of bands and colors are possible depending on information needs. Some combinations give color output that resembles 'natural colors': Water is displayed as blue, bare soil as red and vegetation as green. This combination thus, leads to a so-called Pseudo Natural Color Composite. The image shown is in Pseudo Natural Color that is, vegetation is green and water is blue.

Remote Sensing can be useful in the identification and extent of soil and water contamination. It thus can be a useful tool for those who remediate contaminated sites.
Call for Papers
The Association for the Environmental Health of Soils (AEHS) and The Navy present
The 11th Annual West Coast Conference on
Contaminated Soils, Sediments and Water
March 19 - 22, 2001, DoubleTree Hotel, Mission Valley, San Diego, CA

Sessions: The Association for the Environmental Health of Soils is soliciting platform and poster papers for presentation at the 11th Annual Meeting. Papers and Posters are invited for consideration in the following areas:

- Bioavailability
- Chemical Analysis
- Cleanup Standard Setting
- Contamination at Military Installations
- Environmental Forensics
- Environmental Fate and Modeling
- Heavy Metals (arsenic, lead, chromium and mercury)
- Innovative Remedial Technologies
- MTBE/Oxygenates
- Natural Attenuation
- Perchlorates
- Phytoremediation
- Regulatory Programs and Policies
- Risk Communication
- Soil Chemistry
- Sediments
- Site Assessment/Field Sampling
- And case studies on any of the above

Deadline for Submission is July 16, 2000

For consideration of either a paper or poster please submit a one page abstract containing: presentation title, 300 word narrative; and for each author, name, degree, title affiliation, and complete address and telephone number. Please indicate your presentation preference of oral, poster or either. Email submissions are both welcome and encouraged (send to: heather@aehs.com). Email or hard copies must be received by July 16, 2000 for consideration. Faxed copies are not acceptable.

Publication of manuscripts from both platform and poster presentations will be considered for one of the following:

- Soils and Groundwater Cleanup Magazine
- The Journal of Soil & Sediment Contamination
- Environmental Forensics
- The International Journal of Phytoremediation
- Human and Ecological Risk Assessment

Accepted abstracts will be posted on the Conference Website: www.aehs.com

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