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Green Remediation Best Management Practices: Cleaner Fuels and Air Emissions for Site Cleanups

A fact sheet about the concepts and tools for using best management practices to reduce the environmental footprint of fuel consumption and associated air emissions during site investigation and remediation

The U.S. Environmental Protection Agency (EPA) *Principles for Greener Cleanups* outline the Agency's policy for evaluating and minimizing the environmental footprint of activities involved in cleaning up contaminated sites.[1] Best management practices (BMPs) of green remediation involve specific activities to address the core elements of greener cleanups:

- Reduce total energy use and increase the percentage of energy from renewable resources.
- Reduce air pollutants and greenhouse gas (GHG) emissions.
- Reduce water use and preserve water quality.
- Conserve material resources and reduce waste.
- Protect land and ecosystem services.

BMPs focused on the core elements concerning energy consumption and air quality may also help mitigate and adapt to ongoing climate change.

Overview

Environmental investigation and remediation at hazardous waste sites can involve significant consumption of fossil fuels such as gasoline and diesel by vehicles and mobile or stationary equipment that may act as non-point sources of air pollution. Minimizing emission of air pollutants such as GHGs and particulate matter (PM) resulting from cleanup activities is a core element of green remediation strategies. Efforts to reduce these emissions during site investigation, remedial or corrective actions, and long-term operation and maintenance (O&M) of site remedies must meet Clean Air Act (CAA) requirements and state air quality standards as well as relevant requirements of federal and state cleanup programs. The CAA specifies ground-level ozone, PM, carbon monoxide, nitrogen dioxide, sulfur dioxide and lead as the nation's criteria air pollutants. EPA's air quality criteria and national ambient air quality standards (NAAQS) for criteria pollutants must be met in all state implementation plans.

Burning of fossil fuels results in significant emission of carbon dioxide (CO_2), a GHG that disturbs the earth's natural carbon cycle and greatly contributes to climate changes.[2] Ongoing EPA analyses indicate that CO_2 accounted for 79.5 percent of the GHGs emitted in the United States in 2021.[3] Related EPA studies of GHG emissions by U.S. economic sectors indicate that the transportation sector and electric power sector are the two largest contributors to CO_2 emissions resulting from the combustion of petroleum, coal and natural gas. The majority of fossil fuel directly consumed during site cleanup results from using onroad and offroad vehicles and stationary or mobile equipment powered by internal combustion engines.

EPA's *Green Remediation Best Management Practices: Integrating Renewable Energy* fact sheet provides information about applying solar electric and other renewable energy technologies to avoid or offset the use of grid electricity produced from fossil fuels.[4]

The use of fossil fuels also increases production of ground-level ozone, which can trigger human health problems such as aggravated asthma and reduced lung function. As of late 2020, EPA analyses indicate that about 22 percent of the U.S. population lives within three miles of a Superfund remedial site.[5] Additionally, airborne pollutants are among the impacts that disproportionally affect communities with environmental justice concerns, including those regarding local Superfunds sites; hazardous waste treatment, storage and disposal facilities; and brownfields.[6] EPA is accordingly collecting air quality data in such communities to support improved compliance with state and federal air quality standards.

EPA's Spreadsheets for Environmental Footprint Analysis (SEFA) tool was used to estimate fuel consumption and air emissions involved in corrective action at the Bay Road Holdings LLC site in East Palo Alto, California.[7]

Green remediation BMPs focused on air quality can reduce the environmental footprints of cleanup projects while improving their public health outcomes and helping mitigate climate change. BMPs relating to air quality also help meet goals of the Diesel Emissions Reduction Act, which prioritizes environmental justice and emissions reductions in areas

receiving disproportionate impacts from diesel fleets. EPA's Web-based EJScreen provides information and mapping on socioeconomic demographics and environmental indicators such as Superfund site proximity and diesel PM within a given geographic area.[8]

Fleets of transportation and construction vehicles deployed for site cleanup typically encompass a range of vehicle types. Light-duty vehicles with a gross vehicle weight rating (GVWR) below 8,500 pounds (such as sport-utility vehicles, light-duty trucks and medium-duty passenger vehicles) are commonly used to transport workers, small equipment and small quantities of supplies. Heavy-duty commercial vehicles such as cargo vans or light-duty trucks rated above 8,500 pounds GVWR are often deployed to transport heavier loads and serve as a platform for field equipment such as hollow-stem auger drill rigs needed for collection of subsurface environmental samples.

Nonroad vehicles such as bulldozers, excavators and graders are used for purposes such as demolishing buildings, constructing remedies such as landfill caps, or contouring disturbed ground surfaces. Additionally, tractor trailers may be intermittently required to transport heavy construction equipment or materials to and from the site or to transfer contaminated waste to an offsite facility.

Diesel Consumption and Estimated CO_2 Emissions in an Illustrative Excavation and Soil Amendment Project

Activity	Diesel Consumption (gallons)	CO_2 Emission (tons)*
Removing 35,000 cubic yards of contaminated soil by way of an excavator	4,000	89,800
Hauling excavated soil to a hazardous waste disposal facility 100 miles away by way of tractor trailers	11,666	261,902
Importing wood milling and agricultural waste from sources 50 miles away by way of dump trucks	2,400	53,880
Applying soil amendments and contouring ground surfaces by way of a grader	288	6,465
Using two medium-duty pickup trucks for site preparation and remedy construction over six months	500	11,225
Total diesel consumption and associated air emissions	18,854	423,272

*Based on an emission coefficient of 22.45 pounds per gallon, https://www.eia.gov/environment/emissions/co2_vol_mass.php

Advanced Emission Control Technologies for Vehicles and Engines

Reductions in PM, nitrogen oxides (NOx) and other air pollutants from vehicles and mobile or stationary equipment can be achieved through BMPs such as:

- Replace older vehicles and older equipment engines with newer ones meeting the most recent emission control standards.
- Use newer emission control components to rebuild engines.
- Retrofit diesel engines with exhaust aftertreatment devices.

EPA continues to update fuel economy and emission standards that must be met by manufacturers of onroad and offroad vehicles deployed in the United States. The "Tier 3" emission and fuel standards finalized in 2014 apply to passenger cars, light-duty trucks, medium-duty passenger vehicles, and some heavy-duty vehicles.[9] Vehicles meeting Tier 3 standards are equipped with emission reduction technologies as well as engines that have been calibrated to optimize fuel consumption while minimizing emissions.

"Tier 4" emission standards apply to nonroad compression-ignition (diesel) engines used in machines such as the drill rigs, excavators, pumps and compressors commonly required for site characterization, remedy construction or remedial operations. Tier 4 standards also apply to nonroad spark-ignition engines used in equipment such as generators and forklifts fueled by propane, gasoline or natural gas.[10]

EPA and the California Air Resources Board maintain lists of relevant technologies that have been verified to reduce the harmful impacts of diesel exhaust.[11,12] Technologies commonly integrated in newer vehicles and engines include diesel oxidation catalysts (DOCs) and diesel particulate filters (DPFs). Information about installing DOCs and DPFs in older vehicles is available in EPA technical bulletins.[13]

Offroad vehicles equipped with diesel-electric power trains and Tier 4 compliant engines were used to minimize fuel consumption and air emissions during remedy construction at the Elizabeth Mine Superfund site in Vermont. Use of a bulldozer with an electric power train, for example, decreased its fuel consumption by about 30 percent and increased its productivity by about 10 percent. Deployment of excavators powered by Tier 4 engines over six months was estimated to reduce PM emissions by 90 percent and NOx by 50 percent and improve fuel efficiency by 5 percent.[14]

Another technology that has been integrated in newer vehicles and engines involves selective catalytic reduction (SCR) systems, which reduce the excess NOx formed by a lean-burn engine. EPA conducted a modeling study of the potential changes in local air quality attributable to applying SCR technology in mobile equipment such as diesel-fired generators and in onroad or offroad vehicles deployed for Superfund remedy construction. Results showed a 65 percent reduction of NOx emission could be achieved over a five-day period, leading to a 49 percent reduction in ground-level ozone formation over the same period.[15] The findings are particularly relevant in areas where NAAQS are exceeded (non-attainment areas) and to populations that are disproportionately exposed to ground-level ozone or other air pollutants and consequently suffer associated health problems. Ground-level ozone also reduces respiration and associated photosynthesis in trees and other vegetation providing communities with ecosystem services such as air purification and flood control.

Requirements for emission reduction and tracking are increasingly integrated in contracts for site investigative or remedial services and associated purchase or rental agreements. EPA's Motor Vehicle Emission Simulator (MOVES) can be used to estimate air pollution emissions for criteria air pollutants, GHGs and air toxics associated with onroad vehicle and nonroad fleets.[16] Decisions regarding vehicle or engine replacements may be informed by EPA's Power Profiler, which describes the type and amount of emissions associated with electricity production in specific regions of the United States.[17] In certain applications, government funding under the Diesel Emissions Reductions Act may be available to help cover the costs of replacing diesel vehicles and engines with ones fueled by electricity, which is considered an alternative fuel under the Energy Policy Act.[18]

To evaluate replacement and upgrade options for heavy-duty diesel engines in greater detail, access EPA's web-based Diesel Emissions Quantifier.[19]

Operation and Maintenance

Site management plans and service or product procurements can specify other BMPs relevant to onsite driving and in some cases offsite driving. The manners in which vehicles and equipment are operated and maintained directly affect their performance and fuel efficiency; the harder an engine must work, the more fuel it requires. As a result, many BMPs focused on O&M can help decrease fuel-related project costs.

Eliminating unnecessary vehicle engine idle can significantly reduce fuel consumption and associated air emissions. For example, a Class 6 medium-duty commercial truck is often used to transport large quantities of supplies. A single hour of idling by this type of vehicle during loading or unloading would typically consume approximately 0.84 gallons of gasoline[20] and emit an estimated 16.5 pounds of CO_2 equivalent.[21] Similarly, heavy nonroad vehicles are often used for remedy construction activities such as excavating contaminated materials and building subsurface pipelines. Manufacturers estimate that such vehicles conventionally idle an average of 28 to 38 percent of their operating times.[22]

In addition to unnecessarily burning fuel, excessive idling also shortens engine service lives, poses health and safety risks to vehicle and cab occupants if emission leaks occur, and increases noise pollution in local communities. Relevant BMPs include:

- Manually shut down engines of vehicles not actively engaged for more than 10 seconds, except for work requiring intermittent engine use or when in traffic.[23]
- Engage automatic shut-down devices, which typically can be programmed to cut an engine after as little as five consecutive minutes of idling.
- Install a direct-fired air heater, which consumes only a small amount of a vehicle's fuel supply and eliminates the need for idling to heat an engine or a cab interior.
- Improve a vehicle engine's cold-weather startup ease by installing a coolant heater in the engine compartment or adding a waste-heat recovery system.
- Deploy energy storage batteries in the back of a truck that provides power take-off for auxiliary equipment.
- Recharge laptop computers and mobile devices in vehicles that are in active motion rather than idling.

Application of the *ASTM Standard Guide for Greener Cleanups* (E2893)[24] to plan bioremediation activities at Travis Air Force Base in Solano County, California, indicated that minimizing usage of transportation fuel and related air emissions was a high priority. Bulk quantities of the selected biological reagent (emulsified vegetable oil) were shipped to the site via rail lines rather than trucks. Locomotive engines meeting Tier 4 emission standards are estimated to produce about two-thirds less GHG than typical truck engines. Additionally, the reagents were injected into the subsurface via hydraulic pressure instead of fuel-fired hydraulic pumps.[25]

Fuel conservation can also be maximized by properly maintaining all onroad and offroad vehicles to avoid overworking their engines. Routine maintenance should include practices such as:

- Ensure sufficient inflation and tread and proper alignment of tires, to minimize rolling resistance. For example, a 10 percent reduction in rolling resistance would improve fuel economy by about 3 percent for light- and heavy-duty vehicles. Additional efficiency may be gained by replacing worn tires with models that are SmartWay verified for low rolling resistance.[26]
- Use the vehicle manufacturer's recommended grade of motor oil, which can impact fuel economy up to 2 percent.

- Replace filters in air and fuel systems in accordance with the vehicle manufacturer's recommended frequencies, which typically distinguish between a normal-duty cycle versus a severe-duty cycle that accounts for usage conditions such as unpaved roads or high levels of dust or pollen.
- Clean emission control systems such as SCR systems and DPFs on a regular basis to prevent plugging, remove contaminants, and reduce engine back pressure.
- Check brake parts such as calipers and pads and promptly replace worn parts to avoid brake drag.
- Clean mass airflow sensors to assure the proper air-fuel mixture is entering the engines.
- Replace engine oil on a timely basis to avoid worn piston rings that reduce engine efficiency.
- Secure prompt interim maintenance when the vehicle's "check engine" light becomes illuminated.

Other BMPs focus on sources of air pollutants attributable to diesel, gasoline, propane or natural gas consumed by stationary or mobile equipment deployed in site characterization or in groundwater, soil or sediment treatment systems. For example:

- Use solar or wind energy resources instead of diesel to generate electricity for equipment such as water pumps that recirculate, extract or transfer contaminated groundwater. Any excess energy produced from these renewable resources can be stored in transportable battery banks that could power additional equipment, recharge electric vehicles or provide emergency backup power.
- Use hydrogen fuel cells to operate critical equipment or provide additional backup power. Fuel cell generators are twice as efficient as diesel generators and emit little or no emissions.[27]
- Maintain diesel-fueled compression engines in equipment such as air compressors and blowers in accordance with manufacture recommendations, and retrofit or replace such equipment as needed to meet Tier 4 emission standards.
- Integrate heat exchangers in groundwater treatment systems involving heated fluids, to beneficially use the systems' waste heat. A heat exchange process can eliminate or reduce the use of fuel-fired equipment for purposes such as pre-heating cold fluids entering the treatment stream.
- Replace aged equipment supporting onsite building operations, such as material chilling units and water heaters, with newer models meeting the latest energy-efficiency standards set by the U.S. Department of Energy (DOE).[28]
- Replace gasoline engines with diesel engines meeting Tier 4 emission standards, which are typically equipped with SCR and DPF technologies that reduce NOx and PM by more than 90%.
- Ensure the leak detection systems of pressurized equipment such as propane storage tanks and natural gas pipelines operate at all times, to avoid fugitive emission of methane and other GHGs. Leaky valves and seals typically account for a significant portion of fugitive emissions from an industrial process.
- Downsize energy-intensive equipment that has become oversized as cleanup progresses.

Operation of photovoltaic systems at the Frontier Fertilizer Superfund site in Davis, California, avoids an estimated 147,500 pounds in CO_2 (equivalent) emissions each year. The systems involve a ground-mounted solar array as well as a roof-mounted solar array that together offset 100 percent of the grid electricity used to pump and treat the site's contaminated groundwater.[29]

The California Air Resources Board offers a list of verified diesel emission control devices applying to stationary engines.[30] Related compliance requirements issued by EPA may be used to guide selection and retrofitting of stationary engines at area sources of hazardous air pollutants.[31]

Green remediation BMPs specific to pump and treat technology, bioremediation, soil vapor extraction and other frequently used remediation technologies are described in companion EPA fact sheets.[32]

Transportation Plans

Transportation planning for a site cleanup project can specify strategies to minimize fuel consumption and related air emissions throughout the project's life. General BMPs include:

- Choose the nearest offsite site laboratories, material vendors and waste facilities, to reduce shipping distances.
- Import supplies and export wastes via full rather than partial vehicle loads whenever feasible.
- Facilitate staff carpooling opportunities, to minimize travel to and from the site or other destinations on a given day.
- Deploy plug-in or hybrid electric vehicles to the greatest extent possible as the U.S. transition to electric vehicles continues.
- Schedule heavy shipping or construction activities to occur during spring or autumn, to avoid contributing to ground-level ozone formation that is typically higher during summer due to higher air temperatures and humidity levels.
- Purchase lower carbon fuels where available, such as E15 for gasoline vehicles or E85 for flex-fuel vehicles. Diesel-fueled equipment can often use diesel blends containing up to 20% biodiesel (B20), and renewable diesel (an advanced renewable fuel) can be used safely in diesel engines in any amount.[33]
- Choose material or waste haulers that use SmartWay designated trailers and tractors and SmartWay verified technologies relating to low rolling resistance tires, idling reduction and aerodynamic devices.[34]

Transportation plans can encourage offsite drivers to reduce fuel consumption through sensible driving techniques. Also, certain techniques help reduce local noise pollution attributed to operating transport vehicles. BMPs include:

- Use a suitably sized vehicle for the task at hand. For example, use of an oversized truck to transfer a small amount of waste to a disposal facility results in wasted fuel.
- Combine trips to avoid unnecessary stopping and starting of engines. Multiple short trips can use twice as much fuel as one long, multi-purpose trip that covers the same distance while the engine is warm and at its most fuel-efficient temperature.
- Reduce vehicle loads by offloading any unneeded items, and avoid using rooftop cargo carriers.
- Use overdrive gearing whenever feasible to reduce an engine's speed, which in turn reduces fuel consumption, extends engine life, and lessens engine noise.
- Avoid rapid acceleration, excessive speed and repetitive hard braking, which lowers gas mileage by as much as 30 percent.
- Refrain from using a jake brake in or near residential neighborhoods and other sensitive communities.
- Use a reliable navigation system that enables selecting the shortest route to destinations and avoiding traffic events that may trigger vehicle idling.

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This fact sheet provides an update on information compiled in the August 2010
"Best Management Practices: Clean Fuel & Emission Technologies for Site Cleanup" fact sheet (EPA 542-F-10-008),
in collaboration with the Greener Cleanups Subcommittee of the U.S. EPA Technical Support Project's Engineering Forum.

To view BMP fact sheets on other topics, visit CLU-IN Green Remediation Focus: www.clu-in.org/greenremediation.