"Base-Catalyzed Decomposition Proven on Guam"

When a thermal desorber is enhanced by several new technologies, the result is more than the sum of its parts

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The Base Catalyzed Decomposition Process (BCDP) technology was initially developed by the U.S. Environmental Protection Agency (EPA) for remediating PCB-contaminated soil. It also is applicable to soil contaminated with other chlorinated as well as non-chlorinated organics. The equipment and operating procedures are similar to those of a thermal desorber, but also include several new technologies:

- The addition of sodium bicarbonate to promote lower temperature desorption and partial destruction of chlorinated organics.
- Steam sweep to create an inert atmosphere above the hot soil. The inert gas suppresses the formation of oxidative combustion products like dioxin and eliminates the possibility of combustion occurring in the rotary reactor. Any combustion would produce a positive pressure and contaminants potentially could be released into the environment.
- A novel control system to allow a wet electrostatic precipitator (WESP) in the offgas treatment system to operate without the danger of a fire or explosion, regardless of the levels of organics in the offgas.

These innovations combine to produce a cost-effective, environmentally safe soil remediation technology to operate with an offgas cleaning system that is more than 99.9999 percent efficient in removing PCBs. Concentrated PCB residuals amount to less than 1 percent by weight of soil processed.

BCDP history

BCDP grew out of research done by EPA at the Risk Reduction Engineering Laboratory (RREL) in Cincinnati, Ohio. Laboratory studies showed that when PCB-contaminated soil was mixed with sodium bicarbonate and heated, the bicarbonate caused the PCBs to leave the soil at lower temperatures, and some PCB destruction occurred.

The Pacific Division, Naval Facilities Engineering Command (PACDIV) saw an application for this technology in Guam. Because of the island's remote location, transporting hazardous material to a commercial storage or treatment facility is very expensive. The Naval Facilities Engineering Service Center (NFESC) worked with an R&D contractor, Pacific Northwest National Laboratory (PNNL), to design, build and install the first BCDP unit at a PCB-contaminated site at Naval Station Guam.

After demonstration runs were completed, the Navy's remedial action contractor, IT Corp., assumed responsibility for the operation of the unit. A number of changes were made in the plant to convert it from a demonstration system to a remediation plant. The air capture system was redesigned and rebuilt, a feed preparation building was installed and other changes were made so the plant could be safely and reliably operated through the required

remediation period.
The BCDP on Guam has been operational since February 1996. Site remediation will be complete this year. The information contained in this report is based on remediation phase operating experience in Guam.

Technology applicability

BCDP can be used to treat the same type of material which can be treated by a thermal desorber: contaminated soils, sludges and filter cakes. If PCBs (and possibly other chlorinated compounds) are treated, the bicarbonate catalyst will increase plant efficiency by allowing the soil to be cleaned at a lower temperature and chemically destroying some of the PCBs.
Although the BCDP was initially designed to treat PCB contaminated soil, its performance on other types of contaminants can be predicted. The BCDP will remove both volatile and semivolatile compounds from soil, including very low volatility chlorinated organics. The performance of the air pollution control system (APCS) depends largely on the nature of the organics being removed. High boiling point organics, such as PCBs, are removed largely by condensation and captured on either the WESP or the high efficiency mist eliminator (HEME). Semivolatile water soluble organics are captured in the water through solubilization. Volatile non-water soluble organics and residual PCB vapors are captured by the carbon at the end of the air capture system.
Compounds such as PCBs, which may react with oxygen at elevated temperatures to form even more hazardous compounds such as dioxins, are especially suited to the BCDP. The inert steam atmosphere in the rotary reactor and throughout the air capture system excludes most of the oxygen. The sodium bicarbonate breaks down, releasing carbon dioxide and water to add additional inert gases to the system. At high temperatures, in the absence of oxygen, some pyrolysis will occur and actually break down larger molecules into smaller and, in many cases, less toxic compounds.
The primary factors affecting contaminant removal in the rotary reactor are temperature and residence time. As an example, PCB-contaminated soil requires a temperature of approximately 600^{o}F at a residence time of about one-half hour. As the temperature is raised, the residence time can be reduced. These numbers are approximate because the type of soil contaminated by PCBs is also a factor. The total quantity of organics released in the rotary reactor is an important factor in the overall economics of the system. As only partial destruction of PCBs is caused by the bicarbonate, all the condensable organics released will likely be contaminated with PCBs. This contaminated residual must be disposed of offsite, typically by incineration.
Table 1 lists the codes for some specific Resource Conservation and Recovery Act (RCRA) waste that can be treated by this technology. These compounds can all be successfully treated in standard thermal desorbers, therefore they should be treatable in the BCDP. General contaminant groups that can be treated by the BCDP are shown in Table 2. This table is based on current available information for treatment by thermal desorption. Individual site conditions must be considered to determine the effectiveness of the BCDP. For example, PCBs are released fairly quickly from the coral matrix found in Guam. It is expected that PCBs would be more tightly bound to clay, and that higher temperatures or longer residence times would be required if the PCBs were on clay instead of coral. If the PCBs at a particular site were found together with high levels of non-hazardous organics, the quantity of residuals generated for off-site disposal would be increased.

How the BCDP works

Figure 1 shows a general schematic of the BCDP process. Soil is crushed, mixed with bicarbonate and introduced into the rotary reactor. The rotary reactor in Guam is a standard calciner with a carbon steel shell. As the soil passes through the inside of the rotating shell, diesel burners heat the shell to a temperature of about 900^{o}F. As the soil passes through the unit, the PCBs and other organics volatilize into a vapor and enter the atmosphere in the interior of the shell. Steam is introduced countercurrent to the soil addition. As the organics leave the solid phase and enter the gas phase in the rotary reactor, the steam sweeps them out of the rotary reactor to the cyclone. The cyclone is insulated and the bottom is electrically heated to minimize the amount of condensation and maintain a high temperature. Larger dust particles are removed in the cyclone by centrifugal force and fall out into a collection drum.

The gas passes out of the cyclone to the WESP. The gas continuously cools as it exits the rotary reactor until it enters the WESP. As the gas cools, the heavy semivolatile organics will condense and form an aerosol (micron and submicron size droplets of organic liquid). When the gas enters the WESP, it is given an electrostatic charge and then passes through a vertical tube sheet. The tubes in the tube sheet have an opposite charge to that on the particles in the gas. This causes the particulate and aerosols in the gas to be attracted to the tube walls. As these solid particulates and liquid aerosols contact the walls of the tube, they agglomerate and are washed off by water which is constantly sprayed into the tubes. The WESP is almost 100 percent efficient at removing particulate and aerosols above three microns in size and more than 99 percent efficient in removing particulate and aerosols less than three microns in size.

Although the WESP is ideally suited for removing these small particles, this is the first application of a WESP in this configuration. Because of the strong electrostatic charges within the WESP - up to 40,000 volts - the unit periodically sparks. This spark provides an ignition source, and if the gas in the WESP is within the flammability or explosive limits, a fire or explosion could result. In the BCDP, steam is used to exclude oxygen from the WESP. By maintaining an oxygen level below 5 percent, the WESP can be safely operated with any level of organics in the entering gas stream.

The gas exiting the WESP is very clean. It is essentially free of particulates, and organics that will condense at 212^{o}F have for the most part been removed. This gas stream then enters the primary condenser where the steam is condensed. The primary condenser is a vertical shell and tube heat exchanger using cooling tower water on the shell side. The temperature of the gas is reduced from 212^{o}F to 85^{o}F to 90^{o}F, condensing and removing almost all the steam. After the primary condenser, the only gases left are air that has infiltrated the system and any non-condensible gases generated in the rotary reactor. In the BCDP on Guam, about 130 actual cubic feet per minute (ACFM) of gas enters the primary condenser. The gas flow leaving the primary condenser is less than 30 ACFM, a more than 75 percent reduction in gas volume. This reduced gas volume allows a corresponding size reduction in the remaining components of the system. This feature is unique to the BCDP system on Guam.

The offgas leaving the primary condenser passes to the chiller condenser, a heat exchanger using an ethylene glycol water solution on the tube side. In this unit, the gas is cooled to about 40^{o}F. This condenses additional organics and additional water.

The gas leaves the chiller condenser and travels to the HEME. The HEME is a tightly woven fiberglass pad about 3 inches thick. As the gas passes through this pad, organic aerosols condense because of the additional cooling after the WESP are removed. The removal efficiency of the HEME is similar to the WESP; virtually 100 percent efficient on particles above three microns and more than 99 percent efficient on particles less than three microns in size.

Although the HEME and WESP both remove the same type of material, they do so by very different mechanisms and are positioned in the APCS to complement each other. Solid particulate and aerosols are collected on tube walls in the WESP and flushed off with water. While the HEME will remove solid particulate, it will not drain out of the fabric. If particulate steadily accumulates on the surface of the HEME, it will eventually plug the fabric. Low viscosity organics that collect in the HEME will naturally drain out of the unit. High viscosity organics, however, will not drain and will accumulate and plug the HEME. These high viscosity organics and particulates the HEME will not handle are removed in the WESP.

The HEME serves two major functions. It collects the organic aerosols that form after the cooling that occurs in the gas stream between the WESP and the HEME, and it acts as a backup should the WESP experience a power outage. The HEME is very close to being a fail-safe device. If the WESP should stop functioning, the HEME will receive the high viscosity organics and particulates and will remove them with the same efficiency seen in the WESP. They will, however, slowly plug the HEME until the pressure drop becomes excessive and the HEME has to be taken off line. For this reason, two HEME units are located in parallel. If one unit should plug, the gas stream is switched to the second unit and the first unit is changed out. While the WESP is operating, the HEME will receive a solids-free gas stream containing low viscosity organic aerosols. Under these conditions, the HEME has a very long life.

After the HEME, the gas passes through the induced draft (ID) fan. This fan is drawing gases from the rotary reactor throughout the entire air capture system. Because most of the gas is removed in the primary condenser, the ID fan capacity is very small. The WESP is a very low pressure drop device and the HEME, operated with low air flow, is also a low pressure drop device. In Guam, the ID fan pulls a vacuum of only 2 to 3 inches of water.

After the ID fan, the gas passes through the final polishing carbon and out the vent stack. This carbon will remove most of the residual organic vapors, including some residual PCB vapors that still exist even at the ambient temperature at which the carbon operates. Because of the chiller condenser, the carbon receives a dry gas stream. The gas leaving the primary condenser is water saturated. When this gas is cooled to 40^{o}F in the chiller condenser, it is still water saturated. However, after it leaves the chiller condenser it heats up. The lowest ambient temperature on Guam is about 65^{o}F. Without the chiller condenser, this gas stream would still be cooling as it passed through the carbon and would deposit water on the carbon. By running the carbon dry, its capture capacity is significantly increased.

Performance data

At press time, the BCDP on Guam has processed about 10,000 tons of PCB-contaminated soil. The system has operated at rates of more than two tons per hour. The BCDP will easily achieve total PCB concentration below 2 ppm in the treated soil.

The APCS has operated well. The initial operation of the system in the summer of 1995 was performed without the WESP and chiller condenser because of special fabrication requirements. A stack test performed by the Navy shortly after start-up showed that emissions were very low. PCB removal was about five 9s, or 99.999 percent removal, and levels of other organics in the stack were very low. Average combined dioxin and furan concentrations were 32 nanograms per cubic meter. The Navy performed a second stack test in June 1996, after all the APCS equipment was installed. The switch from air to steam sweep gas (which is condensed in the primary condenser) dropped the stack flow and reduced oxygen in the system. PCB emissions fell to seven 9s, or 99.99999 percent removal. Average dioxin and furan concentrations in the stack fell from 32 to 3.6 nanograms per cubic meter. TEQ dioxin and furans were 0.18 nanograms per cubic meter.

The steam sweep and WESP have been easy to operate.

To ensure that oxygen is below 10 percent, the WESP alarms at 203'F and the power to the WESP automatically shuts down at 188^{O}F. The hot kiln offgas supplies sufficient heat to maintain the WESP temperature in the safe zone, typically between 206^{O}F and 210^{O}F. After leaving the primary condenser, where the steam is condensed, the gas flow is reduced to 30 cubic feet per minute (CFM), as compared to 180 CFM before the steam sweep was added to the system.

The WESP is removing more than 99 percent of the particulate in the offgas and appears to remove most of the organics. Water is recirculated from the WESP sump to the spray nozzles above the sump that flush the WESP tubes. A blowdown of about five gallons per minute (gpm) is sufficient for the removal of contaminants from the WESP. This five gpm stream contains most of the contaminants from the offgas stream and is sent to the water treatment plant.

Before the WESP was operated, a venturi scrubber was used to remove fines from the gas stream before the gas passed through the HEME. The scrubber was not efficient at removing organic mists, and the HEME element would last about a month before the pressure drop became excessive - more than 25 inches water column (w.c.) and the HEME had to be replaced. After about a year of operation with the WESP instead of the scrubber, the HEME pressure drop is less than 1 inch w.c.

During the first year of operation, the average production rate on Guam was 1.3 tons per hour with an 82 percent system availability. Actual operating costs on Guam were $516 per ton. If the high per diem and lodging costs are removed, the operating cost is $418 per ton. The operating cost is inflated because the Guam BCDP is a relatively small unit.

Lessons leamed on Guam can significantly reduce both the capital and operating costs of future BCDP units. For example, the rotary reactor has a carbon steel shell and it cannot be heated above 1,000'F. A stainless steel shell could be heated to around 1500'F and other alloys can be operated at even higher temperatures. Operating at higher temperatures would significantly increase the tons per hour that a given size reactor would produce.

An important concept in the initial design of the APCS was to minimize air infiltration to reduce the oxygen content in the offgas. Actual infiltration rates were unknown, and the APC equipment was sized based on conservative assumptions to ensure it would work. Operating experience has shown that air infiltration is much lower than predicted, and the entire APCS, including ducting, could be reduced in size by 50 percent to 75 percent.

Operating procedures for the BCDP in Guam that can also be applied to future units are continuously evolving and are too numerous to detail. For example, tests conducted during operations showed that heating a fouled HEME element with low pressure steam makes the organics trapped in the element flowable and regenerates the element. This saves the cost of purchasing a new element and disposing of the old element as a hazardous waste, and is much less labor intensive than replacing the element.

The Navy will publish a detailed technical transfer report in the near future.

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