CL:AIRE

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case study bulletin

CL:AIRE case study bulletins provide a source of information on the characterisation and remediation of specific sites in the UK. This case study bulletin describes the application of thermal treatment on contaminated materials at The Avenue near Chesterfield.

Remediation Trial at The Avenue Using Thermal Treatment

1. INTRODUCTION

This bulletin describes a CL:AIRE Technology Demonstration Project (TDP10) in which contaminated material from The Avenue in Chesterfield, Derbyshire was treated using thermal treatment.

MEL Limited in conjunction with United Soils Recycling from the USA, undertook the remediation trial in 2001 to assess the suitability of Enhanced Thermal Conduction (ETC) technology to treat materials from the site.

The objective of the trial was to demonstrate the applicability of thermal treatment for the remediation of the soils at The Avenue site. The success criteria related to how efficiently the technology could reduce levels of a broad range of contaminants at the site, whilst demonstrating a cost-effective alternative to landfill.

This trial was funded by the national regeneration agency, English Partnerships, through the National Coalfields Programme's £104.5M remediation project for The Avenue site, being delivered by East Midlands Development Agency (emda).

2. BACKGROUND TO ENHANCED THERMAL CONDUCTION

The ETC technology uses heat provided by diesel fuelled burners to heat contaminated material and desorb contaminants into the gaseous phase, which is then extracted and treated. The contaminated material is covered by a steel cover (Quonset hut) which retains heat and the volatilised gases.

Heated air at temperatures of between 450-650 ºC is distributed through a system of interlaced perforated pipes and manifolds laid within a treatment cell. The contaminated material is heated by conduction over a period of between 5 and 14 days, depending on the nature of the contamination. Volatilised contaminants migrate into the space between the contaminated material and the steel cover from where they are drawn under vacuum into a vapour treatment system. The treatment can consist of a catalytic or a thermal oxidiser, which destroys the contaminants prior to discharge to atmosphere. After the treatment the steel coverings are removed to allow cooling and rehydration of the soil cell.

The process is predominantly used to remediate materials contaminated with volatile and semi-volatile organic compounds, particularly hydrocarbons. The process is not suitable for the treatment of heavy metals, asbestos bearing wastes or liquids.

3. BACKGROUND TO THE SITE

The Avenue (a former coking plant and chemical works) was constructed in the 1950s and produced 18 million tonnes of smokeless domestic fuel, by-products and town gas until 1992. Prior to this, the site had been host to a colliery, lime and iron works, and also included a former licensed tip and contaminated lagoons. Consequently, extensive contamination was present on the site within tar lagoons, waste tips, site soils, surface and groundwater, tanks, sumps and redundant pipework. The contaminants generally comprised coal tars, lime sludge, acids, phenols, polycyclic aromatic hydrocarbons (PAH), volatile organic compounds (VOC), spent oxide

Figure 1: The completed thermal treatment cell from the burner end.

(commonly known as Blue Billy), ammoniacal substances, heavy metals and asbestos. The site was considered by the Environment Agency to be a polluter of controlled waters including the adjacent River Rother.

The site ceased operations and closed in 1992. It was transferred to English Partnerships' National Coalfields Programme in 1996 and to emda, as English Partnerships' delivery agent, in April 1999. Jacobs (formerly Babtie Group) was commissioned by emda as principal consultants in the remediation and redevelopment of the 98 hectare site. Jacobs identified a number of contaminated materials on the site and managed a series of technology demonstrations (thermal treatment formed one of these) to see which one would be most suitable for treating the materials. Three materials were chosen for this trial - the former waste tip, containing a mixture of contaminated material; the plant area, contaminated mainly by organic materials such as phenols, petroleum hydrocarbons and aromatic hydrocarbons; and spent oxide deposits, mainly composed of metallic cyanides. Further site details are provided in CL:AIRE TDP6 Report, "Biopile Field Demonstration at the Avenue Coking Works".

4. METHODOLOGY

The scope of works comprised the treatment of approximately 900 m^3 of contaminated material in two treatment cells. Each cell was constructed from a variety of the contaminated materials at the site.

4.1 Treatment Area Construction

A 50 m x 50 m area was designated for the thermal treatment operations and was secured using 'Heras' type security fencing around the perimeter. The burner and oxidiser elements of the treatment system were isolated using the same system of interlocking security fence to avoid accidental entry.

A portable 'footing' to receive the Quonset hut, comprising a 100 mm sectional steel beam, was laid at floor level and bolted together to form a rectangle approximately 27 m long by 12 m wide. The treatment cell floor was covered by a Visqueen impermeable membrane, which extended outside the footings, thus creating a 100 mm bunded area within the treatment cell.

A tracking area for the excavator was created around the soil cell to preclude soil debris and any run-off contaminating the concrete floor immediately outside of the treatment area, and to allow materials to be stockpiled close to the treatment cell during construction.

5. CELL 1

5.1 Cell Construction

Cell 1 contained a 100 mm deep layer of unscreened waste tip material within the treatment cell footprint across the whole of the cell. It was considered that some of the tip materials might cause problems on heating, so the material was passed through a 75 mm screen prior to the rest of the cell construction.

In order that an understanding of the suitability of thermal treatment for the various material and contaminant types could be assessed, Cell 1 was divided into two sections. The section closest to the burners, (approximately 8 m long), was built using plant area material. The remaining, and larger section, (approximately 19 m long), being constructed from 'screened' waste tip material.

The steel manifolds were then placed in the centre of the soil layer, and connected along its length. The smaller diameter perforated steel pipes were placed width-wise and inserted into the female housings along the length of the manifold.

Further contaminated soils were then placed on top of the pipework to form the second layer, with the smaller diameter perforated pipes being placed width-wise, as previously described. The only difference being the length of the smaller pipe, which reduced from approximately 6 m in length to 4.50 m to take account of the soil profile.

Finally, soil was placed on the pipework to form the third and final level (Figure 2). The small diameter pipes reducing once more in length from 4.50 m to approximately 3 m.

Thermocouple wires were embedded at a number of positions within the cell to measure the temperature of both the soil and manifolds during treatment.

Upon completion of the treatment cell, the Quonset hut was erected (Figure 3). It consisted of a series of stainless steel panels, which bolted together to form a semi-circular cover for the treatment cell. The joints between the panels were sealed using aluminium tape to aid heat retention within the cell and to prevent escape of vapour emissions from the Quonset hut during the treatment cycle.

Once the Quonset hut was built, the inferno burners were attached to the manifolds via flexible steel ducting (Figure 4). The burners were mounted on a series of trestles, which were built onto a skid. The burners were diesel fuelled and capable of delivering heat to the soil mass via the interlacing pipework at temperatures up to 650 ºC.

Figure 2: Building up the layers in Cell 1.

Figure 3: Moving the stainless steel panels into position.

Figure 4: Fitting the burners.

A catalytic oxidiser (CatOx) was used to draw off the volatilised contaminants in vapour form by vacuum using a fan capable of a 3500 cfm extraction rate. These gases were channelled directly into the burner stream. The burner, attached to the front of the CatOx, heated up a catalyst element to operational temperatures of 250-350 ºC. The contaminants were then destroyed as they passed through the heated catalyst element.

5.2 Pre-Treatment Sampling

On completion of the cell construction, pre-treatment soil samples were taken from eight locations within the cell, the samples being taken from an average depth of 450 mm. Sampling was undertaken in order that a 'before and after' comparison of the materials' reaction to thermal treatment could be determined. The samples were packed in sealed containers and despatched to ALcontrol Geochem for analysis. Sampling was undertaken in accordance with the Sampling Protocol as directed by Jacobs.

5.3 Treatment of Cell 1

Once treatment of Cell 1 began, the CatOx burner was started and run up to the catalyst's optimum operational temperature, (around 200 ºC). Once the CatOx oxidiser was fully operational the inferno burners were brought on-line at 6-hourly intervals.

During treatment, problems with the CatOx were encountered. This was thought to be from deposition of sulphur and hydrocarbons on the surface of the catalyst thus restricting the flow of gas. A particulate filter was installed to try to improve the situation, but this had limited success. The CatOx was therefore replaced by a thermal oxidiser in which contaminants are destroyed at temperatures of above 600 ºC. The thermal oxidiser was sourced from the USA for this project.

Due to these problems, the treatment of Cell 1 was carried out sporadically over several weeks as opposed to the expected continuous period of operation of approximately 2 weeks.

During the treatment cycle the thermocouple temperature readings within the cell and the individual manifolds were taken and recorded on a spreadsheet. This enabled the progress of the treatment to be closely monitored. Once the temperatures had risen to the desired levels, and remained consistent, the system was switched off to allow confirmation sampling of the cell to be undertaken.

Once the soil treatment was complete, the soil cell was dismantled.

Stack monitoring was carried out by Casella Stanger three times per cell (after starting the system, once the optimum cell temperatures had been reached, and prior to shutdown of the treatment) to monitor emissions from the catalytic and thermal oxidisers. On each occasion, monitoring was carried out for a full day. In between the monitoring visits, ambient air quality was monitored using portable monitoring equipment. The gases which were monitored for are listed in section 8.2.

5.4 Post-Treatment

Eight post-treatment soil samples were taken in accordance with the Sampling Protocol, and despatched to the analytical laboratory, ALcontrol Geochem.

Re-hydration of the treated material was necessary, as it dries to a very friable material and can remain hot for a long period of time. Any attempt to dig into the cell can give rise to dust, which in some instances can constitute a possible nuisance or health impact. The soil was re-hydrated using a simple sprinkler system.

Once suitably re-hydrated, the pipes and manifolds were removed from the soil cell using a tracked excavator. The treated materials were then removed to an adjacent stockpile.

6. CELL 2

Cell 2 was constructed after Cell 1 had been treated and decommissioned. It was subdivided into three sections, each subdivision receiving different types of material. The section closest to the burners, approximately 6 m long, was built using spent oxide; the second section, again about 6 m long, was built using a mix of spent oxide and plant area material. The remaining and largest section, at approximately 12 m long, was constructed with waste tip material.

Pre-treatment samples were taken and the Quonset hut erected as described for Cell 1. The thermal oxidiser was used from the start on this cell, and commissioned over the first few days to achieve maximum performance. After treatment, when the performance samples were being taken, some additional samples were taken from materials suspected to be sulphur and naphthalene residues.

Treatment of Cell 2 was halted for 5 days near the start of the treatment to repair damage caused by third party disruption to the power supply. The cell was treated for 16 days in total to ensure that all contaminants had been treated effectively.

As with Cell 1, eight confirmation samples were taken from the treated materials at selected locations around the soil cell. Also included in the post-treatment sampling regime for Cell 2, was a 'blank', taken for quality assurance purposes.

The soil was again rehydrated using the sprinkler system as described above.

Figure 5: Completed Treatment Cell 2, from the thermal oxidiser end.

Figure 6: Treatment cell post-treatment.

7. RESULTS

7.1 Cell 1

Table 1 shows five results from the waste tip material taken from Cell 1 before and after treatment. The two results from the plant area material and one from the spent oxide material are not shown. For comparison, total PAHs and diesel range organics (DRO) are chosen as performance markers.

Table 1: Contaminant concentrations in waste tip material taken pre- and post-treatment in Cell 1.

Sample No.	Total PAH (mg/kg)			Diesel Range Organics (mg/kg)		
	Pre	Post	% Decrease	Pre	Post	% Decrease
WT1	1134	2.3	99.80	2889	54	98.13
WT2	3081	0.9	99.97	4000	20	99.50
WT3	2500	2.3	99.91	4835	45	99.07
WT4	3231	2527	21.78	5694	3994	29.86
WT5	1593	842	47.15	3105	1280	58.78
Mean	2308	675		4.1	1.1	
			Overall reduction = 70.8%			Overall reduction = 73.7%

The treatment proved highly effective (>98% reduction) across three sampling areas, WT1, WT2 and WT3, for both contaminant types. Two sampling areas did not perform as well, WT4 and WT5. It is likely that these were 'cold spots' that suffered from a disruption to the thermal airflow. These sampling locations therefore reduced the overall mean performance of the cell.

After treatment of Cell 1 a uniform covering of the exposed soil mass by a black sooty deposit was discovered and analysed. On average 14,495 mg/kg DRO, 10,510 mg/kg PAHs and 1392 mg/kg total cyanide were found in the material. The volatile organic compounds recorded in this deposit were predominantly naphthalene, dichloromethane, carbon disulphide and benzene. The PAH distribution of the deposit was similar to the distribution recorded in the material before treatment. The PAH distribution suggests that this material was hydrocarbon condensate resulting from the hot gases meeting the cooler air in the void between contaminated material mass and heat shield and condensing, rather than being caused by fuel combustion products.

7.2 Cell 2

Table 2 shows three results from both the waste tip material and spent oxide material taken from Cell 2 before and after treatment. The two results from the plant area are not shown. As above, total PAHs and diesel range organics (DRO) are chosen as performance markers.

Table 2: Contaminant concentrations in waste tip (WT) and spent oxide (SO) material taken pre- and post-treatment in Cell 2.

Sample No.	Total PAH (mg/kg)			Diesel Range Organics (mg/kg)		
	Pre	Post	% Decrease	Pre	Post	% Decrease
WT1	12,140	5.0	99.96	20,517	7.0	99.97
WT2	14,869	718.8	95.17	35,039	533	98.48
WT3	9821	326.4	96.68	18,352	268	98.54
Mean	12,277	350.1		24,636	269	
Overall reduction = 97.2%				Overall reduction = 98.9%		
SO1	404	2.4	99.40	1347	8.0	99.41
SO2	7677	0.9	99.99	27,862	2.0	99.99
SO3	5455	226.3	95.85	13,162	173	98.69
Mean	4512	76.5		14,124	61	
Overall reduction = 98.3%				Overall reduction = 99.4%		

The three samples taken from waste tip material in Cell 2 show a mean reduction in PAH and DRO concentration of 97.2% and 98.9% respectively. The results from the treatment of spent oxide material in Cell 2 demonstrate a mean decrease in PAH concentration of 98.3%. Treatment of DRO was similarly successful, with a mean reduction of >99%.

It should be noted that the pre-treated Cell 2 samples were generally significantly more contaminated than those for Cell 1. This serves as a reminder of the heterogeneous nature of the contaminated materials found on The Avenue site. In addition, even though the percentage reductions in Cell 2 were excellent, there was still residual contaminant concentrations of several hundred mg/kg in half of the post-treatment samples.

Overall, the treatment of Cell 2 was more successful than Cell 1. This is likely to have been in part due to the thermal oxidiser being established as the accepted methodology for emissions treatment. This meant that there were fewer shutdowns, and led to a more even treatment cycle.

8. AIR MONITORING

8.1 Ambient Air Monitoring

As part of the on site Health and Safety Working Plan, MEL staff continually monitored the immediate work zone, breathing zone and ambient atmosphere for the following:

- Lower explosive limit (LEL)
- Oxygen (O_2)
- Carbon monoxide (CO)
- Hydrogen sulphide (H_2S)
- Volatile organic compounds (VOCs)

These measurements were taken using a Multi-Rae PID with H_2S module fitted. The monitoring equipment was used throughout the period of the contract, within the treatment area, at all times when personnel were at work. These instruments were checked and calibrated both by MEL personnel, as well as emda staff in accordance with the manufacturer's instructions.

Analysis of the results show that the levels of the above determinands were below background levels, and within the Occupational Exposure Limit at all times during operations.

8.2 Emissions Monitoring Results

Stack monitoring was carried out for the following: sulphur trioxide (SO_3) and sulphur dioxide (SO_2); hydrogen cyanide (HCN); nitrogen oxides (NO_x); volatile organic compounds (VOC); vapour phase metals; moisture (H_20) and hydrogen chloride (HCl).

During treatment of Cell 1, the emissions from the CatOx showed elevated levels of NOx and VOC. Results from the second monitoring visit showed increased levels of all determinands compared to those of the first visit. The emission levels had almost doubled, demonstrating the requirement for thermal oxidation of the emissions.

Although emission levels for the first visit after installing the thermal oxidiser were elevated further still, this was the initial start-up and commissioning visit. Airflow adjustments and burner input and oxidiser temperature were being adjusted at the time of monitoring, in order that the thermal oxidiser be optimised. The emission results demonstrated that once commissioned, the oxidiser functioned satisfactorily, treating a broad range of off-gases from the treatment process.

9. COST EVALUATION

As with any demonstration trial the costs associated with undertaking a trial are far higher than a full-scale commercial operation due to the economies achieved through scale.

Nevertheless, an estimation of costs was made using the following assumptions:

- the volume of material for treatment would be >50,000 m^3;
- the end use of the site is industrial;
- costs for excavation, screening, haulage, decontamination facilities, welfare and security are excluded.

Based on the costs for the trial and these assumptions, the treatment costs would be approximately £100/m^3. Exclusion of any trial costs incurred, such as mobilisation of the thermal oxidiser, additional analytical costs and reporting, would lower the costs. Moving to a larger scale would also reduce costs in form of attendance and supervision, so that costs of £63-£68/m^3 could be anticipated. Increasing efficiency in heat loss and fuel consumption and use of recycled or alternative fuels could lower the costs further to £55-£60m^3. The full-scale treatment costs would also be dependent on the required target concentrations for the treatment.

10. CONCLUSIONS

The contaminated material responded well to the thermal treatment with contaminant reductions of up to 99% being achieved in both treatment cells. However, in Cell 1, some areas did not receive sufficient air flow so that reductions of only 20% were observed. This led to the mean reduction in both total PAHs and DRO in waste tip material being approximately 70%. Overall, the treatment of Cell 2 was more successful than Cell 1.

Pre-treatment contamination levels in Cell 2 were considerably higher than those measured in Cell 1 for the waste tip material. This highlights the heterogeneous nature of the materials on The Avenue site. Consideration should also be given to the contaminant concentrations still in the materials after a successful treatment (>95% reduction), which may impact their potential reuse.

Problems were initially encountered due to the unexpected levels of contaminants which greatly contributed to the problems with the catalytic oxidiser. Initial analysis of the material and the levels of contamination, and therefore off-gases from the material, were within a range deemed treatable using the catalytic technology.

From the experience gained during the trial, MEL would recommend pre-screening of the materials. This would achieve three goals: agitating and aerating the soils would help to separate the treatable materials from the 'untreatable' elements, such as lumps of concrete, brickwork, plastics, conveyor rubber etc. This would in turn reduce the overall volume for treatment which would also provide more accurate data regarding the contamination levels to be treated.

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Details on The Avenue can be found at www.theavenueproject.co.uk