Thermal Desorption Remediation in Relation to Landfill Disposal at Isolated Sites in Northern Alberta

Remediation Technology Conference
Banff, Alberta

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Presented October 21, 2005 in Banff, Alberta
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This paper is divided into two parts. The first part provides an overview of ATCO Electric Ltd. (ATCO) Remediation Project and the role of conventional contaminated soil excavation and landfill disposal or Dig and Dump (DD) and selection of Thermal Desorption (TD) in remediation of isolated diesel powered generation sites. TD soil process and quality assurance (QA) and quality control (QC) procedures are described. A comparison of TD to DD is provided based on actual $2004 spent remediating two ATCO sites in the Steen River area (total 29,000 tonnes of diesel-contaminated soil) versus two similar sites remediated by DD. The second part of this paper discusses the integral role of TD in the staged remediation for 46,000 tonnes (T) of diesel-contaminated soil at Fox Lake, Alberta. Fox Lake is a remote northern community only accessible by winter road and ice bridge for two (2) months of the year.

TD is the application of heat to organic-contaminated soil to release and thermally destruct the contaminant using high temperatures. In part one, the following aspects are discussed with respect to TD:

- TD process description – how TD works
- Quality Control and Quality Assurance protocols – ensuring effective soil treatment
- Steen River TD Project – two (2) sites remediated using TD, one mainly clay (fine-grained) site – Steen River Original Microwave (21,900 T) and one mainly sandy (coarse-grained) site - Steen River Community (6,500 T), and comparison with similar conventional DD remediation in $2004;
- TD Contracting – performance payment/T, based on tonnage of successfully treated soil that meets Alberta Environment (AENV) 2001 Alberta Soil & Water Quality Guidelines for Hydrocarbons at Upstream Oil and Gas Facilities (ACWS) criteria;
- Production rates and on-stream utilization including maintenance and repair aspects with productivity data presented in tonnes/day;
- Percentage cost breakdown/T - fuel, labour, plant and equipment capital and peripherals, and the percentage cost of TD soil processing to the total project cost;
• TD advantages such as mobility to site, performance payment based on remediated soil tonnage, contaminant destruction, TD onsite treatment of hydrocarbon contaminated groundwater, winter remediation and the role of TD in staged remediation; and
• TD Limitations such as the inability to remediate metals, sensitivity to soil water content, water demands for soil processing and longer time onsite than DD.

Part two discusses the integral role of TD in the remediation of 46,000 T of diesel-contaminated soil at ATCO’s Fox Lake power plant.

In 2005, Fox Lake was accessible over a winter road and 1.15 km ice bridge between February 15 and March 26, 2005. The challenges of ice bridge construction and maintenance, excavation backfilling and soil transport at -30° C weather conditions and vehicle movement coordination are discussed. Further aspects of the project include:

• 24 hour site operations and soil hauling;
• Ice bridge construction, specifications, truck restrictions and traffic coordination over the ice bridge;
• Site deconstruction and demolition, contaminated soil excavation and backfill;
• Costs for site preparation, excavation, contaminated soil hauling for TD soil processing, backfill haul costs and TD soil processing costs.
• The role of Little Red River Cree Nation consultation and liaison to facilitate Band Council Resolutions and Band cooperation for road use, access road construction, backfill sources, and community traffic controls;
• First Nation training opportunities and employment during excavation and TD soil processing.
1.0 ATCO REMEDIATION PROJECT BACKGROUND

ATCO under Alberta Regulation 165/2003, *Isolated Generating Units and Customer Choice Regulation* is remediating and/or reclaiming subsurface impacts that had occurred at isolated generating units (sites) prior to December 31, 2000. ATCO identified 103 sites and 77 of these sites are required to be remediated and/or reclaimed to Alberta Environment (AENV) 2001 guidelines *Alberta Soil & Water Quality Guidelines for Hydrocarbons at Upstream Oil and Gas Facilities (ACWS)*. The sites are shown in Drawing 1.

The Alberta Energy and Utilities Board created, through Decisions 2002-102 and 2003-036 a Remediation Review Committee (RRC) to oversee and audit the remediation program which is in its third year of an anticipated five year program. The sites are predominantly contaminated with petroleum hydrocarbons (diesel fuel) that are associated with former or existing aboveground or underground storage tanks. The remediation criteria are dependant on the site’s location, zoning and end land use.

The EUB decisions require the remediation work at each site to be done to a standard that will enable ATCO to obtain a Reclamation Certificate from AENV where feasible, given the objective at the sites. Where a Reclamation Certificate is unattainable because of land use and ownership a comfort letter is to be obtained from AENV.

Site contamination occurred mainly through the loading, storage and dispensing of diesel fuel. Diesel fuel filter failures, offloading releases, leaks or failures in hoses, piping and joints, and aboveground or underground storage tank releases were the main sources of diesel fuel contamination at these sites. Petroleum lubricants, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), glycols, and metals generated limited contamination.

The remediation work comprised of DD or TD treatment of contaminated soils as well as removal of underground facilities such as concrete foundations, screw anchors, storage tanks, pipelines and grounding grids.
2.0 REMEDIATION METHODOLOGIES

DD and TD are two remediation technologies used by ATCO to date. Both DD and TD use conventional excavation of contaminated soil, transporting soil by truck or loader, and following soil disposal (DD) or treatment (TD), the excavation is backfilled, compacted and the site reclaimed in the same manner. The main differences between these two remediation technologies are; soil disposal in an approved landfill and using imported soil backfill (DD) or; soil treatment and using the remediated soil to backfill the excavation (TD).

As of December 2004, ATCO had remediated 43 of 79 sites; 40 by DD and 3 by TD. In 2004, the average cost to remediate a site by DD ranged from 127 $/m$^3$ to 350 $/m^3$ with an average of 158 $/m^3$.

2.1 Dig and Dump

DD is paying a tipping fee ($/T) to dispose of contaminated soil in an approved landfill and obtaining suitable unfrozen soil to backfill the excavation. Ideally, backfill is obtained on the backhaul from the landfill to minimize additional truck time and mileage.

2.2 Thermal Desorption Process

TD is a mobile technology that heats contaminated soil to boil off organic contaminants such as; gasoline, diesel, aviation fuel, heating oil, waste oil, pesticides, PCBs, dioxins and furans, gas plant and flare stack residues. Metals are typically not treated by TD.

TD principles are simple, but the actual thermal desorption is only one of six stages of the treatment process outlined as follows:

- Soil excavation and transport to TD;
- Soil preparation at TD;
- Thermal desorption treatment chamber (rotary kiln);
- Treated soil discharge and quenching;
- Contaminant off gas and dust treatment – baghouse, and
- Contaminant destruction and exhaust - afterburner/oxidation.
The treatment process begins with excavating petroleum-contaminated soil and preparing the soil by mixing for consistent grain size, moisture content and contaminant concentrations. The soil then passes over a conveyor belt weigh scale that measures tonnage and feed rate into the desorption chamber.

Desorption chamber temperature and residence time is changed depending on soil grain size and moisture content. Heat vaporizes (boils off) water at 100°C consuming energy before hydrocarbons are desorbed in the 300°C range. Higher soil moisture content and fine grain size increases the desorption chamber residency time and energy consumed for effective treatment.

Treated soil exits the TD chamber at over 300 °C before quenching with water to cool the soil, suppress dust, and re-hydrate the soil for compaction (8-10% soil moisture). Daily productivity of 500 T requires approximately 100 m$^3$ of water.

The desorbed gasses and dust are filtered through a baghouse. Filtered dust is mixed with the hot treated soil or recycled through the desorption chamber.

The afterburner or catalytic oxidizer chamber is where oxygen is added to clean-burn contaminants at the high temperature required to destroy the contaminants (>860°C). Water vapor (steam), carbon dioxide (CO$_2$) and (atmospheric) nitrogen (N$_2$) are the principal exhaust gases.

2.3 Assessing TD as a Treatment Technology versus DD

The majority of ATCO sites to be remediated are located in northern Alberta. During initial stages of the Isolated Generation Remediation Project, ATCO found DD effective and economic for smaller volume (up to 2,000 T) sites within 100 km of a suitable landfill. In 2003, Thurber assessed alternate remediation technologies (TD, landfarming, biopiles and in-situ bioremediation) versus the following criteria; cost effectiveness and verified remediation within one field season (necessary to meet remediation of all sites by 2007). TD met these criteria whereas landfarming, biopiles and in-situ bioremediation required ongoing project management, site monitoring and questionably verifiable remediation.
In 2003, Thurber compared DD to TD and found that based on 4,000 T of PHC soil, DD soil trucking at 12 $/T for the first 100 km, 8 $/T every 100 km thereafter, a landfill tipping fee of $20/T and backfill cost (including loading) of 5 $/T, DD costs approximately 45 $/T, which compares with the 47$/T for TD at Steen River.

Thermal Desorption was assessed to be a viable remediation option where the volume of petroleum contaminated soil was estimated to be greater than 4,000 T (2,500 m$^3$) and the one-way haul distance to a Class II landfill was greater than 100 km.

Factoring in reduced road use (increased safety and decreased road maintenance costs) for TD, sites may become more favorable for TD. Also, once a TD unit is in the area, the economics for smaller volume sites in the area are more favorable.

3.0 TD FIELD EXPERIENCE – STEEN RIVER PROJECT

From August 25, 2005 through November 25, 2005, two ATCO sites in the Steen River area; Steen River Microwave (SRM) and Steen River Community (SRC) power plant were remediated using TD. Steen River is approximately 165 km north of High Level on Highway 35, and 45 km south of the Alberta-Northwest Territories border as shown in Drawing 1.

Practical field experiences of TD remediation from these sites are discussed;

1. SRM - larger (21,900 T), fine-grained (Silt to clay) site, and
2. SRC power plant – smaller (6,500 T), coarse-grained (sand) site.

3.1 STEEN RIVER MICROWAVE (SRM)

In 2004, Telus was operating a microwave relay station with a large tower anchored with guy wires. Site preparation required the temporary re-location of one Telus guy-wire.

The site consisted of gravel or occasionally clay fill, up to 0.6 m thick, overlying peat, or native lacustrine clay. Narrow, pinching and swelling silty-sand channels meandered through the clay. Diesel contamination migrated through the silty-sand
channels, seeped into the underlying clay and was disseminated through much of the clay. Clay till was encountered between 0.4 and 4.0 m, and extended beyond the 7.5 m maximum depth of investigation. Groundwater seepage did not occur during excavation. Excavation required 15 days, soil processing required 45 days, backfilling and compaction took 15 days and site restoration was complete in 3 days. SRM site and TD activities were interrupted by SRC activities.

<table>
<thead>
<tr>
<th>Site</th>
<th>Steen River Microwave</th>
<th>Wabasca</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remediation Process</td>
<td>TD</td>
<td>DD</td>
</tr>
<tr>
<td>Excavation Volume</td>
<td>11,100 m³</td>
<td>11,110 m³</td>
</tr>
<tr>
<td>Grain Size</td>
<td>fine grained</td>
<td>fine grained</td>
</tr>
<tr>
<td>Truck haul</td>
<td>560 truck loads</td>
<td>490 trucks</td>
</tr>
<tr>
<td>Haul Distance</td>
<td>17 km to TD</td>
<td>146 km to High Level</td>
</tr>
<tr>
<td>Soil Volume Treated</td>
<td>21,900 T</td>
<td>15,400 T</td>
</tr>
<tr>
<td>Time Required</td>
<td>45 days</td>
<td>29 days</td>
</tr>
<tr>
<td>Average Productivity</td>
<td>486 T/day</td>
<td>530 T/day</td>
</tr>
<tr>
<td>Soil Processing Cost/T</td>
<td>$47/T</td>
<td>$20/T</td>
</tr>
<tr>
<td>Treatment Cost</td>
<td>$1,029,300 treatment</td>
<td>$384,000 tipping</td>
</tr>
<tr>
<td>Total Project Cost</td>
<td>$1,572,000</td>
<td>$1,540,000</td>
</tr>
<tr>
<td>Project Cost/T</td>
<td>$141/m3</td>
<td>$139/m3</td>
</tr>
</tbody>
</table>

Note that $147,000 spent trucking petroleum-contaminated soil to TD and backhauling treated soil to SRM could have been saved if the TD could have been located onsite.

### 3.2 STEEN RIVER COMMUNITY POWER PLANT (SRC)

The site was a self-contained mobile power plant. A new power plant and contained fueling station was to be installed on the remediated site.

The site consisted of sand and gravel interbeds and clay till that extended beyond the maximum 8.0 m depth of investigation. Each of these units was laterally discontinuous and of variable thickness. Diesel migrated vertically through the granular sands and gravels to the water table at approximately 2.5 - 3 m below grade.
Petroleum hydrocarbon contaminated groundwater from offsite was encountered in the excavation. Test burns using the contaminated groundwater as quench water in the TD process were conducted and chemical analysis of the treated soil met criteria. Groundwater was therefore treated at no direct cost to the project.

The new SRC plant design required 100% SPD compaction under the building footprint. Due to freezing winter conditions, conventional soil compaction could not attain 100% SPD. Using warm TD process stockpiles the required excavation backfill and compaction to 100% SPD specification was achieved.

<table>
<thead>
<tr>
<th>Site</th>
<th>Steen River Community</th>
<th>Foggy Mountain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remediation Process</td>
<td>TD</td>
<td>DD</td>
</tr>
<tr>
<td>Excavation Volume</td>
<td>5,900 m³</td>
<td>5,225 m³</td>
</tr>
<tr>
<td>Grain Size</td>
<td>coarse grained</td>
<td>coarse grained</td>
</tr>
<tr>
<td>Truck haul</td>
<td>159 trucks</td>
<td>260 trucks</td>
</tr>
<tr>
<td>Haul Distance</td>
<td>2 km to TD</td>
<td>160 km to High Level</td>
</tr>
<tr>
<td>Soil Volume Treated</td>
<td>6,500 T</td>
<td>6,927 T</td>
</tr>
<tr>
<td>Time Required*</td>
<td>12 days*</td>
<td>29 days*</td>
</tr>
<tr>
<td>Average Productivity</td>
<td>540 T/day</td>
<td>237 T/day</td>
</tr>
<tr>
<td>Soil Processing Cost/T</td>
<td>$47/T</td>
<td>$19/T</td>
</tr>
<tr>
<td>Treatment Cost</td>
<td>$305,500</td>
<td>$131,500</td>
</tr>
<tr>
<td>Total Project Cost</td>
<td>$780,000</td>
<td>$844,000</td>
</tr>
<tr>
<td>Project Cost/T</td>
<td>$132/m³</td>
<td>$152/m³</td>
</tr>
</tbody>
</table>

* Operational Days – not including weather delays at Foggy Mountain

The Foggy Mountain haul included approximately 60 km of gravel road and weather delayed the project. Foggy Mountain work was delayed through rain and road access problems which increased non-productive time on site. SRC also incurred some non-productive time onsite, however SRC TD total site productivity of 132 $/m³, compares favourably with Foggy Mountain DD.

Overall, for the Steen River Project remediation the TD on-stream utilization factor was 78%. TD throughput averaged approximately 450 - 500 T/day.
4.0 COMPARING DD to TD

4.1 TD Cost Factors

Nelson conducted all aspects of site work from site preparation through excavation, TD soil treatment, backfill and compaction to site reclamation. The following data are a summary of the cost breakdowns from the Steen River Project.

<table>
<thead>
<tr>
<th>Task</th>
<th>% of Total Project Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nelson TD Soil Processing Cost at 47 $/T</td>
<td>55%</td>
</tr>
<tr>
<td>Nelson Peripheral Costs</td>
<td>26%</td>
</tr>
<tr>
<td>Other ATCO Costs</td>
<td>18%</td>
</tr>
<tr>
<td>Total % Project</td>
<td>100%</td>
</tr>
</tbody>
</table>

Nelson Peripheral tasks include site preparation, excavation, trucking, water supply, rentals, backfill, compaction and site reclamation, and comprise close to 30% of the total Nelson project costs. The TD soil processing fee comprises the other 70% of the total Nelson project costs. Other ATCO costs include project administration, consultation and chemical analysis.

The Nelson soil processing cost was the largest cost component (55%) of the total Steen River project cost. Nelson estimates their Steen River soil processing fee of 47 $/T was made up as follows.

- 30% - 40% Fuel
- 40% Labour
- 20% Plant and Equipment
- 10% Peripherals (soil handling, tank rentals)

Fuel (recycled oil, diesel, natural gas, propane or heating oil) is the largest TD variable cost factor. Fuel consumption depends on fuel type (energy yield), soil moisture content, grain size and elevation. The cost of recycled oil increased 60% in 2004, and together with distance and site access to Fox Lake, the TD unit rate soil processing cost increased from $47/Tonne at Steen River to $57/Tonne at Fox Lake.
After fuel cost, adequate water supply – quantity (200 L/T of treated soil or approximately 100 m\(^3\)/day), quality and rate, is the next most important TD input requirement.

4.2 DD versus TD SELECTION CRITERIA

Key considerations when comparing the TD and DD technologies are;

1. Landfill distance, availability, fees and available backfill;
2. Available time frame for site remediation;
3. Trucking costs and availability;
4. Fuel costs and availability;
5. Water - TD requires approximately 100 m\(^3\) of water every 24 hours of production. A near-site source of quality water is required for hauling to site, or a well will be required to provide the required water; and
6. Road permitting, access, and maintenance costs.

4.3 TD ADVANTAGES

- TD can be located anywhere highway truck loads have road access, including gravel, ice roads and bridges.
- Once TD is present in an area, the economics for TD remediation of nearby (satellite) sites, improves, whereas for DD, economics for smaller sites remain unchanged.
- TD is less dependent on trucking and fewer road kilometres traveled results in safer conditions and less road maintenance.
- Remediate contaminated groundwater through the TD quench system.
- TD year-round operation produces supply of clean, unfrozen fill satisfactory for compaction during winter, whereas DD requires an alternate suitable, unfrozen backfill source that may not be available during winter.
4.4 TD CONSTRAINTS

- Excavation proceeds at a faster rate than the TD can process soil, therefore TD usually requires more time onsite than DD.
- Fuel – TD is more cost-sensitive due to greater fuel consumption relative to DD sites.
- Requires 100 m$^3$/day of suitable water.

5.0 FOX LAKE STAGED REMEDIATION

Fox Lake, as shown in Drawing 1, is located approximately 175 km east of High Level on Highway 58 and 20 km on winter road and a 1.15 km ice bridge over the Peace River. Fox Lake road access is limited by an ice bridge from approximately January 15 to March 15.

Since 1972, the ATCO Fox Lake power plant supplied the community of 1,700 persons. Diesel fuel was re-supplied annually and stored in aboveground diesel storage tanks with a total capacity of approximately 1.6 million litres. Site investigations in 2000 found an estimated 9,000 m$^3$ of PHC. In December 2004, a pipe expansion joint failed and approximately 78,000 L of diesel was released onto snow-covered and frozen ground. Drilling in December 2004 and January 2005 revised the total volume of PHC soil to 18,000 m$^3$.

The site consisted of laterally discontinuous interbeds of glacio-lacustrine silt, clay and sand. Massive sand was intersected at depths that ranged between approximately 2.6 and 3.8 m, which extended beyond the maximum 6.4 m depth of investigation. Depth to groundwater ranged between 5.5 m and 5.8 m below existing ground surface. Groundwater flows in a northeast direction towards Peace River.

ATCO Fox Lake Staged Remediation

During the winter of 2004 – 2005, ATCO constructed a transmission line to supply Fox Lake community electricity requirements. The existing power plant was no longer required and was to be decommissioned and the site PHC soil remediated.
The optimal TD setup is onsite, using TD-processed soil for backfill. Onsite TD eliminates the cost of trucking contaminated soil, the cost of imported fill and trucking imported fill to the site, and soil remediation is not subject to weather delays due to road conditions.

Based on the large volume of contaminated soil and the limited time frame to move heavy loads across the ice bridge, a staged remediation plan was developed as follows:

- Decommission the plant site;
- Excavate and transport contaminated soil across the ice bridge, for later TD treatment;
- Verify the extent of the excavation;
- Backfill the excavation, and
- De-mobilize across the Peace River before the ice bridge went out.

In 2005, it took 40 days to construct the 1.15 km long, 1.5 m thick ice bridge rated for the 105 T required to support the loads required to decommission the plant and salvage assets such as fuel storage tanks. The ice bridge was available for five weeks from February 15 to March 26. Ice bridge restrictions included traffic control at both ends, a maximum total weight of 105 T on the ice bridge, a speed restriction for loaded or unloaded haul trucks of 5 km/hr on the ice bridge, and limitations on passing loaded trucks.

Site preparation began February 15th and excavation began February 21, running 24 hours a day through to Mar 11th. A total of 1,100 truckloads traveled across the ice bridge with a total truck cycle time of 2.25 hours.

2.5 km of new snow-road was constructed in order to haul backfill to complete the excavation. 2,500 loads of borrow material was hauled over 10 days to backfill the excavation area.
The project costs were as follows:

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site preparation</td>
<td>$67,000</td>
</tr>
<tr>
<td>Excavation</td>
<td>$373,000</td>
</tr>
<tr>
<td>1,100 trucks hauling PHC soil to Wentzel TD for processing</td>
<td>$730,000</td>
</tr>
<tr>
<td>2,600 trucks hauling free backfill to excavation</td>
<td>$300,000</td>
</tr>
<tr>
<td></td>
<td>$1,470,000</td>
</tr>
<tr>
<td>TD Soil Processing – 46,000 T at 55 $/T</td>
<td>$2,555,000</td>
</tr>
</tbody>
</table>

Trucking the contaminated soil and backfill added approximately $1,000,000 to the cost of the project.

**Aboriginal Involvement**

ATCO aboriginal liaison included Mr. Wayne Erasmus and Mr. Alex McGillivray to facilitate Band Council Resolutions (BCRs) for site access roads, backfill sources and 24 hour site operations, and community traffic control (school busses and civilian traffic across ice bridge and winter road safety). Ice bridge maintenance and traffic control was handled by aboriginal contractors hired by ATCO.

ATCO rented a 40-person camp from Little Red River Forestry, (an aboriginal company) for accommodation and meals for almost one year. The camp was located approximately 3 km east of the Highway 58 Wentzel River crossing.

During Fox Lake plant site excavation (February – March, 2005), Nelson employed 14 aboriginal equipment (backhoe, trackhoe and loader operators), as well as truck operators, truck drivers and general site labourers. During TD soil processing at the Wentzel site (June to September 2005). Nelson employed 8 aboriginal equipment operators, truck drivers and labourers.