# PLANTING CROPS ON LAND SPREAD WITH TANK BOTTOMS: A POSSIBLE DISPOSAL SOLUTION FOR OILFIELDS

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## ABSTRACT

Tank bottoms from a Williston Basin oilfield were applied to test plots in which crops were subsequently planted. Naturally occurring microbes reduced the 6% total petroleum hydrocarbon (TPH) concentration to 3.8% in a few months (a 37% reduction), but reduced it no further, possibly due to an insufficient amount of nitrogen or water or both. For the first three years of the study, the 6% TPH test plot did not grow crops. It was apparent that the high (6%) application rate of this high paraffin oil seriously restricted the infiltration of water into the soil; this is considered to be the primary cause of crop failure, rather than toxicity of the tank bottoms. After manure was applied in the fall of the third year, crops were successfully grown the following season. Two years after that, when the manure had degraded, crop growth was again very poor. The lack of water may have also affected the process of microbial oil degradation.

The second phase of the study examined the addition of straw and large amounts of nitrogen and phosphate fertilizer to new test plots. A 0.6% TPH concentration was applied to two test plots which had been previously planted to spring wheat. Because there had been no rain, the crop was poor, and there was concern that the application of oil plus tilling would kill the crop. When it did rain later in the summer, the seed left in the ground germinated and successfully produced a crop. The addition of straw did not increase the chances of crop growth; rather, it reduced the yield of the crop significantly, even with a higher rate of fertilizer application. The original 0.6% TPH concentration was reduced to 0.14% in one year, a 77% reduction, suggesting that lower application rates may remediate faster, in addition to allowing crops to grow.

This study suggests that application of low concentrations of tank bottoms on agricultural land may be possible, but additional research is needed to discover how to control the hydrophobic effects of this disposal method. The addition of manure (rather than straw) to land spread with tank bottoms appears to be favorable to plant growth by increasing water infiltration and retention.

***Key words:*** *tank bottoms, oilfield waste dispoasl, bioremediation, landfarming, hydrophobic soils*

## INTRODUCTION

Bioremediation of oil spills has been studied extensively over the past 30 years. This is a process in which naturally occurring microorganisms consume the oil and produce $CO_2$ and $H_2O$ as by-products (Biederbeck, 1993; Bleckman, 1989). After the Exxon Valdez disaster in 1989, large amounts of money were allocated for study of cleanup efforts to help environmental efforts throughout the world (EPA, 1990). During that time, studies were also undertaken to determine if bioremediation would be useful in the disposal of oilfield wastes. One such waste product is the material found in the bottoms of oilfield storage tanks. This material, known as tank bottoms, is a mixture of crude oil, salt water, sand, and scale from the tank itself. It is not saleable material and must be disposed of in an environmentally safe manner. Tank bottoms are commonly shipped to and stored in hazardous waste landfills. This disposal method is expensive, and these landfills may not be secure; lawsuits may be brought against companies long after materials have been buried.

Because of the cost and risk of disposing tank bottoms in landfills, a group of oil producers in the Williston Basin supported a study to look for an alternative solution. In 1994, the Energy Committee of the Chamber of Commerce of Williston, North Dakota, initiated a project which was designed to demonstrate that tank bottoms could be spread on agricultural land and bioremediated so that crops could be subsequently planted. The Williston Research and Extension Center, an extension of the North Dakota State University Agricultural Research Station in northwest North Dakota, donated a portion of their land for the demonstration, and the North Dakota State Health Department granted permission to carry out the project.

It should be noted that the process of spreading waste oil on soil, or landfarming, has become a standard oil field practice and is commonly used to remediate spills or to dispose of waste oil. An oil company may utilize a designated area for spreading oil, but that land is not farmed. This study is distinctive in its effort to plant crops in agricultural test plots spread with waste oil. The intent of this project is to provide the North Dakota Industrial Commission and the North Dakota State Department of Health with information that will help set guidelines for farmer/operator contracts allowing tank bottom spreading on agricultural land near oil field tank batteries.

## PROJECT DESCRIPTION

The study was conducted in two phases. The first phase ran from July 1994 to October 1998 and included extensive analysis of the soils for the first three years. The second phase ran from May 1997 to October 1998 and focused on the role of straw and fertilizer in the remediation process.

**Figure 1**. First application of tank bottoms to plots at the Williston Research and Extension Center.

### *Phase I*

The first phase used a 20 ft by 50 ft test plot and a control plot of the same size. The soils at the test and control plots were classified as Williams-Bowbells silty: all normal very fine sandy loams, loams, silt loams, and silts. Both plots sloped gently to the southeast.

Eleven barrels of tank bottoms from the Fryburg Oil Field (near Medora, North Dakota; production from the Interlake, Madison, Red River, and Devonian formations) were spread over the test plot using hand tools (Figure 1). An analysis of the oil is presented in Table 1. Because the tank bottoms consisted of 60% total petroleum hydrocarbons (TPH), the amount applied to the soil was 2600 lb or a loading rate of 6% TPH by weight to the top six inches of soil. The tank bottoms were then tilled into the soil, running three times north and south and three times east and west over the entire plot (Figure 2). Both plots were tilled monthly for the duration of the study.

Soil samples of both the control and test plots were analyzed over the next three years to

**Figure 2**. Tank bottoms were incorporated into the soil by tilling.

monitor total petroleum hydrocarbon (TPH), soil moisture, pH, conductivity, CEC, cations (Ca, Na, and Mg), anions (Cl and sulfate), SAR, and fertility (nitrogen, potassium, phosphorus). These analyses are plotted on Figures 3 through 5.

Nitrogen was added to this test plot at a rate of 100 lb/acre (2.3 lbs/1000 sq ft) over the course of the study, and these additions are noted on Figure 4.

One year after tank bottoms were spread (May 1995), both plots were planted in barley, spring wheat, lentils, and safflower. All crop plants grew well in the control plot. In the treated plot, only the barley emerged; it grew for about one month and then turned yellow and died. Gypsum was added to the test plot at a rate of 100 lb/1000 sq ft. The crops in both plots were then plowed under.

The following year (May 1996) the test plot was given an application of nitrogen (6.9 lb/1000 sq ft of 34-0-0) and phosphorus (1.3 lb/1000 sq ft of 0-44-0) and both plots were planted in Logan barley, Amidon hard red spring wheat, Linton flax, Trapper peas, and safflower variety 6011. Very little growth appeared in the test plot, while the crops in the control plot grew at a normal growth rate.

It was observed that soil in the test plot contained water puddles several days after a rain, while during the same time soil in the control plot had absorbed the rain and dried out. The soil beneath the puddles was dry. Using a clear plastic cup, it was further demonstrated that the soil was not absorbing water. It appeared that this hydrophobic property of the

**Table 1**. Tank bottoms sample analysis for Phase I.

| Component | Percentage |
|---|---|
| Oil | 60.04% |
| Water pH | 7.28 |
| Conductivity | <0.04 mmhos/cm |
| Sodium | 6,920 ppm |
| Chromium | 9.9 ppm |
| Lead | 19.7 ppm |
| Silver | <0.5 ppm |
| Barium | 11.6 ppm |
| Arsenic | <0.5 ppm |
| Selenium | <0.5 ppm |
| Cadmium | <0.5 ppm |
| Mercury | <0.1 ppm |
| Benzene | 385 mg/kg |
| Toluene | 1720 mg/kg |
| Ethylbenzene | 310 mg/kg |
| Xylene | 933 mg/kg |

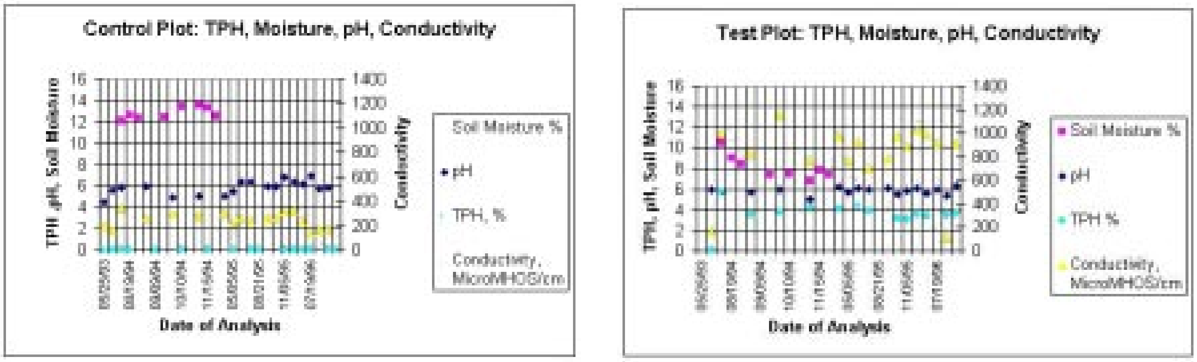


**Figure 3**. Total petroleum hydrocarbon, soil moisture, pH, and conductivity for the control plot and test plot through time.

oil-contaminated soil was a critical factor in its inability to produce crop growth. In July 1996, one gallon of surfactant (NoBurn, 89.9% Sarsaponin-Schidigera extract) was obtained to determine if the soil could be made to absorb water after application of the surfactant. Before the application of NoBurn to the test plot, two simple lab trials were performed. A sample of the soil from the test plot was placed into a foam cup; NoBurn was applied and thoroughly mixed into the soil. When water was added to the sample, it was absorbed. Another sample of soil was obtained from the test plot and placed in a plastic plate. NoBurn and seeds of wheat, barley, peas, and safflower were added; the seeds germinated and the plants grew well. This suggested that seed germination and plant growth was not inhibited by the oil, but rather by the lack of water in the soil. However, when NoBurn was applied to small areas within the test plot, it did not appear to condition the soil enough to support plant growth.

In October 1996, a truckload of manure (4000 lb/1000 sq ft) was applied to the southern half of the treated plot along with pelleted sulfur (200 lb/1000 sq ft), gypsum (200 lb/1000 sq ft), nitrogen (8 lb/1000 sq ft of 34-0-0), and phosphorus (2 lb/1000 sq ft of 18-46-0). In May 1997 and 1998, both plots were planted in hard red spring wheat. The manured half of the test plot grew crops (yielding 35.7 bushels/acre in the test plot for the 1997 growing season) as did the control crop, but the unmanured half of the test plot had no growth in either year (Figure 6).

***Phase II***

In October 1996, the project was scaled down and continued with two new test plots plus a new control plot. These plots were all 50 ft by 50 ft in size. Three barrels of tank bottoms from a production site near Keene, North Dakota, were spread on the two test plots. An analysis of the oil is presented in Table 2. Because the tank bottoms consisted of 77% TPH, we may estimate an application rate of 0.6%.

Because the soil in the test plot in Phase I was observed to shed water, it was proposed that straw could be added to the Phase II plots to increase water infiltration. One-half of each of the two Phase II test plots (plot #1 and plot #2) and the Phase II control plot was spread

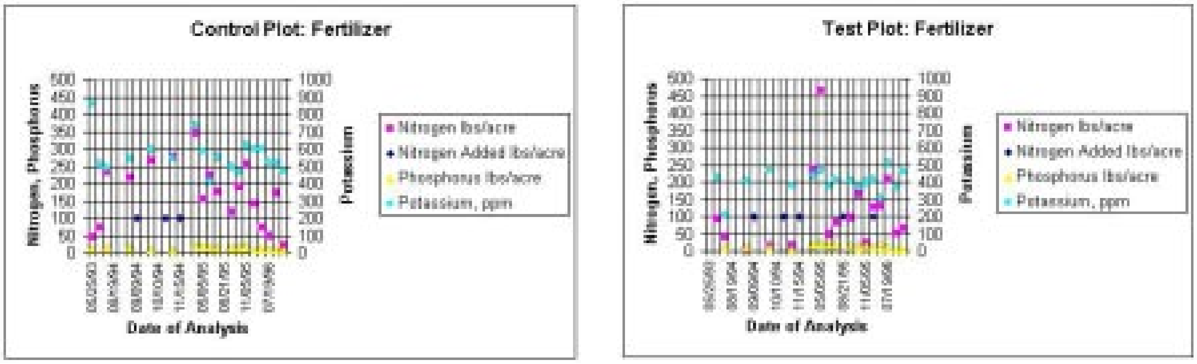


**Figure 4**. Nitrogen, phosphorus, potassium analyses for the control plot and test plot through time.

with straw at a rate of 45 lb/1000 sq ft. Test plot #1 received an application of fertilizer (34-0-0 at 40 lb/1000 sq ft and 18-46-0 at 80 lb/1000 sq ft). Test plot #2 also received an application of fertilizer (34-0-0 at 160 lb/1000 sq ft and 18-46-0 at 80 lb/1000 sq ft). The control plot received no fertilizer. The test plots were analyzed in June and October 1997 and the results are tabulated in Table 3.

All of the plots were planted in May 1997 (before the tank bottoms were applied) with hard red spring wheat, variety 'Keene.' Crops were successfully grown; the yield of each area of the plots is listed in Table 4.

Samples were analyzed for total petroleum hydrocarbons at the beginning of Phase II of the project (May 1997, before tank bottoms were spread) and the following spring (March 1998). These results are tabulated in Table 5.

## ANALYSIS

During Phase I, the total petroleum hydrocarbon (TPH) content of the soil dropped from 6% to about 3.8%, a reduction of about 37%.

**Table 2**. Tank bottoms sample analysis for Phase II.

| **Component** | **Percentage** |
|---|---|
| Water (pH 8.1, NaCl 12895 ppm) | 21% |
| Oil | 55.2% |
| Paraffin (7.73% asphaltenes, 14.34% wax) | 22.07% |
| Iron sulfide | 0.88% |
| Calcium carbonate | 0.62% |
| Magnesium as Magnesium carbonate | 0.07% |
| Zinc as Zinc Sulfide | 0.05% |
| Strontium as Strontium carbonate | 0.01% |
| Sodium as Sodium chloride | 0.10% |
| Total | 100.00% |

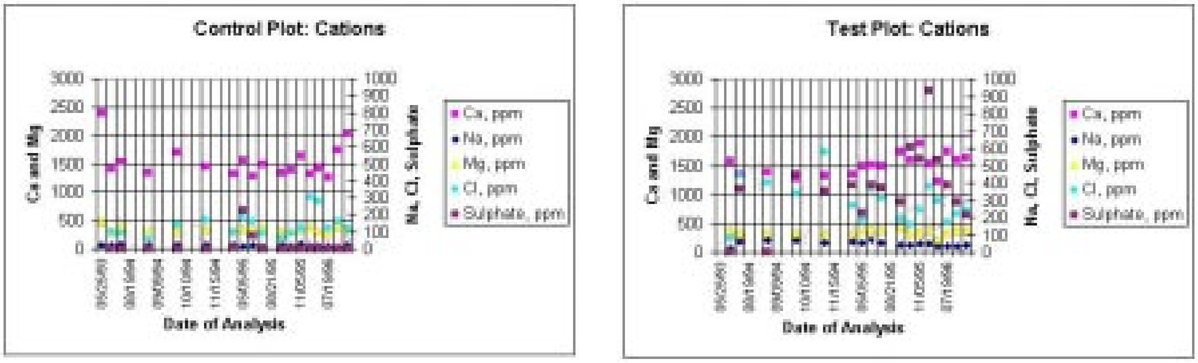


**Figure 5**. Calcium, sodium, magnesium, chloride, and sulfate analyses for the control plot and test plot through time.

As can be seen in Figure 3, it appears to have made that drop during the first few months, risen slightly in the winter months (probably a sampling aberration), and then dropped to its present level in the following summer. This lack of further TPH reduction may be due to the action of the microbes; initially they may have broken down the oil into other petroleum hydrocarbons and then eventually those products were further broken down to $CO_2$ and $H_2O$. It is also possible that some constituents of the oil were not utilized by resident microbes. Another factor may be the lack of water; oilfield operators in the Denver Basin include sprinkling contaminated soil with water to insure rapid breakdown of oil (Flynn, 2000).

The pH of both the test plot and control plot was similar. The conductivity, chloride, and sulfate were markedly elevated in the test plot, but were considered well within an acceptable range for barley and field peas (Ayers and Westcot, 1976).

In Figure 3, it is striking that the soil moisture in the test plot is about 50% less than the control plot. Intuitively, the water-repelling property of the oil and paraffin would cause this low soil moisture. Furthermore, it is possible that the successful crop growth in oily soils does not depend upon oxidation of the oil by microbes, but rather on getting sufficient water to the plants. After surfactant was applied to the oily soil, it was observed that the primary cause of poor plant growth was a lack of moisture in the soil rather than toxicity of the soil.

Figure 4 displays both soil fertility analyses and the fertilizer applications. The most impor-

**Table 3**. Nitrogen-phosphorus-potassium analyses for Phase II plots. May values are pre-fertilizer treatment.

| Date | Control | | Test Plot #1 | | Test Plot #2 | |
|---|---|---|---|---|---|---|
| | Straw | No Straw | Straw | No Straw | Straw | No Straw |
| May | | 44-23-295 | | 42-21-315 | | 36-11-185 |
| June | 31-19-315 | 59-28-345 | 100-121-450 | 62-93-340 | 108-101-235 | 190-120-200 |
| October | 31-12 | 33-20 | 143-63 | 137-63 | 227-62 | 236-62 |

**Figure 6**. After manure application to the original test plot, dark green crops grew (note the area adjacent to the test plot—upper left of photo). The bare area is the test plot that did not receive manure.

tant observation was the nearly complete removal of nitrogen in the test plot during the first year. Following each of three applications of nitrogen, the control plot showed high levels of nitrogen, while the test plot showed very low levels of nitrogen. Furthermore, with application of nitrogen, one would expect to see a commensurate decrease in the TPH values, but this was not the case. It is likely that insufficient nitrogen was applied to the test plot to allow the microbes to oxidize the oil. Other workers (Gawel, 1995, McMillan, 1994) have suggested that the most efficient microbial activity will occur when the carbon: nitrogen: phosphorus ratio is 100: 10: 2.5 to 5. If it is assumed that the oil contained 80% elemental carbon (1800 pounds), then 180 pounds of nitrogen should have been applied, but in fact only about 16 pounds were applied.

Because other studies suggested that oil-loading rates of from 5 to 10% by weight could be applied to the soil with success (Kincannon, 1972), it was considered that the loading rate of 6% in Phase I would be acceptable. However, this may be more practical for non-cultivated lands. A field experiment in Alberta, Canada (Pojasok et al., 1992), showed that crops planted into soil with 0.5% freshly applied oil produced half the yield of untreated control plots. In both greenhouse and field trials, the 0.5% to 1% loading rate produced the fastest percentage of oil degradation. Two applications of 0.5% gave the fastest rate of degradation (Macyk et al., 1992). This rate approximates the loading rate of Phase II (0.6%), in which crops were successfully grown.

The biodegradation of the 0.6% to 0.14% (an average of the two test plots in Phase II) records a TPH reduction of 77%, a much higher rate than in Phase I. These results reinforce the importance of low TPH application rates. Not only does it appear to control the success of crops, but it may also control the rate of remediation of oil-contaminated soil.

The addition of manure appears to have been very beneficial in promoting plant growth in the Phase I test plot in the first year after

**Table 4**. The crop yield for the Phase II plots.

| Yield, bushel/ acre | Control | | Test Plot #1 | | Test Plot #2 | | Original Plot |
|---|---|---|---|---|---|---|---|
| | Straw | No Straw | Straw | No Straw | Straw | No Straw | Manured Plot |
| 1998 | 21.0 | 23.6 | 20.5 | 22.9 | 33.9 | 21.5 | 35.7 |
| 1999 | 23.7 | 22.6 | 32.3 | 31.6 | 29.8 | 32.7 | 11.8 |

application of the tank bottoms. However, as the manure biodegraded, the plot reverted to its original hydrophobic state and crop growth was poor in the third year after application. It is likely that the manure added enough wetable material to allow water infiltration and retention and thus allowed the crops to grow. The resident microbes may have preferred the manure to the oil, breaking it down and consuming less oil.

## CONCLUSIONS

Agricultural land spreading of tank bottoms from Williston Basin oilfields may successfully grow crops in the same year as the application with a loading rate of 0.6%. If a loading rate of 6% is used, it is unlikely that the soil will grow crops, largely due to lack of water infiltration. Large, frequent applications of fertilizer may be required to maintain nitrogen concentrations that are favorable for the oxidation of oil by microbes. Application of manure appears to be beneficial due to its effect of increasing water infiltration and retention, and may promote plant growth within a few years following a 6% loading rate.

Although this study offers encouragement for future collaboration between farmers and oilfield operators in dealing with tank bottoms, additional research is necessary. Because the soil may be rendered hydrophobic by the oil, there should be assurance that the practice of spreading tank bottoms on agricultural land does not bring a legacy of poor crop performance.

## ACKNOWLEDGMENTS

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**Table 5**. Total petroleum hydrocarbon percentage in Phase II plots.

| | Control No Straw | Test Plot #1 No Straw | Test Plot #2 No Straw |
|---|---|---|---|
| May 1997 | .0083% | .0077% | .0089% |
| March 1998 | .0064% | .091% | .18% |
| March 1999 | No Sample | .0455% | .0436% |

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