Sustainable Environmental Remediation (SER) Through Bioremediation of Petroleum Contaminated Soils*

Satya Ganti, *Sarva Bio Remed, LLC*

Abstract

Reduction in the amount of greenhouse gases (GHGs) emitted per industrial or residential operation is a primary objective for any sustainable remediation project. Employing bioremediation solution will significantly reduce the amount of energy needed to treat a ton of petroleum-contaminated soils. However, since the actual time for cleanup using our bioremediation products takes about three weeks, we are able to measure the energy savings. The present paper discusses case studies on some of the projects completed in the US, the European Union and in Brazil using our bioremediation products. The paper also compares the time and cost of bioremediation to the calculated costs of conventional excavations and transportation to a landfill site and determines the carbon footprints for each. We conclude that bioremediation should be a primary approach for treating petroleum contaminated soils. It has been shown that the bioremediation using our products promotes functional ecological revitalization by restoration of the natural fauna and flora at the cleanup sites.

Introduction

Sustainable Environmental Remediation (SER) is an important concept for achieving cleanup of contamination in soil and groundwater worldwide and it has been our effort to reach the goal of maximizing the social aspects of sustainability, namely addressing environmental remediation keeping in view the social and economic issues. We present a bioremediation solution that meets all the basic requirements for the sustainable remediation, namely:

- Accelerating a natural degradation process with fine grained nutrient control
- Reducing greenhouse gases (GHG) using
    - Minimal transport
    - Minimal use of mechanical equipments
- Reducing contaminants within short periods of time to pre-spill levels
- Addressing social and economic aspects of remediation
    - As an example the Virginia Department of Environment Quality deploys our products to limit the cleanup costs to less than $1000
    - Reducing the amount of volatile Organic Compounds (VOC) produced due to and during the remediation process.

US EPA identifies the process of green remediation as a practice of considering environmental impacts of remediation activities at every stage of the remedial process in order to maximize the net environmental benefit of a cleanup. The volumes of carbon dioxide emissions produced on an annual basis for non green remediation systems are very large and are given below.

*Published in the "**Proceedings of International Conference on Green remediation: Environment, Energy and Economics"** held at University of Mass., 2010.

Table 1: Estimated CO_2 emissions using of five types of cleanup technologies

Sl. No.	Remediation system	Amount in Metric Tons/year
1	Pump & Treat	323,456
2	Thermal Desorption	57,756
3	Multi-Phase Extraction	12,000
4	Air sparging	6,499
5	Soil Vapor Extraction	4,700
6	Bioremediation	Not determined in the reference

US EPA has indicated that there should be greater reduction in the costs of operations and maintenance (O & M) for different remedial designs and use environment friendly utility sources like wind energy or solar energy. Our bioremediation solutions effectively reduce energy consumptions for remediation of petroleum contaminated soils. In our experience the cost of treating one ton of heavily contaminated soils with TPH (total petroleum hydrocarbons) concentrations exceeding 100,000 ppm is about $78.00 which is less than the cost of moving and disposal of soil at landfill is $84.00 per ton (Personal communication from the information given by the contractors in VA).

Accelerating natural degradation process with fine grained nutrient control

Bioremediation of contaminated soils through 'natural attenuation' is a well recognized fact. However, it generally takes a very long time to achieve the standards of remediation stipulated by the state and federal regulators. We have been able to jump start the process using our products containing live bacteria available in a ready to use form and thus are able to accelerate the natural degradation process using optimal concentration of nutrients. This is shown in case studies below.

Case study 1: Remediation of soil contaminated with heating oil spill

At a Pennsylvania residence, during servicing there was a release of oil due to overfill of the heating oil tank resulting in a major oil spill in the basement. The environment company cleaned up the spill as per the protocol and the residual soil was treated with our product and after three weeks, the values of BTEX and volatile organics were less than the values stipulated by PA DEP as shown in Figure 1 below. DEP declared the site safe as both the soil and the ground water showed values less than stipulated; however the DEP stipulated that ground water monitoring be continued for one year before the complaint is closed. The results of the ground water monitoring data are given below in Table 2.

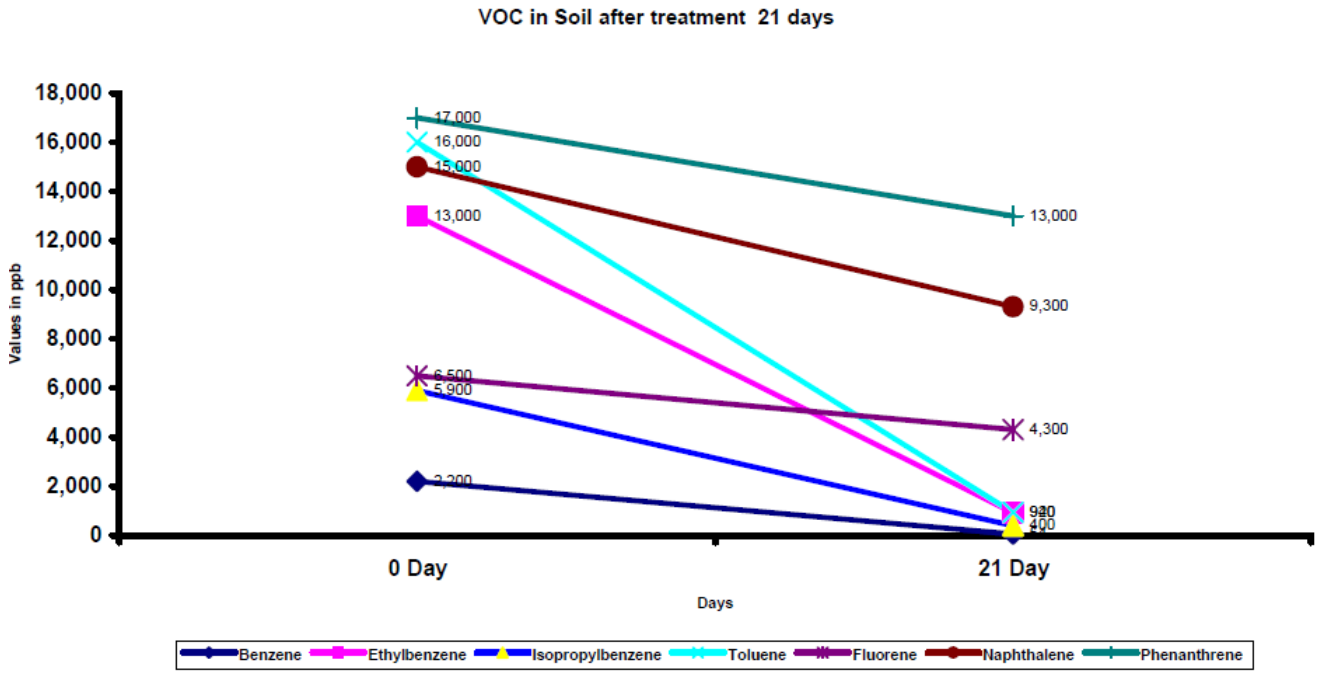


Figure 1: Graph showing reduction of volatile organic compounds in soil

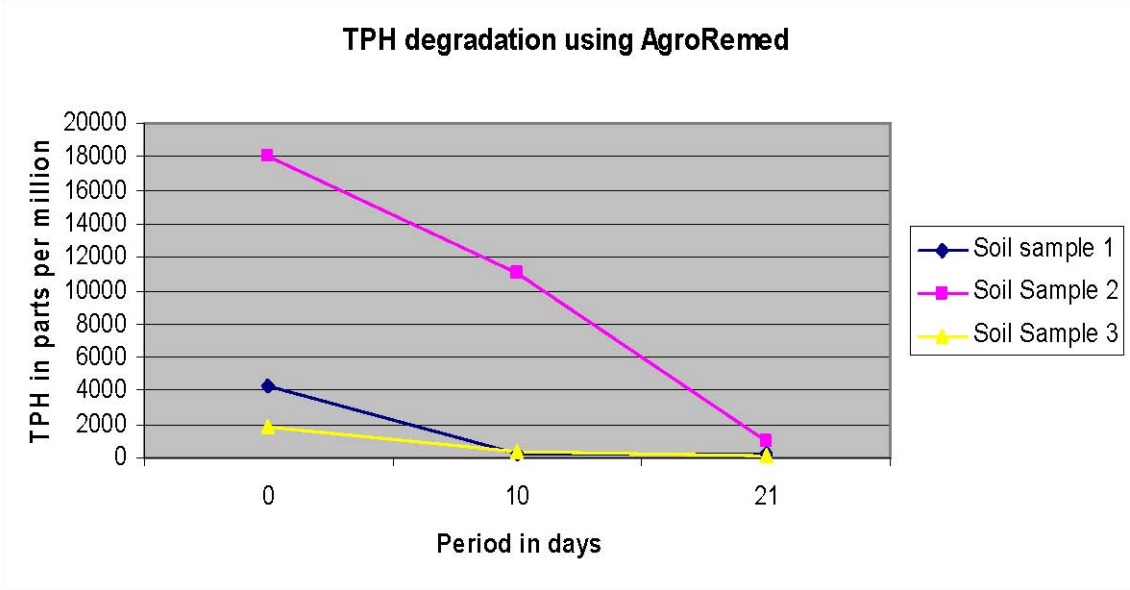
Location/Date	Benzene	Ethylbenzene	Cumene	Fluorene	Naphthalene	Toluene	Phenanthrene
MSC	5	700	1,100	1,500	100	1,000	1,100
West Sump							
2/16/2005 (Before)	120	130	28	970	2,800	340	2,700
3/11/2005	12	54	25	160	280	64	430
3/29/2005	NS	NS	NS	NS	NS	NS	NS
5/2/2005	NS	NS	NS	NS	NS	NS	NS
1/19/2006	<1	<2	<2	<2	<2	<2	<2
4/25/2006	<1	<2	<2	5	<2	<2	16

Table 2: Results of groundwater monitored for one year showing values for BTEX below the health standard stipulated by the State (Values are in parts per million)

Case Study 2: Pilot Project on Remediation of contaminated soil in Virginia

Virginia Department of Environment Quality (VA DEQ) decided to evaluate our product for on site cleanup of contaminated soil at an oil terminal located near the City of Newport News in Virginia. The pollution complaint for the site for evaluation was first filed in 1991 and since then the city has been incurring expenses towards standard operations and maintenance practices to handle any free product. In 2006, VA DEQ decided to evaluate the effectiveness of our products for the cleanup with the single objective that the project would terminate on 21st day with only 2 readings, first one on the 10th day and the second one on the 21st day to confirm the validity of the process and the results are given below. As can be seen, the total contaminants were reduced to below 1000 ppm in three weeks and since this process is *in situ*, the energy consumption during the entire process was close to zero.

Figure 2. Reduction of greenhouse gases (GHG) using minimum transport &



mechanical equipments

Case Study 3: Cleanup of soils contaminated with transformer oil

In Brazil, a state owned utility plant has frequent spills of transformer oil at the utility poles in the field and many times these sites are not easily accessible and often do not have power outlets. In these situations it is difficult to use any other solution but a bioremediation solution. Since our products are available in a ready to use liquid form and are available as “use as received” the application of our solution was quite simple and required little operational support as can be seen in the photographs below (Figures 3 and 4). The analysis of the results of the soil after treatment at a depth of 70 cm, showed

an average value of 36 ppm, which was lower than the value stipulated by the regulators of 50 mg/kg. A total of 10 piles/stacks of soil were treated with AgroRemed BR CTBA. There was no physical removal of soil by trucks nor was any additional mechanical support equipment used preventing production of greenhouse gases. The site was cleaned

in four weeks' time without expensive implements.

Figures 3 (Left) show the product being transferred from the drum into a garden sprayer and Figure 4 (Right) shows application on the piles of contaminated soil and gravel.

Case Study 4. In situ bioremediation at a gas station

Soil below the pavement under a canopy at a working gas station showed contamination with diesel and the owner wanted to clean up the station without excavation and shut down of the station. The company selected our product for in situ treatment after drilling 25 injection wells around the area of contamination our product was added directly into each of these wells (Figure 5 & 6). The project was started on December, 15 2009 and after one week the temperatures dipped below freezing and remained so for the first three months of 2010. The values of aliphatic, aromatic and BTEX constituents were monitored and as seen from the table below these values were recorded to be less than stipulated by the regulators.

Figures 5 (Left) shows the canopy of a gas station and Figure 6 (Right) shows the application of our products through an injection well.

Case Study 5: Roadside Assistance

There are frequent accidents on highways and major roadways resulting into spillage of fuel onto the embankment alongside of the road. In these situations, excavation of soil and hauling the same to the landfill site is conventionally practiced, resulting in transport of hazardous contaminants. However in certain situations, Virginia DOT and WV DEP consider use of our product to reduce movement of contaminated soil to a landfill site and have used in situ bioremediation particularly where the underlying utility lines prevent safe excavations as seen in figures 7 and 8 below. In this case, the TPH of the soil was reduced from 26,000 ppm to 96 ppm in three weeks. An advantage of in situ remediation is reduced costs for laboratory monitoring as
our products generally remediate in three weeks. This aspect was particularly mentioned in a meeting.

Sensitivity to social and economic constraints

Case Study 1: Improvement of indoor air.

In a residential facility, an heating oil spill was cleaned up through excavation, removal of contaminated soil and the area was covered with clean soil and gravel before the basement was sealed as per the standard protocol. The homeowner returned and noticed that the house was still filled with noxious heating oil odors. A new contract was now awarded to a different contractor with standing instructions that there will not be any invasive work in the house. Our product was added to the residual contamination beneath the freshly sealed basement through available points of injection and the indoor air was monitored. The results show that during the second air sampling the values were almost non-detectable after a single application of our product. The treatment was non-invasive and the basement was not damaged during the application. The house was reoccupied as

Figure 7 (Left) showing the accident site with the underlying cables on left preventing excavation of soil and Figure 8 (Right) the site of in situ bioremediation.

there were no odors in the house and the owner was fully satisfied. The VOC contamination was completely removed by treatment at the site. In our opinion it is relocation of soil and persons indirectly contributes to an increased carbon footprint.

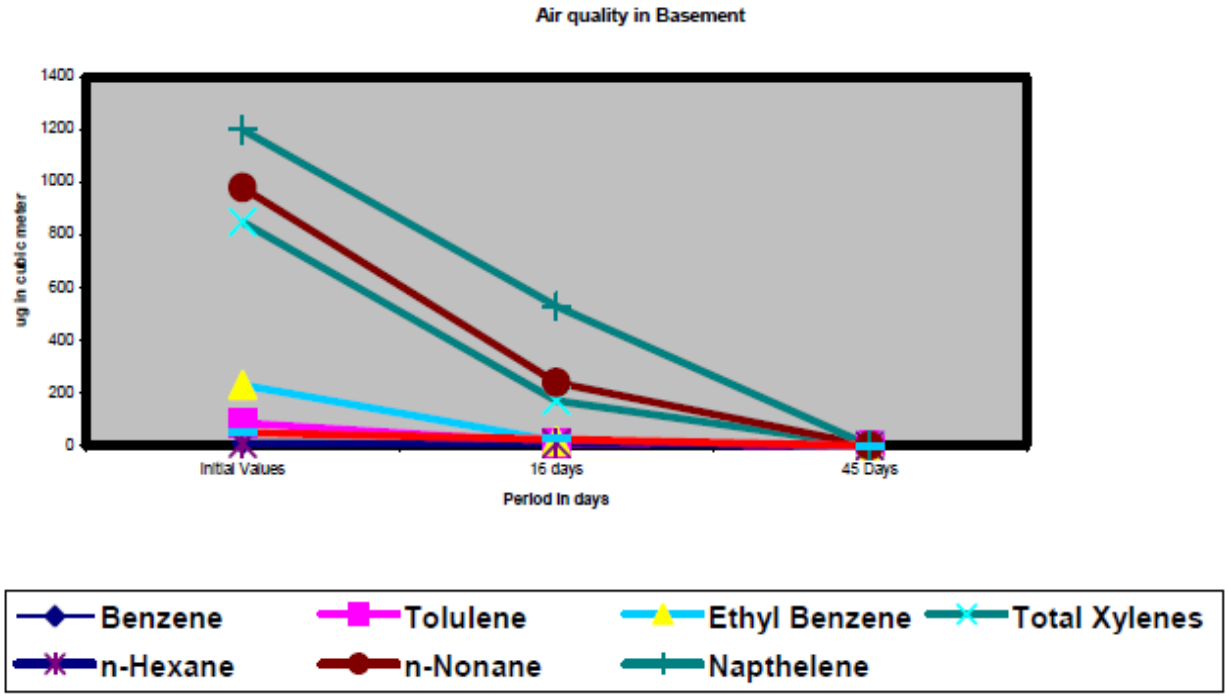


Figure 9.: Graph showing the reduction of VOC with one application of our product.

Case Study 2: Vapor intrusion in the house.

The owner of a house reported a strong smell of heating oil in the living room and other areas of the house emanating from the unused Underground Storage Tank (UST) located on the opposite wall of the garage (Figures 10 and 11). At the insistence of the owner to use only non invasive methods, a soil sample was collected from the area around the UST without damaging the flooring, and the Total Petroleum Hydrocarbons (TPH/DRO) was 43,000 ppm --more than three times the value for saturated soil. VA DEQ agreed that it would not be possible to remove the UST without damaging the structure and concurred to apply one of our products to remediate the contamination in the soil in situ and after two applications in the area of contamination. The soil sample was analyzed for TPH and semi-volatiles and the results showed that the value had dropped to 143 ppm almost 99% of the original value and the presence of odor was eliminated and the pollution complaint was closed by the DEQ.

Figures 10 (Left) showing the house with oil stains and Figure 11 (Right) after treatment

Bioremediation: A complete solution

Case Study 1: Contained open water spill

In a remotely located mine in Canada, there was a release of diesel in the water in the contained berm, and it was being absorbed by an oil absorbent boom. However, the boom absorbed water and sank to the bottom, releasing all the absorbed oil. The company ordered 5 gallons of our product for in-situ cleanup of the contaminated water as seen in figure 12 below. Our product was added directly into the water and even in the most unfavorable temperature conditions, the contaminant was completely destroyed in six

Figure 11 & 12. The spill in a contained berm in Canada was treated with single addition of our product as seen in Figure 12 on the right.

weeks' time and the water was discharged in the waste stream (see figure 13 below). Most importantly there was no waste for disposal. The water temperatures had dipped

below freezing and it was raining throughout the period. However, the product worked after one application to the satisfaction of the customer. There was no need for maintenance or any supervision and the water was released in the waste stream.

Case study 2: Treatment of contaminated soil at a Gas Station.

We had carried out a project for in situ remediation of contaminated soil underlying the pavement by directing our product through 25 injection points around area below the canopy. The results in Figure 14 below indicate that the soil was free from contamination and the values were below those stipulated by the regulators.

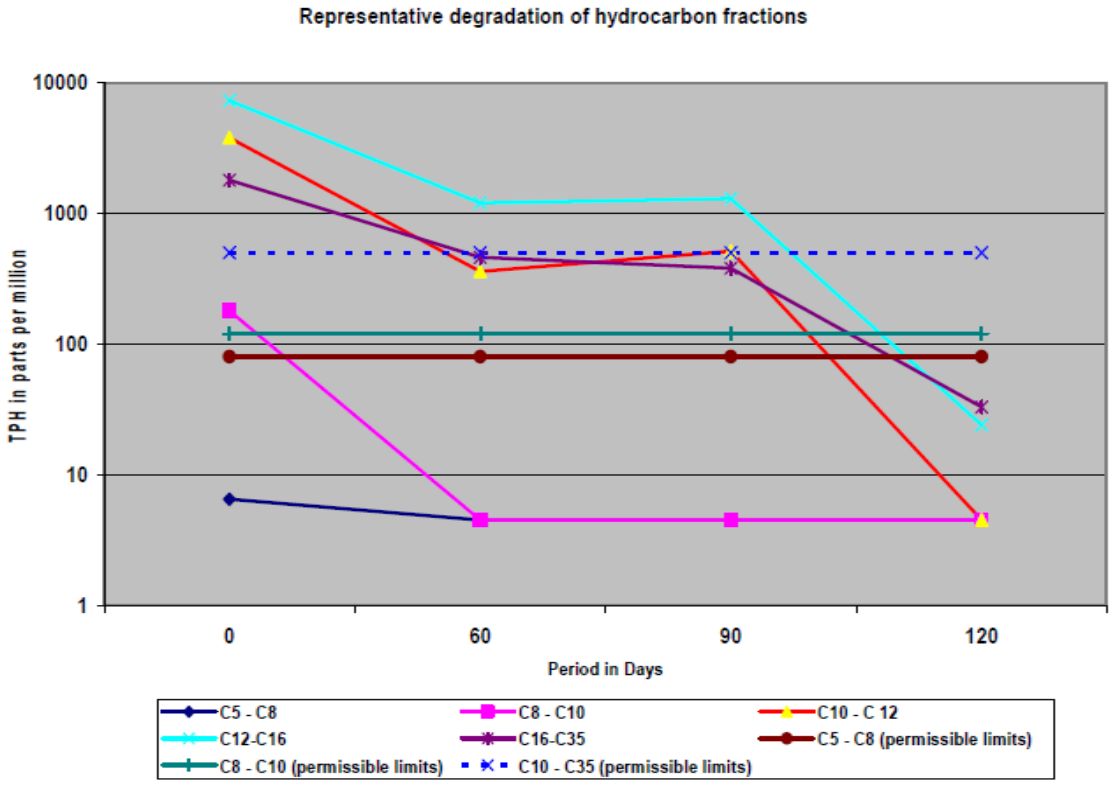


Figure 13. Degradation of hydrocarbon fractions in contaminated soil after addition of our product at a gas station when the temperatures were - 12 °C

Possible release of excess nutrients during bioremediation

The table below shows the product composition and the concentration of nutrients when the product is applied in the ratio of 1:10 (1 part of our product to 10 parts of oil). Low amounts of nitrogen released by our product reduce the potential for the formation of an algal bloom in water. The table below shows the product composition and the concentration when the product is applied in the ratio of 1:10 (1 part of our product to 10 parts of oil). We believe that these low amounts of nitrogen will reduce the potential for the formation of an algal bloom due to addition of our products.

Table 3: Product composition indicating nutrient levels in our products

	Composition	**Application value (1:10)**
Ammonia (as N)	**210 ppm (mg/L)**	**21 ppm**
2-Butoxyethanol	**<0.1 (mg/L)**	**.01 ppm**
Lauryl phosphate	**15.5 (mg/L)**	**1.5 ppm**
Carbon dioxide	**906**	**90.6**
Standard plate count	**9 MM CFU/ml**	**900,000 CFU/ml**

Conclusions

It is seen from the case studies above that in-situ bioremediation using our products meets the general guidelines provided by the USEPA for Green Remediation and cleanup of petroleum contaminated soils.

Our technology is a low energy approach and since the contaminants are permanently destroyed, it helps in recovery of the economy and in restoring social structure of the local communities, particularly for state funded projects. Since our products permanently eliminate fuel oil fumes from contaminated soils without using any mechanical support equipment, the carbon footprint using our solutions is much smaller than other engineering alternatives.

Literature Cited:

Green Remediation: Incorporating Sustainable Environment Practices into Remediation of Contaminated Sites. Link