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Green Remediation Best Management Practices:
Pump and Treat Technologies

Office of Superfund Remediation and Technology Innovation | Quick Reference Fact Sheet

The U.S. Environmental Protection Agency (EPA) *Principles for Greener Cleanups* outlines the Agency's policy for evaluating and minimizing the environmental "footprint" of activities undertaken when cleaning up a contaminated site.[1] Use of the best management practices (BMPs) recommended in EPA's series of green remediation fact sheets can help project managers and other stakeholders apply the principles on a routine basis, while maintaining the cleanup objectives, ensuring protectiveness of a remedy, and improving its environmental outcome.[2]

Overview

Pump and treat (P&T) technology typically is selected in a cleanup remedy to hydraulically contain contamination and/or restore an aquifer to beneficial use. Opportunities to reduce the energy and environmental footprint of a P&T remedy, which are available during site characterization and the remedy selection, design, construction, and operation phases, rely on effective planning and continual re-evaluation of P&T operations. Options for reducing the footprint vary based on the site conditions and cleanup objectives as well as the configuration and components of a planned or existing P&T system. Effective footprint reduction activities will complement the cleanup objectives while aligning with related guidelines such as *Executive Order 13514: Federal Leadership in Environmental, Energy, and Economic Performance*.[3]

P&T remedies often operate for long periods, in some cases decades, due to the nature of the technology and the nature of contaminant transport in the subsurface. As a result, operation of a P&T system, compared to system construction, can contribute significantly to the energy and environmental footprint of a P&T remedy. The best opportunities typically relate to optimizing efficiency of long-term operations, particularly in terms of energy and other natural resource consumption.

Continuous motor operation under load (for pumps, blowers, and other machinery) during a 30-year period of operation uses over 240,000 kWh of electrical energy per motor horsepower or over 2.7 billion BTUs of energy per motor horsepower (hp). This amount of energy is equivalent to the electricity used by more than 22 homes over one year.

Illustration of a P&T system with a fairly complex treatment process indicates how a system relates to each of the five core elements of green remediation. Components in this example can be removed to focus on how a simpler P&T system could affect the environmental footprint during operations.

P&T Component	Examples of Environmental Effects During a Complex P&T Operation
Groundwater Extraction	▪ **Energy** use (and associated **air** emissions) caused by generating electricity from fossil fuels to power extraction pumps ▪ **Materials** use for well construction, maintenance, and rehabilitation ▪ Removal of contaminated **water** and protection of other groundwater ▪ Potential dewatering of wetlands and disrupting wetland **ecosystems** located near extraction wells
Process Equalization	▪ **Energy** use (and **air** emissions) for pumps used to adjust pressures among treatment components
Metals Removal (chemical addition, precipitation, settling, filtration, and solids handling)	▪ **Energy** use (and **air** emissions) for electricity operating mixer motors and filter feed or solids handling pumps ▪ **Materials** use from chemical addition ▪ **Waste** disposal from removed solids, such as metals or biosolids ▪ Infringement on **land** and **ecosystems** from landfill space for waste disposal
Air Stripping	▪ **Energy** use (and **air** emissions) for electricity to operate a blower ▪ **Materials** use for chemical cleaning of a stripping system
Off-Gas Treatment and *Granular Activated Carbon Filtration*	▪ **Energy** (and **air** emissions) for electricity to preheat off-gas prior to vapor treatment ▪ **Materials** and potential **waste** disposal for granular activated carbon
Effluent Tanks	▪ **Energy** use (and **air** emissions) for electricity to pump water across a multi-step treatment process
Discharge to Surface Water	▪ Net withdrawal of local groundwater resources when extracted **water** is discharged to surface water
Building Operations	▪ **Energy** use (and **air** emissions) for electricity to power lights, ventilate a building, and potentially provide heat
Long-Term Operation	▪ Affects on **land** use and the local community and long-term stewardship of **land** and nearby **ecosystems**

Designing a P&T System

Recommended green remediation BMPs for designing a P&T system are intended to: maximize opportunities to address different portions of a contaminant plume in unique ways; modify or reconfigure a system according to changes in a contaminant plume over time; and supplement the system with other remediation or auxiliary technologies to reduce the P&T burden as groundwater cleanup progresses and new products or processes become available. P&T system design planning relies on robust delineation of the contaminant plume and source area. Early planning can also include a renewable energy assessment to determine whether solar, wind, or other resources could meet all or part of the electricity demand of P&T opera-tions; in turn, results of that assessment could influence the P&T design.

Cleanup at the former Nebraska Ordnance Plant involves use of a 10-kW wind turbine to power groundwater circulation wells for air stripping and ultraviolet treatment.

A P&T system's rate of groundwater extraction, anticipated duration, and quality of influent and the site's treatment goals typically have the greatest affect on the environmental footprint of the system. Use of the BMPs for technology selection and system design can address these traditional factors and help project managers evaluate how the factors contribute to consumption of energy, water, and other natural resources or result in air emissions and waste generation through the life of a cleanup project. System designers should also consider the site's anticipated reuse, to identify potential approaches for combining the needed infrastructures and minimizing long-term land disturbance.

Extraction Rates

The rate of groundwater extraction for a P&T system directly impacts the system's energy and materials use and waste management options. Optimization of extraction rates typically begins with a thorough site investigation that enables accurate well placement and helps determine the suitable number of extraction wells. [For more information, see: *Green Remediation Best Management Practices: Site Investigation*.[4a]]

Best practices for determining the optimal rate of groundwater extraction include:

- Establish an appropriate target capture zone and thoroughly evaluate the groundwater extraction needed to provide complete capture
- Base the capture zone analyses and design on parameters of actual aquifer test data and consider the use of modeling (with appropriate input information) to design the extraction system
- Consider designing a network of extraction piping that initially provides a conservative hydraulic capacity for the planned treatment system (perhaps by increasing pipe size or laying additional pipe when a trench is open), which allows for future modular increases or decreases in the extraction rate and treatment modifications, if needed; for example, the footprint of placing an additional extraction pipe that ultimately may be unused may be significantly smaller than remobilizing at a later date or overpumping a smaller network for many years
- When continuous pumping is not needed to contain the plume, consider whether pulsed rather than continuous rates of pumping can maintain the rate of groundwater transfer and treatment needed to ensure a protective remedy; additional gains in energy conservation may be possible by pumping during off-peak utility periods
- Consider reinjecting treated water downgradient of the extraction system to flatten the hydraulic gradient in the vicinity of the extraction wells, increase the capture zone width near the extraction wells, and potentially reduce the overall extraction rate; hydrogeologic consultation is recommended to ensure that reinjection does not adversely affect extraction efficiency, and
- Consider diverting upgradient, uncontaminated groundwater around the contaminant plume to reduce the amount of water to be extracted; feasibility of groundwater diversion would likely involve evaluation of environmental tradeoffs such as disturbance to land, ecosystems, and subsurface hydraulic conditions.

Duration of Operations

BMPs to help reduce duration of full-scale P&T systems (and reduce cumulative energy consumption, chemical and material use, and waste disposal) rely on adequate site and contaminant plume characterization. This information also can help evaluate the potential for using other remedial technologies to remove all or part of a contaminant source, which could reduce the P&T load as well as duration. Project managers should consider approaches that use supplemental technologies without compromising cleanup progress, schedules, and goals. Approaches could include:

- Collecting information on appropriate use of monitored natural attenuation (MNA) for the diffuse portion of the plume, in conjunction with EPA's MNA guidance[5]
- Considering technologies that can operate in conjunction with P&T, such as in situ chemical oxidation, thermal remediation, or bioremediation in the source area, and
- Planning options for implementing a remediation "polishing" technology at a stage when contaminant concentrations are reduced to a target level.

Influent Water Quality

Typically, design of a P&T system's treatment process is significantly driven by the quality of influent water. Loading of a particular constituent affects the size or specifications of given treatment processes, such as sizing of an air stripper or the adsorption medium in an air stripping system. In addition, treatment of different types of constituents such as metals, ketones, and ammonia often need specific processes that may use significant quantities of energy and materials and can generate significant quantities of waste.

Project managers should carefully evaluate "nuisance" contaminant constituents such as iron and manganese, which can easily foul system components or lead to more complex treatment systems that may involve additional energy and resources. Depending on a number of factors such as concentrations and depth intervals of these constituents, portions of the contaminant plume might be more effectively treated with other technologies such as in situ chemical oxidation or in situ bioremediation. If the extracted water contains iron, manganese, or other similar metals, a range of options could effectively address these constituents in ways that produce a different footprint. Options typically include:

- More frequent cleaning of components
- Use of downstream equipment that is less prone to fouling
- Use of a sequestering agent
- Metals removal via chemical addition and precipitation, and
- Use of alternate discharge options.

Concentrations of chemicals of concern in system influent may unexpectedly change over time. Frequent monitoring and use of real-time methods for concentration measurement will help identify changes quickly and prepare for treatment modifications throughout the project life. Continued use of an unmodified system that has become oversized over time can be a major cause of inefficiency.

Green remediation strategies for P&T design also involve evaluation of the options for discharging treatment effluent. Discharge to surface water, reinjection to the subsurface, and discharge to a publicly owned treatment works (POTW) all may be subject to federal or state regulatory requirements. One particular option may allow the overall remedy to have a lower footprint than other options; for example, discharge to a POTW will involve additional energy, materials, and waste before water is finally discharged to surface water.

Primary Treatment Technology Alternatives

Project managers should consider life cycles (and environmental tradeoffs) of feasible treatment processes when designing an aboveground treatment process for extracted groundwater. Several different technologies exist for addressing the same compounds or class of compounds, and each technology will present unique advantages, disadvantages, and footprints at a specific site. For example, air stripping, granular activated carbon (GAC), advanced oxidation, and bioreactors can all remove or destroy volatile organic compounds. Air stripping or GAC may make the smallest environmental footprint for a majority of sites, but in some cases ultraviolet oxidation (UV/Ox) may be more effective and leave a smaller footprint despite its additional energy and chemical use.

In general, resource efficiencies can be gained by:

- Using more than one treatment technology (from both the effectiveness and environmental footprint perspective) for each aspect of the treatment train
- Planning for elimination of treatment train components that will become unnecessary as site conditions change, and
- Using a form of renewable energy or waste heat; solar thermal panels, combined heat and power, or water-source heat pumps can provide the needed heat, and heat exchangers enable reuse of heat rather than discharging it as part of the effluent.

Applications for solar thermal energy (which generally incur lower capital costs than photovoltaic systems) include heating, cooling, ventilation, hot water heating, or process heating.

Selection of Chemicals and Process Materials

Chemical and materials use can contribute significantly to the environmental footprint of a P&T system. BMPs regarding use of chemicals for ex situ groundwater treatment focus on selecting the optimal vendor, type of chemicals, and dosage.

- Attempt to obtain needed chemicals and materials from local manufacturers in order to avoid long-distance transport, or from manufacturers in regions where grid electricity has relatively low emission factors[6]
- Consider chemical and material disposal needs, including offsite disposal of hazardous waste
- Consider the resources consumed during manufacturing or processing of treatment chemicals
- Consider the potential for these chemicals or treatment byproducts to be present in treatment effluent and the potential effects of these chemicals on human health and the environment
- Conduct sufficient bench-scale tests to help optimize chemical dosage, which minimizes chemical use during treatment, and
- Provide containment around chemical storage and batching areas to contain leaks.

When running process water or air through filters or adsorption media:

- Use liquid filters that can be backwashed to avoid frequent disposal of disposable filters
- Consider benefits of pre-treatment or pre-filtering prior to use of adsorption media such as GAC so that media are replaced based on chemical loading rather than fouling caused by solids loading
- Weigh the footprint advantages and disadvantages of preheating vapors prior to treatment with vapor-phase GAC; for example, preheating can significantly reduce relative humidity (an efficiency deterrent) but increases the system's energy demand, and
- Consider the source materials used to generate treatment media; for example, GAC media used in adsorption units can consist of virgin or reactivated coal-based GAC or virgin coconut-based GAC.

Collection and Disposal of Treatment Waste

Green remediation strategies for P&T remedies also consider the options for waste management.

- Take advantage of opportunities for chemical salvaging and material reuse, including regenerating rather than disposing of GAC, identifying uses for precipitated metals solids, and identifying uses of recovered product (such as creosote recycling or energy generation)
- Reduce the frequency and tonnage of hauling process-derived solid waste by improving solids dewatering with a filter press or other technologies, particularly if the energy used for dewatering can be offset by renewable energy, and
- Use sequestering agents to keep a maximum amount of iron and manganese in solution, to prevent equipment fouling, rather than removing them and generating additional process waste.

Profile: GCL Tie and Treating Superfund Site
Sidney, NY

- *Conducted remedial system evaluation (RSE) of a P&T system extracting 78 gallons of groundwater per minute (gpm) and treating groundwater through green sand filtration (for manganese and iron removal), air stripping and liquid-phase GAC (for organic compounds), and vapor-phase GAC (for off-gas emissions)*
- *Derived RSE results suggesting discontinued pumping from the intermediate zone (where the contaminant plume appeared to decrease independently), which could decrease the extraction rate by 23% and reduce costs while continuing to meet cleanup goals and schedules*
- *Estimated that implementation of the modified pumping plan could: avoid generating 1,000 gallons of liquid, listed hazardous waste needing offsite disposal; reduce annual electricity use by 8,000 kWh/year; and reduce carbon dioxide (CO_2) emissions by 4.8 tons/year*
- *Derived an additional RSE suggestion to bypass the existing air stripper that had become oversized as conditions changed, which could reduce electricity use by 200,000 kWh/year and CO_2 emissions by 120 tons/year*

Effluent Management and Related Standards

Treatment processes are driven in part by relevant federal or state standards for water quality discharge and off-gas emissions. Project managers should consider:

- "Going beyond" compliance with water and air quality standards under federal or state mandates and permitted emission or discharge, to further reduce P&T footprints on local water and air quality; the extra steps may or may not involve additional resources, and
- Establishing project goals for natural/materials resource consumption and conservation, using Executive Order 13423 as a guideline;[7] for example, use renewable energy from onsite resources to meet at least 10% of the treatment system's energy demand, and recycle 100% of all routine waste such as paper or electronic equipment.

When evaluating potential methods of effluent discharge in light of environmental tradeoffs, options include:[8]

- Reinjection of treated groundwater to the subsurface, which can recharge an aquifer with valuable water and avoid the need to treat background constituents (but may involve additional site activities to prevent well fouling or installation of additional well galleries); reinjection is commonly viewed as an environmentally favorable option because it replenishes an aquifer

- Release to surface water or storm water systems; this option typically involves stringent discharge standards and substantial monitoring requirements and expedites transport of water out of the watershed
- Discharge to a POTW or other regional water treatment plant, which may allow more efficient offsite treatment of certain contaminants such as ketones and ammonia (but might involve additional pre-treatment steps or redundancy with the onsite treatment system); for some complex treatment streams, treatment by a POTW or other regional water treatment plant may be a more efficient use of resources than building and operating another onsite treatment plant, and
- Beneficial onsite reuse of treated water (such as for irrigation, dust control, and constructed wetlands) to reduce the overall capacity needed by the local water supply network; treated water also may be used as a substitute for potable water in some plant operations such as chemical batching, process cooling, and use of water-source heat pumps for heating and cooling.

Profile: Havertown PCP Site
Havertown, PA

- *Reassessed performance of an operating P&T system employing four recovery wells and an ex situ treatment process involving three 30-kW UV/Ox lamps, a peroxide destruction unit, and two GAC units*
- *Took two UV/Ox lamps offline, based on system assessment indicating changing contaminant parameters*
- *Reduced electricity consumption by at least 168,000 kWh per year, due to turning off two UV/Ox lamps*
- *Reduced emissions by approximately 105 tons of CO_2, 280 pounds of nitrogen oxides, and 1,500 pounds of sulfur oxides each year, based on eGRID (version 1.1 for Pennsylvania); smaller offsite footprints also can be attributed to the avoided cooling water and fuel-harvesting resources needed for electricity generation and intermediate power loss on the electric transmission grid*

Electricity Use

The recommended BMPs for efficient use of electricity in P&T systems are designed to closely examine the demands of pump and fan motors and auxiliary equipment on a site by site basis. Factors that can significantly affect electricity consumption (and vary considerably in terms of power demands) include the type of pump needed for a given application, pump efficiency, motor efficiency, pump loading, use of variable frequency drives (VFDs), pump and pipe conditions, and the available fuel blend. The needed power also ranges considerably (possibly from 0.5 hp to 100 hp) depending on other site-specific factors such as treatment flow rates, contaminant types, and treatment processes. Best practices for electricity conservation include:

- Sizing pumps, fans, and motors appropriately and using energy efficient motors (such as National Electrical Manufacturers Association Premium® labeled motors)
- Using gravity flow where feasible to reduce the number of pumps for water transfer after subsurface extraction
- Installing VFDs to set constant or variable flow rates rather than throttling flow with valves; in many applications VFDs can reduce a pump's energy demand up to 50% while avoiding damage to mechanical equipment
- Considering processing via batch flows, operating portions of the treatment process train during off-peak utility periods, and installing amp meters to evaluate consumption rates on a real-time basis
- Using air- or water-source heat pumps and natural gas, propane, or other fuels in place of electrical resistive heating whenever possible; regardless of the heat source, set thermostats to temperatures needed for freeze protection, especially when the system is operating unattended, and
- Routinely check for and correct leaks in compressed air lines or inefficient use of compressed air; air-operated pumps are often less efficient than electric pumps.

Detailed information on selecting and improving performance of motors, pumps, and fans, as well as guidelines for improving overall energy efficiency of plant operations, is available from the U.S. Department of Energy's Industrial Technologies Program.[9]

Annual Energy Consumption of a Common P&T System	
Extraction system employing five 1-hp pumps	40,000 kWh
Operation of a 1,500-square-foot P&T building occupied three days per week, with electrical resistive heating in winter	25,000 kWh
Aboveground process-water treatment by an air stripper fitted with a 5-hp blower	40,000 kWh
Air stripper off-gas emission treatment with vapor-phase GAC, and vapor preheating with a 2kW in-line heater	16,000 kWh
Data monitoring/processing	10,000 kW
Total annual electricity consumption	131,000 kWh
Carbon footprint equivalency:[10] 94 metric tons of CO_2	

Constructing a P&T System

BMPs being developed or already in place for the construction business sector can apply to construction of a P&T system. The practices focus on three categories of activities that can significantly reduce a construction project's footprint.

Stormwater Discharge Controls

The areal footprint of a P&T system with respect to stormwater runoff is typically small. Although impervious services are commonly limited to building roofs, parking areas, and access roads, stormwater runoff and associated erosion and sedimentation should be minimized. EPA's proposed effluent limitation guidelines and standards for construction activities provide examples of strategies for preventing or controlling sediment (and pollutant) movement at a site.[11] Efforts should be made to minimize continuous impervious surfaces unless they serve as a cap as part of a soil remedy; gravel roads, porous pavement, and separated impervious surfaces can be used for this purpose. Maximum vegetative cover across the site will also reduce stormwater runoff and soil erosion and provide wildlife habitat.

Green Structures and Housing for Aboveground Treatment Processes

P&T systems typically need a building to protect groundwater pumping equipment and house the aboveground components. Although the sizing of needed buildings varies considerably, construction of every building offers opportunities for resource efficiencies. Life cycle construction strategies for buildings generally account for factors such as deconstruction and materials reuse as well as anticipated use and maintenance. The recommended practices also relate to housing of individual components of the treatment equipment. Project managers should:

- Adapt practices and goals addressed in the Federal Green Construction Guide for Specifiers,[12] which addresses provisions relevant to Executive Order 13423, environmentally preferable purchasing, energy efficient products, and industry standards of other organizations such as ASTM International
- Borrow practices from the U.S. Green Building Council's LEED® rating system for new building construction;[13] related checklists and guidelines outline specific parameters and a range of tangible performance goals that apply to building siting, site preparation, water efficiency, energy efficiency and renewable energy, air protection, other natural resource protection, materials resources, and indoor air quality, and
- Attempt to locate treatment equipment in an existing building with existing utilities/infrastructure wherever feasible, but evaluate these buildings for potential efficiency upgrades; the footprint associated with operations could outweigh the footprint of construction.

Examples of green building methods for industrial purposes such as water treatment include:

- Consider using water-source heat pumps on treatment plant effluent, ground-source heat pumps, mobile waste-to-heat generators, or furnaces/air conditioners operating with recycled oil, to provide space heating and cooling
- Seal all process tanks and air duct systems to ensure adequate building ventilation for workers and to reduce energy loss, and install energy recovery ventilators to allow incoming fresh air while capturing energy from outgoing, conditioned air
- Insulate all pipes and equipment tied to treatment processes needing heat
- Maximize use of skylights for direct or indirect natural lighting of work areas
- Consider using high efficiency sprayers when equipment needs rinsing with fresh water
- Prevent damage to equipment through use of surge protection devices, and program the equipment to restart in phases to avoid additional power surges that trip circuit breakers, and
- Maintain all leak detection equipment and repair any leaking equipment in a timely fashion.

Fuel Consumption and Alternatives

Recommended practices for fuel conservation and related GHG reductions during construction of a P&T system focus on:

- Retrofitting engines to accommodate diesel emission controls or replacing obsolete engines; catalysts and filters should be verified by EPA or organizations such as the California Air Resources Board
- Conducting full and appropriate engine maintenance as recommended by manufacturers
- Limiting idling of fuel-powered vehicles, equipment, and machinery to a maximum of three minutes whenever possible; certain equipment such as drill rigs, however, commonly need longer idling times to maintain efficient work flow, and
- Switching to ultralow-sulfur diesel or biofuel meeting the ASTM D6751 standard, to reduce engine wear.

More information about fuel consumption and alternatives is available in: *Green Remediation Best Management Practices: Using Clean Fuel Technology in Site Cleanup.*[4b]

Operating and Monitoring a P&T System

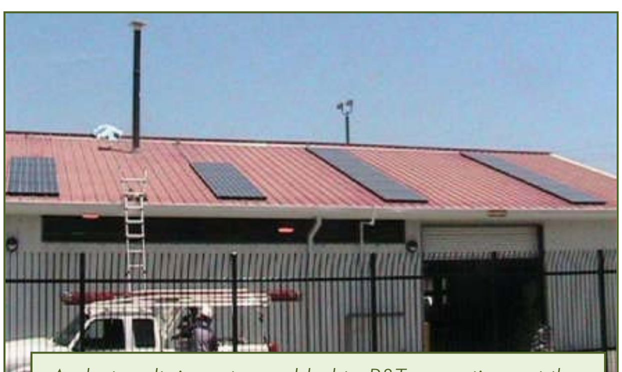
Opportunities for resource efficiencies and conservation that are identified and planned during remedy design should be thoroughly documented to ensure that decision makers and operations contractors have sufficient information supporting decisions during operation and maintenance (O&M) and long-term groundwater monitoring. Potential documents for recording this information include cleanup contracts, feasibility studies, site management plans, and quality assurance project plans; for example, contracts could specify:

> *The contractor shall evaluate all reasonably feasible renewable energy sources when conducting work related to selecting a cleanup remedy, constructing a cleanup remedy, and when optimizing an existing cleanup remedy. Sources of renewable energy include solar, wind, and biomass and biogas.*

Other examples of contract language and procurement information are available in EPA's *Green Response and Remedial Action Contracting and Administrative Toolkit*.[14]

Best management practices for ongoing P&T operations address relatively routine activities as well as those promoting continuous improvements to system performance – the "check-do, recheck-redo" process. In particular, continual reassessment is needed to identify opportunities for downsizing the existing equipment or taking any equipment offline. Important activities for O&M and associated practices include:

- Periodically bench-scale testing alternative chemicals to determine whether changing groundwater parameters warrant different chemicals or when new products become available, and
- Re-evaluating potential for renewable energy sources as new technologies or financial incentives become available; one alternative may be purchasing renewable energy certificates that could extend to site reuse.



A photovoltaic system added to P&T operations at the Pemaco Superfund Site in Maywood, CA, contributes 5,900 kWh of electricity each year to high-vacuum dual-phase extraction of groundwater.

Equipment Maintenance

- Conduct manufacturer-recommended preventative maintenance of all processing and building equipment on schedule and conduct any needed repair in a timely fashion
- Automate mechanical and electronic equipment as much as possible and implement a telemetry system to reduce frequency of site visits and reduce extra late-night or weekend trips responding to alarms
- Employ an electronics stewardship plan that ensures purchases of EPEAT® and EnergyStar® products, power management for data centers, and recycling or reuse of expended electronic equipment or media
- Strive for fewer, longer days for O&M labor rather than more frequent, shorter days to reduce transportation to and from the site
- Identify suitable reuse for equipment no longer needed, and
- Check for any equipment that could be removed from continuous operation in the treatment train but retained for potential reintegration if needed.

Sampling and Analysis of Process Water

- Collect and analyze representative samples to ensure good process-related decisions, to avoid unnecessary resource consumption associated with unneeded sampling
- Maximize use of real-time measurement technologies such as sensors, probes, and meters to monitor processing conditions, and use program alarms to notify operators of any system or component failure
- Retain local laboratories or use an onsite laboratory program if possible to reduce the footprint associated with transportation of samples, and
- Request electronic deliverables to minimize materials and fuel consumption associated with hard-copy data reports, which also facilitates data sharing across team members.

Sampling and Analysis of *Groundwater* in Monitoring Wells

- Use long-term monitoring optimization approaches to eliminate redundant or otherwise unnecessary sampling; decision support tools such as monitoring and remediation optimization system (MAROS) software can be used to perform statistical trend analysis for optimizing sample locations, sampling frequency, and analytical parameters, and
- Minimize traffic and land disturbance during sampling through BMPs such as restricting traffic to confined corridors and protecting ground surfaces with biodegradable covers.

Profile: British Petroleum Site
Paulsboro, NJ

- *Uses an onsite 275-kW solar field consisting of 5,800 photovoltaic modules to generate electricity for operating six recovery wells, including pump motors, aerators, and blowers*
- *Transfers extracted groundwater into a biologically activated carbon treatment system*
- *Generates 350,000 kWh of electricity each year through use of the solar field, which meets 20-25% of the P&T system's energy demand*
- *Eliminates emission of 571,000 pounds of CO_2, 1,600 pounds of sulfur dioxide, and 1,100 pounds of nitrogen dioxide each year through avoided consumption of fossil fuel-generated grid electricity*
- *Integrates ongoing groundwater cleanup with site reuse as a new port facility along the Delaware River, in partnership with state and local agencies; Port of Paulsboro operations are expected to generate $100 million annually in revenue and taxes*

Routine Checks and Balances

Making a P&T system more effective and efficient over time relies on awareness that site conditions, regulations, and technology options may change during the operating period and may differ significantly from those considered at the time of design.[15] As a result, one of the most significant BMPs for reducing the environmental footprints of a P&T system is to monitor these changes and periodically revisit these practices, perhaps on an annual basis, to identify appropriate system modifications. Standard operating procedures should include tracking of all electricity, natural gas, water, and materials consumption on a regular basis to identify any trends that may lead to increases in efficiency.

Green Remediation: A Sampling of Success Measures for P&T Operations[16]

- *Reduced electricity consumption and GHG emissions through use of energy efficient pumps and auxiliary equipment*
- *Increased percentage of electricity for groundwater extraction or aboveground treatment supplied by onsite renewable energy resources*
- *Reduced consumption of potable water due to substitution by treated water in chemical batching and cooling processes*
- *Reduced waste streams as a result of regenerating rather than disposing spent GAC and salvaging precipitated metals solids for offsite industrial use*
- *Beneficial reuse of treated water for restoration of onsite wetlands and ecosystems*
- *Reduced P&T loads due to integration of polishing technologies as contaminant concentrations decrease over time*

References [Web accessed: 2009, November 30]

[1] U.S. EPA; *Principles for Greener Cleanups;* August 27, 2009; http://www.epa.gov/oswer/greencleanups

[2] U.S. EPA; *Green Remediation: Incorporating Sustainable Environmental Practices into Remediation of Contaminated Sites*; EPA 542-R-08-002, April 2008; http://www.cluin.org/greenremediation

[3] Executive Order 13514: *Federal Leadership in Environmental, Energy, and Economic Performance*; October 5, 2009

[4] U.S. EPA; *Green Remediation Best Management Practices:*
[a] *Site Investigation;* EPA 542-F-09-004, December 2009
[b] *Using Clean Fuel Technology for Site Cleanup;* EPA 542-F-09-008, January 2010

[5] U.S. EPA; CLU-IN; multiple references at: http://www.cluin.org/techfocus/default.focus/sec/Natural_Attenuation/cat/Guidance/

[6] U.S. EPA; eGRID; http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html

[7] Executive Order 13423: *Strengthening Federal Environmental, Energy, and Transportation Management*; January 24, 2007

[8] U.S. EPA; *Options for Discharging Treated Water from Pump and Treat Systems;* EPA 542-R-07-006, 2007

[9] U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy; Industrial Technologies Program, Best Practices; http://www1.eere.energy.gov/industry/bestpractices/techpubs_motors.html

[10] U.S. EPA; *Greenhouse Gas Equivalencies Calculator;* http://www.epa.gov/RDEE/energy-resources/calculator.html

[11] U.S. EPA; *Effluent Limitations Guidelines and Standards for the Construction and Development Point Source Category;* proposed rule, November 28, 2008; 73 CFR 72561-72614

[12] U.S. EPA; *Federal Green Construction Guide for Specifiers*; http://www.wbdg.org/design/greenspec.php

[13] U.S. Green Building Council; *LEED for New Construction*; Version 3, April 2009; http://www.usgbc.org

[14] U.S. EPA OSWER/OSRTI; *Green Response and Remedial Action Contracting and Administrative Toolkit*; http://www.cluin.org/greenremediation/subtab_b2.cfm

[15] U.S. EPA; *Elements for Effective Management of Operating Pump and Treat Systems;* EPA 542-R-02-009, December 2002; http://www.cluin.org/rse

[16] U.S. EPA; CLU-IN; Remediation Optimization; P&T application descriptions, guidance, and remedial system evaluations at: http://www.cluin.org/rse

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For more information, contact:
Carlos Pachon, OSWER/OSRTI (pachon.carlos@epa.gov)
U.S. Environmental Protection Agency