CONSTRUCTION AND OPERATION OF A BIOTREATMENT FACILITY FOR REMEDIATION OF HYDROCARBON CONTAMINATED SOIL

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INTRODUCTION

Ground water resources can be rendered unfit for use by hydrocarbon contamination in the parts per billion (ppb) range (i.e.; levels greater than the drinking water standard of 5 micrograms per liter). Contaminated soils around fuel handling facilities often contain spilled or leaked petroleum products in the thousands of parts per million (ppm) range (milligrams per kilogram). These soils present a source of contamination that can release product continuously and/or at every rise and fall of the ground water level. Rain and surface water can leach through the source of contamination and transport hydrocarbons to the ground water.

In early 1989, six 30,000 gallon underground jet fuel tanks were removed from an out of service facility in Tennessee. During the removal operations, routine soil samples were taken for lab analysis. The samples were analyzed utilizing a total petroleum hydrocarbon method. This method, EPA 418.1, uses infrared light to detect the presence of petroleum hydrocarbons in soils. The results of the analyses showed that the soils around and beneath the tanks contained petroleum hydrocarbons at an average level of approximately 3500 milligrams per kilogram (mg/kg) and in certain localized areas or hot spots as high as 7500 mg/kg.

Little vapor was detected in field analyses with a flame ionizing vapor detector. This observation, relative to the laboratory data, indicated the hydrocarbon contamination encountered consisted of the heavy end components of the various jet fuels lost since operations began in the 1960's.

Subsequent excavation produced 3500 cubic yards of soil contaminated to levels above the State regulatory limit of 100 ppm. This soil had to be disposed or treated and several methods of treatment were considered including: offsite landfilling, offsite incineration, onsite incineration and onsite biotreatment. The first two methods were not chosen due to their high cost and continuing liability. Onsite incineration was not feasible due to air permitting problems. The eventual choice was onsite bioremediation due to both environmental and economic considerations.

Because of the restricted size of the site, land farming was not a viable option. Therefore biotreatment cells were designed in order to have microbes destroy the hydrocarbons which were present in the soil. Design and construction of the two required cells took 8 weeks. Operation of the cells continued for 9 months, at which time the soils were remediated to below the level of regulatory concern; in this case 100 mg/kg.

The average TPH of the soils was reduced from 3500 mg/kg to less than 35 mg/kg or ppm. The eventual levels of remediation were 99% removal or 2 orders of magnitude reduction. The results of the monthly monitoring are presented in Figure 1.

BIODEGRADATION PROCESS

In order to successfully biotreat hydrocarbon contaminated soil, several factors must be controlled. These factors include oxygen supply, trace nutrient supply, moisture content and temperature. A bioassay of the soils was conducted which revealed that hydrocarbon degrading bacteria were present on the site. A bench scale (pilot) study was undertaken which determined these naturally occurring bacteria were already acclimated to the type of soil present and to the climate occurring at this site.

The bench scale study further showed that by adding nutrients such as nitrogen and phosphorous, keeping the soil at an optimum moisture content of 50% to 85% and aerating the soil the bacteria could be induced to more efficiently use the hydrocarbons as a source of food.

The engineering problem was to scale up the pilot study from a few pounds of soil to encompass almost 5000 tons of soil.

BIOCELL CONSTRUCTION

Adjacent to the tank removal site, an area of approximately one acre was available for the remediation. The size of this one acre site dictated the design of the biocells. The pilot study had shown that the soils as removed from the excavation were not porous enough to allow oxygen to flow to the microbes within the interior of the cell. Therefore a bulking agent was necessary to create void spaces within the soil to allow air and nutrient flow.

The ratio of bulking agent to soil required to obtain adequate air flow turned out to be approximately 1 to 4 by volume. Several types of bulking agents were tried including gravel, wood chips and peat moss. By trial and error wood chips were found to be the most effective. In all, approximately 1000 cubic yards of wood chips were blended with the 3500 cubic yards of soil producing almost 5000 cubic yards of material that would have to be contained within the biocells.

Volume calculations revealed that the two cells proposed would need to be 150 feet long by 65 feet wide and 6 to 7 feet high. This configuration allowed the two cells to be placed side by side approximately 20 feet apart leaving a 10 foot margin all the way around for access and buffer.

Construction began by spreading a 3 inch layer of sand on the area that would become the footprint or base of each individual biocell. Using the natural grade of the site, a sump was constructed in the lower corner of each cell. The sump was sized to hold 100 gallons of leachate. A 6 inch berm was also constructed around the perimeter of each cell base using the sand material.

A 30 mil. PVC liner was placed on top of the sand which, together with the 6 inch berm built from the sand, became the base of the biocell. Over the 30 mil. PVC liner a geodrain and a geofabric were placed. This allowed the nutrients and moisture placed into the cells to drain through them and move down gradient along the geodrain to be collected by the sump for recycling.

Once this phase of the construction was complete, the soil blending operation began. Using front end loaders, soil and wood chips were roughly blended together in the ratio of 4 volumes of soil to 1 volume of wood chips. After this material had been mixed several times in the bucket of the front end loader, it was placed into a hopper and further blended using a pug mill.

A conveyor belt was then used to place the mix in piles until it was needed in the biocells.

Using a low ground pressure bulldozer, a two foot thick lift of soil was placed in the bottom of the first cell. On top of this was placed the aeration system. The aeration system consisted of two inch PVC piping which had 3/8 inch holes drilled at ten o'clock, two o'clock, four o'clock and eight o'clock every 6 inches along the pipe. This pipe was laid horizontally on the first lifts of soil mix and surrounded with crushed gravel in order to keep the holes from plugging. The aeration piping was placed on 10 foot centers and extended out of one side of the pile and connected through individual 2 inch ball valves to a 4 inch manifold.

The perforated portion of the piping was limited to the center of the biocell to within approximately 5 feet of the surface on either side. A two foot square plywood collar was placed at the end of the pipe and around the pipe where it exited from the pile in order to keep air from short circuiting from the surface along the outside of the pipe. At each end of the 4 inch manifold, a Rotron vacuum blower was connected to draw air through the aeration system.

After the aeration piping was placed and surrounded with a gravel pack, another 2 foot lift of soil was placed into the cell. On top of this lift the nutrient supply piping was placed, also surrounded by a gravel pack. Finally, the last 2 foot lift of soil mix was placed and the entire cell covered with a second 30 mil. PVC liner in order to control temperature, dust and prevent rain infiltration.

A 500 gallon tank was used to provide a mixing vessel for the nutrients. This tank was connected through a pump to the nutrient supply system. Nutrients were mixed in the tank and pumped through the pipes in turn to each cell to maintain a level of moisture of between 50% and 85%. The nutrients used were normal agricultural fertilizers which supplied nitrogen and phosphorous for growth of the microbes.

Sump pumps were also installed to pump leachates from the sump of the cells to a second 500 gallon holding tank. It was then used for make-up water and returned to the cell. Additional city water was added as needed.

Thirty-five gallon size plastic drums were installed between the aeration fan and the 4 inch manifold to act as water knockouts so that entrained moisture would not go through the aeration fans. Water from these drums was also used for make-up.

Nutrients were introduced into the biocells and the aeration fans started up on October 22nd, 1989.

OPERATION AND MAINTENANCE

In order to avoid excessive vacuum in the aeration system and possible collapse of components, bleed valves were installed between the fans and the water knockouts in the aeration system. The fans were started with these bleed valves open and vacuum was monitored as they were closed and aeration was begun in the pile. Later it was found that air would move through the pile with little resistance and the bleed valves were able to be closed almost immediately.

Pressure in the aeration system ran a negative 1.5 pounds per square inch (psi). The aeration system calculations showed that approximately 300 cubic feet per minute of air was moving through each biocell. This is equivalent to 2 changes of air in the pore spaces of the cell per hour. One hundred gallons of nutrient solution was then introduced into each cell and overall moisture levels were monitored.

Each biotreatment cell was divided into 6 zones in order to monitor effectiveness of the treatment and to assure even distribution of the nutrients throughout the cell. The system was run until December 15, 1989, when it was shut down and the lines drained in order to prevent freezing in the nutrient system.

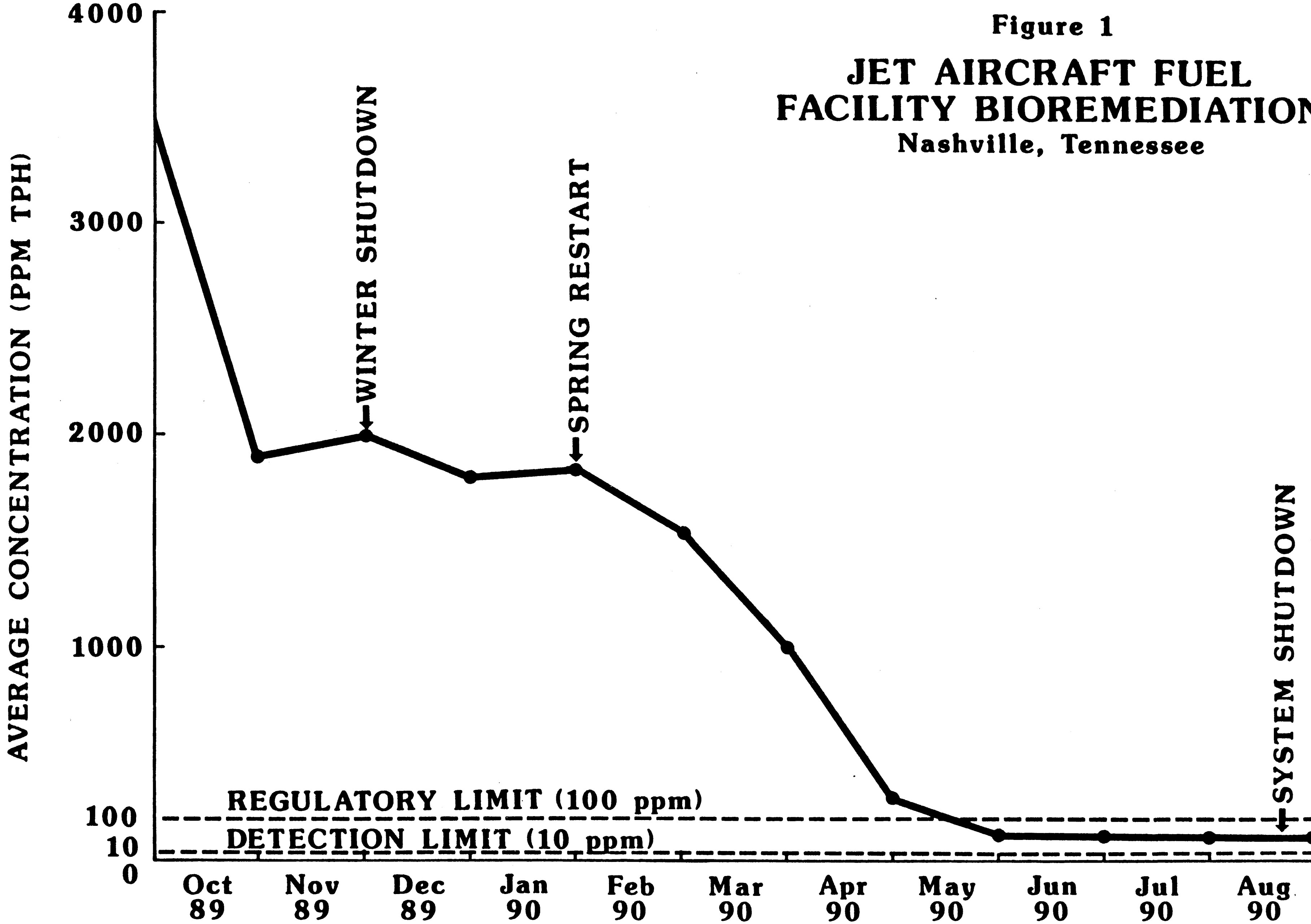
During this operational period, samples were taken from the 6 zones of each of the 2 biocells. The samples were analyzed for total petroleum hydrocarbons and then averaged to give an indication of the efficiency of the operation of the cells. During this time, average total petroleum hydrocarbons fell from 3500 ppm to approximately 2500 ppm.

The system remained shut down during subfreezing temperatures from December 15, 1989 until March 15, 1990, then

Figure 1

JET AIRCRAFT FUEL FACILITY BIOREMEDIATION

Nashville, Tennessee



nutrients were re-introduced into the system and the aeration system restarted. Samples taken in March showed that little biodegradation had occurred while the systems were shut down. During April and May, the hydrocarbon levels continued to drop as the weather became warmer. By the end of May, average levels had reached 1000 ppm.

As the weather became even warmer during June and July, water consumption in the cells went up considerably and average total petroleum hydrocarbons levels dropped to 300 ppm. By the end of June, in some cells they were down to the 50 to 60 ppm level. The system was operated during July and into the middle of August and each individual cell was monitored to be sure that all were below the 100 ppm level.

During July and August, individual zones of the cell were targeted to insure that the entire area was remediated. By the middle of August 1990 all zones were below 50 ppm and some were below detection levels. The average level of the total petroleum hydrocarbons in each cell was below 35 ppm.

The soil is now below regulatory concern and may be returned to the excavation with no further treatment.

CONCLUSIONS

Degradation of hydrocarbons found in soil by naturally occurring bacteria has been shown to be both cost effective and environmentally sound. Over the course of the 9 month period and particularly during the 3 months of warm weather during the summer, biomass was created from the hydrocarbon contamination in the soils. After treatment, these soils no longer presented a threat as a source of hydrocarbon contamination to ground water.

The successful large scale application of bio-remediation technology, as described herein, shows that by proper engineering, a large mass of soil can be effectively cleaned without the use of incineration or external heat sources.

The total cost of this remediation was under $100 per cubic yard or about $350,000 at this site.

During the operation at this site, soil samples were taken on a monthly basis from the 6 zones into which the cells had been divided. Moisture levels were measured by the use of tensiometers in the soil pile. The air exhaust from the fans was monitored with an organic vapor analyzer to be certain that simple venting was not the method used to remove the hydrocarbons.

No hydrocarbons were detected in the exhaust gases from the fans. In addition, the exhaust gas temperature of the fan ran about 75 degrees Fahrenheit even when ambient temperature was below 40 degrees indicating considerable generation of heat by biological activity within the soil pile. Temperature probes were not placed within the soil piles but probably will be in any future operations in order to monitor biological activity. Also noteworthy, the shutdown during the winter months was not due to a biological necessity but in order to keep the pipes from freezing in the cold weather. In the future, heat tracing or other methods may be used in order to operate year-round. The results of this sampling program indicated that the hydrocarbon levels dropped in accord with what would be expected with the level of nutrients supplied and the ambient temperature.

The average monthly cost to operate the two biocells was approximately $7,000 to 8,000 per month. This included the sampling activities, lab analyses, site visits, maintenance and approximately $200/300 per month in electrical costs to run the 4 two-horse power blowers in the two soil cells. This project has demonstrated that bioremediation is a practical means to treat soils contaminated with hydrocarbons on a large scale.

The biocells have since been de-commissioned and the remediated soil returned to the excavation. The site was graded and seeded and is now available for re-use.

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