BIO REMEDIATION OF HYDROCARBON CONTAMINATED SOILS: EXPERIENCES FROM AUSTRALIA

W.M. TROTTER

Environmental Scientist for Groundsearch EES, Auckland, New Zealand

SUMMARY

Bioremediation is an effective way of remediating hydrocarbon contaminated soils and is a widely used technique in Europe, the US and Australia. The landfarming technique involves the application of nitrogen and phosphate to the soil, monitoring the soil pile to ensure optimum moisture and pH conditions are met along with ongoing aeration to ensure an adequate supply of oxygen is available to ensure maximum micro-organism population growth. A landfarming bioremediation facility needs to be adequately managed to ensure the community and surrounding environment are not affected by the remediation process. On site management practices include: dust suppression, noise and odour control, stormwater runoff control, sediment and erosion control, groundwater monitoring and regular sampling to monitor the progress of the remediating soil.

INTRODUCTION

Bioremediation is becoming increasingly popular as a method of cleaning up a wide range of contaminated sites around the world. In New Zealand it's application is relatively new but in other parts of the world such as Europe, the US and Australia the method is common place.

To date the most effective application of the method has been the clean up of hydrocarbon contaminated soils and water, but leading bioremediation consultancies are now developing methods for remediating soils with toxic metal contamination. This involves the introduction of genetically engineered micro-organisms which can accelerate and enhance their capacity to breakdown of these chemicals (Saville, 1991).

This paper is presented as an introduction to the landfarming technique and its application to hydrocarbon-based contaminated soils. The information presented in this paper is a combination of my experiences in the remediation of a decommissioned petrol depot in Eastern Australia (September 1995) and background information. For client security no details of the location of the site will be given.

BIOTECHNOLOGY: AN INTRODUCTION

Bioremediation is based on harnessing natural bacterial activity of micro-organisms to decontaminate hydrocarbon polluted soils. Bacteria remove contamination by converting the chemical pollutant into cell biomass, carbon dioxide and water. It is essential during the process to optimise site conditions to ensure their activity is enhanced. This is achieved by a variety of management practices which will be discussed later. The energy needed to drive these biochemical conversions is generated by the bacteria transforming a portion of the absorbed organic carbon into carbon dioxide and water, as illustrated by Eq. 1 (Lapinskas, 1989).

$$C_nH_{2n+2} + O_2 \rightarrow C_5H_7N2O^* + CO_2 + H_2O \qquad (1)$$

Actual biochemical pathways of biochemical degradation of hydrocarbon contamination depends on the particular substrate and the type of organism involved. Heterotopic aerobic microorganisms are almost exclusively involved in hydrocarbon decontamination because oxygen is a vital component needed for the process to occur (Lapinskas, 1989).

Bioremediation provides an alternative to more expensive and environmentally harmful remediation techniques such as incineration and removal to landfills.

Landfarming

This technique adopted by our company at the site in eastern Australia to clean up the hydrocarbon contaminated soil is commonly termed "enhanced landfarming". The technique involves the addition of nutrients, moisture and oxygen to the soil to produce the optimum conditions for micro-organism growth and hence degradation of the offending pollutant. Typically optimum degradation rates occur over the temperature range of 30-40° C (Lapinskas, 1989) at moisture contents that will vary for the different substrates encountered.

Vegetation or available mulch is often added to the remediating soil. Vegetation mulch has a composting affect on the soil thereby raising its temperature and increasing the microbial activity, while also breaking up the physical structure of dispersive soils and stiff clays, allowing fertilisers and oxygen to better penetrate the soil to greater depths as well as acting as a blanket to trap any remanent odours.

The same remediation technique is used for most types of hydrocarbon contaminated soil, whether it be from the light fraction, petrol end, or from the heavier oil and diesel end of the range. The soil volume affects the time taken for remediation of the soil, a smaller volume resulting in a more concentrated remediation effort. Warm weather conditions will also increase remediation rates.

SETTING UP LANDFARMING FACILITIES

In eastern Australia I was involved in the removal and transportation of 2000 m^3 of hydrocarbon contaminated soil as well as the construction of the bioremediation facility. In many cases, with respect to urban service station remediation, bioremediation is carried out on site, however in this case a patch of land at the local landfill facility was made available.

Typically a bioremediation pad needs to contain a low permeability clay or synthetic base, which has the vegetation and topsoil removed. This base is constructed to gently slope to one end for stormwater management and compacted to prevent the infiltration of leachate and rainwater runoff.

The pad is bunded to redirect any upslope surface runoff from around the outside of the pad and to capture and retain any runoff from within the remediation pad area. These are typically designed to withstand a 1 in 5 year storm event.

A drainage sump is located within the bund in the downslope corner. In the case of the pad I was involved in a 4 metre wide and 1 metre deep sump was designed. This was rather an overkill given the rainfall characteristics of the region, and perhaps reflected the NZ influence in its design. The water collected in the sump is recycled and irrigated over the treatment area to keep the material at an optimum moisture content.

At the site existing gum trees surrounding the site were used as a screen which helped to minimise visibility and dust movement.

Problems encountered

The site kindly made available by the local council was an area used for the disposal of night soil and grease trap waste from the local community for the past 30 years. This waste was pumped into 1.5 metre deep trenches which ran down the slope to the direction of the creek and into a sump 2 metres wide and at least 80 metres long. Five years prior to our involvement at the site the landfill manager filled in these liquid trenches with on site clay fill and let the area revegetate. We were completely unaware of the problem prior to construction of our facility. We were aware of the on the opposite side of the track in which grease trap waste from local restaurants and fast food outlets was dumped daily, but the past use of the other side of the track was not known.

The problem surface during rolling when the 20 tonne roller got bogged in the large sump on the lower part of the site. It was immediately evident from the smell! and the colour that this was grease trap and nightsoil waste. Samples were immediately dispatched to the laboratory to define its constituents so as to determine whether this would further contaminate our soil.

The waste contained several metals at toxic levels (ie. Zinc, Arsenic and Lead) along with the expected heavy oils and PAHs (poly aromatic hydrocarbons). While the oils would be likely to respond to bioremediation techniques, the metals would contaminate the soils we were bringing in. The heavy oils and even the PAHs can be successfully bioremediated but over a much longer time frame than that for petrol contaminated soils. Typically gas works soils contaminated with coal tars and phenols have been successfully cleaned up in within 15 months with a cost saving of 15-20% over landfilling (Saville, 1991). It was decided to remove as much of this grease trap and night soil material as possible and back fill the trenches with additional clay fill. The contaminated soil was stock piled on a corner of the pad and a proposal is underway to bioremediate this for the local council.

REMEDIATION MANAGEMENT

Soil was transported to the site in tarpaulin covered trucks, with all trucks accounted for using signed tracking documents. The soil was spread out on the biopad in a 300- 400 mm thick layer. At this site the soil is kept at the optimum moisture content by;

1. recycling sump water and mobilising by use of a sprinkler system, and
2. use of recycled landfill leachate which is dispersed by onsite sprinkler trucks.

A state of optimum moisture content is maintained to enhance the growth of microbial bacteria within the waste and tensiometers will be placed at various locations in the soil to monitor the moisture levels.

During treatment the soil is tilled fortnightly, using a tractor to ensure ample oxygen is available for aerobic conditions required to enhance microbial population growth.

Samples are regularly collected from the remediating pile and analysed to evaluate how well the treatment is working and to determine if different nutrients or treatment methods are required. Results are required to be checked by the local council and the regulating authority the EPA (Environmental Protection Agency) before the soil can be returned to the site or used as topsoil or night cover within the landfill. In this case the site was backfilled with overburden clay from a local quarry and the remediated soil was given to the local council. Given adequate time the soil could be a high grade topsoil suitable for use in park and garden development around the town. Generally speaking this soil is expected to b designated clean for refilling after 4 months.

ENVIRONMENTAL PROTECTION PRACTICES

Runoff Control

As previously mentioned surface water runoff from within the pad is collected in a large sump and use to irrigate the remediating soil. Surface water from outside the pad is not an environmental concern and is directed around the bioremediation pad by 2 metre wide drains.

In periods of unusually heavy rainfall, excess water from the bioremediation pad by overflow the sump, in which case it is directed through a series of vegetated overflow drains with a total length of 20 metres arranged in a zigzag fashion to allow any sediment in the water to drop out and also to control and slow down the flow rate at which excess water reaches the creek.

Odour control

Soil contamination by total petroleum hydrocarbons or benzene, toluene, ethyl benzene or xylene (BTEX), may produce odours for a short time when initially disturbed, but they tend to disperse quickly, disappearing within a few hours.

The case study site was located well away from residential properties and odour was not considered a problem. If odour is a problem mulch or polythene can be spread over the remediating pile to reduce the odour. The use of mulch is advantages as it provides green waste which increases the humic and nutrient content in the soil.

Dust suppression

Factors which contribute to dust production include;

1. a cleared site,
2. stored backfill or topsoil material,
3. constant movement of machinery over a working site that is free of surface cover and,
4. wind blowing over a cleared site.

Generally dust can be controlled during traffic movement by water truck sprinkling. At the case study site with the access track was regularly used by small trucks dumping grease trap waste so the responsibility of the track was still managed by the landfill.

Sediment control and erosion

The control of sediment are important to consider when undertaking any earthworks. To recognise this the bunds were revegetated to further stabilise them and the overflow drain system previously described, was established.

Noise control

Noise producing machinery is needed when aerating the pile, and its use is logically kept to normal working week day hours.

MONITORING SYSTEMS

The surrounding environment needs to be monitored to ensure that the remediation process is in no way affecting it. At this site we installed four piezometers. One piezometer was located upstream of the pad to act as a background reference point, while a second was situated between the grease trap ponds and the biopad to monitor any movement from the ponds to the pad. Two further piezometers were located in the creek lowland area to monitor any downstream effects. Water was collected monthly from the monitoring points and analysed for total petroleum hydrocarbons.

ALTERNATIVE BIOREMEDIATION TECHNIQUES

The major limitation with traditional landfarming practices is the availability of space. For the technique to be effective soil at a maximum depth of 400 - 500 mm depth can be treated. This can pose logistical problems and a large surface area is required to treat fairly limited volumes of soil. Another restriction is the tilling or rotovation depth, usually 600 mm maximum. Further the maintenance of moisture content is a challenge given such a thin soil layer which is subject to the effects of wind and sun, and there is still a possibility of the downward migration of contaminated water or nitrogen into the groundwater.

Soil banking systems are an alternative to landfarming, however to go into their engineering, construction and management would warrant a paper in itself. Generally speaking the soil is thoroughly mixed then combined with a specialised inoculum of nutrients, substrate and trace elements followed by the set up of an active aeration, drainage and irrigation system. The soil is piled into a dimension that will depend on available space at the site with the systems mentioned above installed prior to covering the pile in polythene or some similar impervious material. Once again runoff of leachate from the soil pile or bank is used to irrigate the remediating soil (Lapinskas, 1989).

Insitu bioremediation is also typically carried out especially on urban service station sites. In many cases the site is excavated in stages and a part of the site is remediated then reinstated and remediation then moves onto the next stage. The method is typically slower than landfarming techniques but often necessary in cities where a bioremediation pad can not be established due to the lack of available or suitable land.

CONCLUSION

Biotechnology has proven effective for the remediation of hydrocarbon contaminated soils around the world. I have been involved in the enhanced landfarming aspect of biological treatment systems in Eastern Australia where they are used with significant success in the clean up of hydrocarbon polluted soils. This technique provides a cost effective alternative to incineration or landfilling (Lapinskas, 1989).

Disadvantages of bioremediation include its chemical specific nature where all organic pollutants may not be treated at one site, the procedure may produce toxic compounds through for example the oxidation of PAH's, and nutrients used in the process if not carefully managed may become polluting to groundwater aquifer systems (ie. nitrate and phosphate).

REFERENCES

Environmental and Earth Sciences, 1995. *Detailing the preparation, operation and monitoring of the bioremediation pads at the..., Eastern Australia.* Environmental and Earth Sciences Report.

Lapinskas, J 1989. Bacterial degradation of hydrocarbon contamination in soil and groundwater, *Chemistry and Industry* (4 Dec 1989): 784-789.

Saville, J 1991. Bioremediation of sites contaminated by organic chemicals - the natural answer, *Synopsium of the Victoria Branch of the Institute of Engineering, Australia.*