POPs-Wastes Applicability (Refs. 1 and 5):
Anaerobic Bioremediation Using Blood Meal was able to rapidly degrade toxaphene in soil to achieve cleanup goals in bench- and pilot-scale tests. Bench-scale tests have indicated that the technology is also effective in treating dichlorodiphenyltrichloroethane (DDT). Full-scale implementations have successfully treated several toxaphene-contaminated sites. The quantity of soil treated at these sites ranged from 250 to 8,000 cubic yards. This technology does not typically achieve greater than 90 percent contaminant reduction.

POPs Treated:	Toxaphene and DDT
Other Contaminants Treated:	None
Application:	Ex-situ

Technology Description (Refs. 1 and 5):

Overview

This technology uses biostimulation to accelerate the degradation of toxaphene in soil or sediment. It involves the addition of biological amendments, including blood meal (nutrient) and phosphates (pH buffer), to stimulate native anaerobic microorganisms. Blood meal is a black powdery fertilizer made from animal blood. The typical dosage of blood meal and sodium phosphate is one percent by weight of contaminated soil. This is sometimes augmented with one percent by weight of starch to rapidly establish anaerobic conditions. The standard recipe uses monobasic and dibasic phosphate salts in equal proportions (monobasic:dibasic - 1:1) to maintain soil pH around 6.7. The low phosphate/starch recipe uses three times more dibasic than monobasic phosphates (monobasic:dibasic – 1:3) and maintains soil pH around 7.8.

The soil to be treated is mixed with amendments and water. Mixing methods including blending in a dump truck, mechanical mixing in a pit, and mixing in a pug mill have been used to produce homogeneous soil-amendment mixtures. The mixture is transferred to a cell with a plastic liner, and excess water is added to provide up to a foot of cover above the settled solids. The water provides a barrier that minimizes the transfer of atmospheric oxygen to microorganisms in the slurry, which helps maintain anaerobic conditions. The lined cell is covered with a plastic sheet to isolate the cell from the environment, and the slurry is incubated for several months. The slurry may be sampled periodically to measure treatment progress. Once treatment goals have been met, the cell is drained. The slurry is usually left in place, but it may be dried and used as fill material on site. The slurry also serve as a source of acclimated microorganisms for use at another toxaphene-contaminated site.

Anaerobic degradation of toxaphene usually results in the production of intermediates such as less chlorinated congeners of toxaphene. Further degradation of intermediates results in the production of carbon dioxide, methane, water, inorganic chlorides, and cell mass.

Status and Availability (Refs. 2 and 6):
The technology has been implemented at full scale to treat toxaphene-contaminated sites. Four such sites are:

(1) The Laahty Family Dip Vat (LDV) site (253 cubic yards in one cell)
(2) The Henry O Dip Vat (HDV) site (660 cubic yards in two cells)
(3) The Gila River Indian Community (GRIC 1) site (3,500 cubic yards in four cells)
(4) The GRIC 2 site (8,000 cubic yards in five cells)

EPA's Environmental Response Team (ERT) is the developer of the technology. The technology is unlicensed and is available through the ERT. The biological amendments (blood meal, and monobasic and dibasic phosphates) are inexpensive and commercially available.

Design (Refs 1, 5):
Factors that need to be considered when designing an anaerobic bioremediation process using blood meal include:

- The presence of active toxaphene-degrading bacteria
- Soil characteristics
- Volume of soil to be treated
- Concentration of toxaphene in contaminated soil
- Cleanup goal
- Availability of space on site for the construction of treatment cells
- Odor mitigation requirements as determined by surrounding land use and the proximity of residences
- Need for agreements with landowners and community leaders
- Climate
- Security issues
- Availability of water

THROUGHPUT (REFS. 1 AND 5):
Throughput of a technology that does not operate like a batch processing plant is hard to define. Remediation involves a series of steps including construction, mix preparation, and treatment. Treatment is usually the slowest step. Factors that can influence treatment time include, the type of microbial communities present, amendment dosage, contaminant concentration, treatment goals, and the presence of inhibitors (such as very cold environments). In general, treatment time can vary from five weeks to two years.

WASTES/RESIDUALS (REFS 2, 3 AND 6):
Products of toxaphene degradation include lower-chlorinated chlorobornane congeners, chloride ions, cell mass, carbon dioxide, and methane. Chlorobornane congeners have been shown to degrade completely during treatment. However, treated soil can contain low concentrations (below cleanup goals) of unutilized toxaphene and lower-chlorinated chlorobornane congeners.

Gaseous wastes produced can include methane and hydrogen sulfide. Therefore, odor concerns should be considered. If treatment cells are not left in place at the end of remediation, solid wastes can include debris from the demolition of treatment cells and associated temporary facilities. Debris potentially contaminated with toxaphene will require testing to determine its hazardous nature in compliance with local, State, and Federal requirements prior to disposal.

MAINTENANCE (REFS. 2 AND 6):

- Periodic addition of water to treatment cells to maintain water level
- Maintaining treatment cells to prevent leaks
- Maintaining cover integrity
- Monitoring for gas buildup
- Monitoring for fugitive odors
- Soil sampling to monitor remedial progress

LIMITATIONS (REFS. 2 AND 6):

- The anaerobic process is affected by temperature. Spring and summer are the best periods for operation. This technology cannot be used in extremely cold climates.
- This technology requires a bench scale test to determine applicability at a given site, and to estimate treatment duration.
- At a minimum, five weeks are required for treatment.

- This technology typically does not achieve greater than 90 percent contaminant destruction.
- Blood meal accelerates the rate of reductive dechlorination of toxaphene, but does not affect the extent of dechlorination.
- Unfavorable soil chemistry can inhibit the process. Unfavorable soil chemistry may result from the presence of bioavailable heavy metals including mercury, arsenic, and chromium; solvents; and pesticides (including toxaphene).
- Level C personal protective equipment is required when working with blood meal.

FULL-SCALE TREATMENT EXAMPLES (REFS. 1, 2, 5 AND 6):

Anaerobic bioremediation using blood meal and phosphate amendments has been implemented at a full scale at twenty two (22) Dip Vat sites in the Navajo Nation. Other sites where this technology has been applied at a full scale to remediate toxaphene-contaminated soil include:

(1) The Ojo Caliente Dip Vat site
(2) The Laahty Family Dip Vat site
(3) The Henry O Dip Vat site
(4) The Acoma Reservation at Sky City
(5) The Gila River Indian Community (GRIC 1) crop duster site
(6) The GRIC 2 crop duster site

The resources used for this fact sheet contain performance data on nine applications of this technology. Performance data for each of these sites is presented in Table 1 at the end of this fact sheet. Three of these sites are discussed below in greater detail. The unit cost of implementation at these sites in USD ranged from $98 to $296 per cubic yard.

Laahty Family Dip Vat (LDV) site

The LDV site is located in The Zuni Nation, New Mexico. Soil at the site was contaminated with toxaphene at an average concentration of 29 milligrams per kilogram (mg/kg). A total of 253 cubic yards (cy) of soil was excavated and stockpiled on site. A cell with dimensions, 73 feet (ft) by 30 ft by 4 ft (deep) was constructed and lined with a plastic liner. Contaminated soil was placed in a concrete mixer and mixed with biological amendments and water. Blood meal and monobasic phosphate were added, each at a dosage rate of 10 grams per kilogram (g/kg) of contaminated soil. Dibasic phosphate salts were also added at a dosage rate of 3.3 g/kg soil. The nutrient-amended soil slurry was then placed in the lined cell. Water was added to provide one foot of cover above the solids in the cell. The cell was then covered with a plastic sheet and incubated. Samples were collected periodically to monitor progress. The toxaphene concentration decreased in the anaerobic cell from an initial concentration of 29 mg/kg to 4 mg/kg in 31 days. This corresponded to an overall reduction of 86 percent. The post-treatment concentrations were below the 17 mg/kg action level established for the site. In 2004, the total cost of treatment in USD was $75,000. Consequently, the unit cost of treatment at this site was $296 per cubic yard.

Henry O Dip Vat (HDV) Site

The HDV site is located in The Zuni Nation, New Mexico. Approximately 660 cy of soil at this site was contaminated with toxaphene at an average concentration of 23 mg/kg. Two cells were constructed for soil treatment:

- The north cell (Cell 1) was 75 ft by 35 ft by 5 ft (deep).
- The south cell (Cell 2) was 65 ft by 30 ft by 5 ft (deep).

Both cells were lined with plastic liners. Blood meal and sodium phosphate were added to contaminated soil and placed in a mixing pit using a backhoe. The dosage rate of blood meal was 5 g/kg of contaminated soil, while that of monobasic phosphate was 10 g/kg of contaminated soil.

Dibasic phosphate salts were also added at a dosage rate of 3.3 g/kg. Water was added to the soil in the mixing pit, and the resulting soil slurry was extensively mixed. Once mixed, the soil slurry was transferred to anaerobic cells 1 and 2. Water was added to provide one foot of additional cover above the solids in each cell. Each cell was then covered with a plastic sheet and incubated for 61 to 76 days. Samples were collected on day 1 and day 61 from Cell 1 and on day 1 and 76 from Cell 2. Analysis of the samples indicated that the average toxaphene concentration was reduced from 23 mg/kg to 8 mg/kg. This corresponds to a percent removal of approximately 67 percent removal in 68 days. The post-treatment concentrations were below the 17 mg/kg action level established for the site. In 2004, the total cost of treatment in USD was $65,000. Consequently, the unit cost of treatment at this site was$98 per cubic yard.

Gila River Indian Community Site

The Gila River Indian Community (GRIC) site is located in Chandler, Arizona. Approximately 3,500 cy of toxaphene-contaminated soil required treatment at this site. Four lined cells were constructed with dimensions of 178 ft by 43 ft by 7 ft (deep). This dosage rate was lower than for other sites to reduce costs. The dosage rate of blood meal, sodium phosphate, and dibasic phosphates was 5 g/kg of contaminated soil. Blood meal and phosphates were first mixed in a pit, and then blended with contaminated soil using a pug mill (100-300 cy/hr throughput). The mixture was then transferred to cells filled with water to 25 percent capacity. Additional water was then added to the cells to provide one foot of cover above the solids. Each cell was then covered with a plastic sheet. Samples were collected from the cells after initial setup and at the end of 3 months, 6 months, and 9 months. The removal of toxaphene in GRIC site soil took longer than usual due to the reduced amendment dosage rates. The average toxaphene concentration at the end of 180 days ranged between 4 mg/kg and 5 mg/kg demonstrating 83 to 88 percent toxaphene removal. The samples collected at day 272 showed residual levels of 2 to 4 mg/kg corresponding to a percent removal between 87 and 98 percent. The post-treatment concentrations were below the 17 mg/kg action level established for the site. In 2004, the total cost of treatment in USD was $793,000. Consequently, the unit cost of treatment at this site was $226 per cubic yard.

Table 1
Performance Data for Anaerobic Bioremediation of Toxaphene Using Blood Meal at Selected Sites

Site Name	Untreated Concentration (mg/kg)	Treated Concentration (mg/kg)	Period (Days)	Percent Reduction	Volume Treated (cy)
Navajo Vats Chapter					
Nazlini	291	71	108	76	NA
Whippoorwill	40	17	110	58	NA
Blue Canyon Road	100	17	106	83	NA
Jeddito Island	22	3	76	77	NA
Poverty Tank	33	8	345	76	NA
Ojo Caliente	14	4	14	71	200
Laahty Family Dip Vat	29	4	31	86	253
Henry O Dip Vat	23	8	68	67	660
Gila River Indian Community					
Gila River Indian Community (Cell 1)	59	4	272	94	
Gila River Indian Community (Cell 2)	31	4	272	87	
Gila River Indian Community (Cell 3)	29	2	272	94	
Gila River Indian Community (Cell 4)	211	3	272	98	3,500

Note:
mg/kg: Milligrams per kilogram
NA: Not available
Source: Refs. 1, 2 and 6

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PATENT NOTICE:
This technology has not been patented.

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