APPLICATION OF AN IMMUNOASSAY TECHNOLOGY TO MANAGEMENT OF WATER TREATMENT DURING SITE REMEDIATION - THEBACHA CAMPUS AURORA COLLEGE, FORT SMITH, NWT

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Abstract

This project addressed the clean-up of 100,000 litres of leaked diesel heating fuel in groundwater and the remediation of hydrocarbon-impacted soil at Aurora College in Fort Smith, NWT. The project resulted in a number of 'firsts' in the NWT including vacuum well-point dewatering to enable earth-moving equipment access for remediation, on-site (TORR™) treatment of water produced from dewatering and on-site immunoassay technology testing of water prior to release into the town's lagoon system. Before the commencement of site grade restoration, heat exchange piping was installed into the excavation base as part of the first NWT implementation of a ground-effect heat exchange system for classroom and office cooling. The project provided an on-the-job work opportunity for 20 technology students of the college Heavy Equipment program who provided much of the labour effort related to earth-moving equipment. The project was funded by the Government of the NWT with a total budget of $1.5 million; for completion of the project without the participation of Aurora College trainees, the estimated budget for outside contractors would otherwise have been over $4 million.

The project faced a number of challenges related to implementation and quality assurance of which the main assurance requirement was the confirmation that treated water complied with quality criteria established in consultation with the Town of Fort Smith for town sewer and lagoon use. With the fastest turnaround time for sample shipping and laboratory analytical testing and reporting being on the order of four to six days, an on-site testing system for dissolved hydrocarbons was implemented for this project using commercial (EnviroGard™) immunoassay testing equipment.

Immunoassay testing allows users to make semi-quantitative measurements of contaminants such as priority pollutants and pesticides down to detection levels approaching laboratory analyses. Immunoassay measurements were typically conducted in less than 30 minutes and allowed the determination of water treatment system performance and provided assurance that treatment was conducted under controlled conditions. For this project, a combination of field immunoassay testing and duplicate laboratory analysis was applied to the measurement of total BTEX and TPH and assisted decision-making regarding contingency treatment responses within a matter of hours rather a week. The field and laboratory results were checked throughout the project

especially when values above action levels were detected. A comparison of the field and analytical laboratory results is discussed in this paper including the advantages and disadvantages of immunoassay technology with implications for project control during accelerated site characterization and site remediation of remote sites across Canada's northlands.

In February 2003, this project was recognized by the Consulting Engineers of Alberta (Environmental Award of Excellence) and again in October 2003 by the Association Of Consulting Engineers of Canada (Environmental Award of Excellence).

Biographies

Paul R. Morton, P. Geol., is a senior hydrogeologist and engineering geologist with EBA's environmental practice in Edmonton providing expertise in the overlapping field of hydrogeology, environmental and engineering geology. He has 15 years of progressive consulting experience in Canada, Malaysia and the UK, plus a background of five years industrial experience in wellsite petroleum geology.

George W. Ruddock, P.Chem., is president of Osprey Scientific Inc., and has 24 years of working in chemistry as a Technical Support Specialist, Laboratory Manager and running a technical supply company. He also teaches training field screening courses and consults in Canada and overseas on chemistry matters.

Project Description and Issues

In 1996, a major underground heating oil spill was uncovered during routine excavation work at Thebacha Campus, Aurora College in Fort Smith, NWT. The objective of this project was to halt the movement of the heating fuel in groundwater moving towards a residential area and to remediate hydrocarbon-impacted soil in accordance with NWT regulatory criteria. Heating fuel leaking for many years from a storage tank travelled with groundwater across an area that included a college campus building property (Trades Building), a roadway (Raven Crescent), and the frontages of residential properties adjacent to the roadway (Photo 1).

Photo 1: Thebacha Campus, Aurora College, Fort Smith, NWT
(Excavation site in left centre between Trades Building and Raven Crescent)

Students and staff of the Trades Building were potentially at risk by volatile hydrocarbon inhalation from pooled separate-phase heating fuel beneath the building. Nearby residents were also at risk from dissolved-phase hydrocarbons travelling off site in groundwater. Remediation of the hydrocarbon source was warranted to address the separate-phase heating fuel and hydrocarbon-impacted soil not complying with NWT regulatory criteria.

Laboratory analyses revealed that the majority of soil hydrocarbons were in the C_{11} to C_{15} carbon fraction range, typical of a diesel heating fuel or a mineral spirit source. This hydrocarbon range is detected within the laboratory total extractable hydrocarbons (TEH) category of sample analysis for which a large data set had been created during site investigation and hydrocarbon testing by EBA following initial discovery of the spill. Using the compiled TEH data, groundwater and soil hydrocarbon concentrations were interpreted and contoured to show the horizontal and vertical extent of hydrocarbon impact (Figure 1).

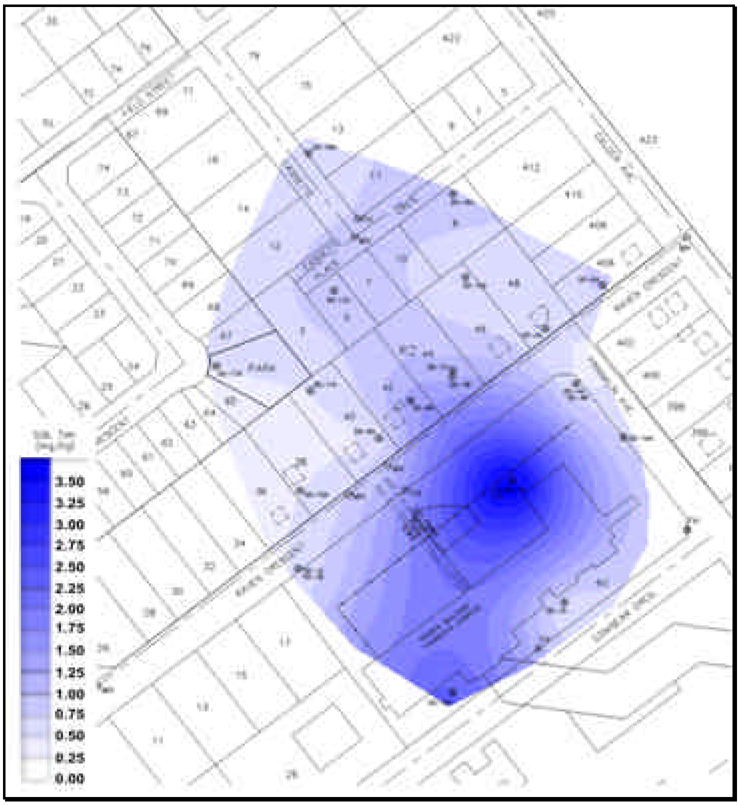

Figure 1: Total Extractable Hydrocarbon (TEH) Concentrations Prior to Remediation

Contoured soil TEH data revealed an impacted soil volume on the order of 15,000 m^3 on the Trades Building property. Years of seepage movement on the water table had resulted in a body of hydrocarbon-impacted soil over 100 m long as hydrocarbon migrated downgradient from the tank source within clayey silt and sandy silt soils towards the Slave River. The impacted soil also extended 4 m vertically, related to seasonal water table fluctuation, and commenced at 5 m depth below surface grade. Therefore, the hydrocarbon-impacted soil was covered over by about 10,000 m^3 of non-impacted (clean) soil.

The quantity of leaked heating fuel was high enough that separated-phase liquid hydrocarbon to 'pooled' on the water table and spread beneath the Trades Building and downgradient approaching a nearby roadway (Raven Crescent) with buried utilities and adjacent residential properties. This created a potential concern for the health of students and staff using the Trades Building as potential receptors of volatile hydrocarbons via the inhalation pathway. Dissolved hydrocarbon was also detected in groundwater in the frontages of downgradient residential properties creating similar human health concerns for the residents. Several public meetings were held to inform residents and the general public about site conditions and alternative solutions prior to final selection and implementation.

Water Treatment

An oil-water separation technology new to western Canada was selected by EBA and incorporated into the water treatment system to process groundwater extracted by the vacuum well point dewatering system. The complete treatment system adopted for the project consisted of sediment control (open-top sedimentation tank and bag filters), followed by oil-water separation (TORR™, Earth (Canada) Corp.) followed by an air stripper tower (Photo 2) and water release into the town sanitary sewer and lagoon.

Photo 2: On-site Water Treatment System

Originally, equipment for treating oily marine ballast, the TORR™ oil-water separator was in early commercial trials for the environmental industry in eastern Canada at the time of the initial stages of this project. EBA reviewed specifications of the equipment and its capabilities to separate oil-water emulsions and remove oil droplets down to five microns, which was considered suitable for the project. The TORR™ separator was incorporated into the water treatment system to give an added measure of treatment given uncertainty and significant variation in hydrocarbon concentrations in extracted groundwater.

EBA staff, along with Aurora College trainees, provided full-time monitoring of the water treatment system through on-site testing and by confirmatory laboratory analyses (Enviro-Test Laboratories, Edmonton). Stringent control of water discharged into the town’s sewer was required and this was not possible using a conventional commercial laboratory where the fastest available turnaround time for reporting of water sample results is in the range of 48 to 72 hours.

For monitoring and control of the water treatment system performance, EBA implemented on-site water quality testing using immunoassay testing equipment (EnviroGard™, Strategic Diagnostics Inc.) for total BTEX (benzene, toluene, ethylbenzene, and xylenes) and TPH (total petroleum hydrocarbons). The equipment uses a variety of micro-pipettes and reaction tubes (Photo 3).

Photo 3: Water Quality Monitoring Using Immunoassay Analysis By EBA

The particular immunoassay technique used is based on enzyme-linked immunosorbent assay with a high degree of sensitivity and selectivity and has been approved by the U.S. EPA for selected analyses. In Canada, use of the technique has mainly been related to PCB analyses in soils, for example, the environmental work at DEW Line sites in the high Arctic. Given the short length of the Fort Smith remediation project, an on-site portable commercial laboratory would not have been economical. EBA selected this testing technique to provide a high level of on-site control to the project and ensure compliance with the discharge criteria for BTEX and TPH and ultimately protection of the town’s sewage network and treatment lagoon.

The lagoon had two pre-treatment cells and the main cell (Photo 4), which had a sixty-day retention time, after which water was released to the Slave River.

Photo 4: Town of Fort Smith Water Treatment Lagoon

Environmental Immunoassay Methodology

The kits used for the field analysis were semi-quantitative immunoassay kits (Strategic Diagnostics Inc.) supplied by Osprey Scientific Inc. The basis of the kit is an enzyme linked immunosorbent assay (ELISAs), which is based on combining selective antibodies with sensitive enzyme reactions to provide an analytical system capable of detecting very low levels of contaminants. Kits used for remediation include PCBs, BTEX, TPH, PAH, TNT, RDX, and PCP for soil and water analysis. Pesticide kits are used for water analysis. The kits measure in parts per billion (ppb) level in water and parts per million (ppm) level in soil. Some pesticide kits are capable of measurement to the sub ppb level in water.

There are four formats available for this monitoring technology including magnetic particles, coated tubes, coated plates and latex particles. In this case, a coated tube format was used because it met the small volume of samples (one to two) being measured at multiple times a day during the water treatment. The times included morning start-up, midday, and the end of the day to check if the process was in control and water could be released. The treatment water was analyzed directly for both the BTEX and TPH.

The kits used for this project are designed with four calibrators in each the kit, which include a negative control (NC) and three standard concentrations. Those concentrations were 0, 0.1, 0.5 and 3.0 ppm of BTEX and 0.1, 1.0 and 5 ppm of Total Petroleum Hydrocarbons. To prevent losses due to volatility, the BTEX standard solutions were made up just prior to the calibration of the system. The BTEX stock solutions were prepared by doing a serial dilution from a concentrated standard. The TPH calibration was performed with stock solutions that came with the kit, as they are considered stable solutions. A four-point calibration for both kits was run daily and the calibration data was used for comparison to the daily sample analysis results.

The analysis was set up with four calibrators followed by one to two test samples. The kit is based on a competitive reaction; the component of interest (i.e., BTEX) and an enzyme conjugate to compete for the binding sites found on specific antibodies attached to the inside of the tubes. The enzyme conjugate is composed of the component of interest, a protein and an enzyme, and the latter reacts with a chromogenic substrate to cause a colour change which quantifies the amount of enzyme conjugate bound to the sites on the tube interior surface.

The enzyme conjugate and component of interest are allowed to incubate in the tube containing the antibodies for 10 minutes. If the component of interest is high (i.e., high concentration of BTEX), then all of the antibody binds with those molecules; if the component of interest is low (i.e., low concentration), the antibody will bind with the enzyme conjugate. After the incubation is complete, the excess enzyme conjugate is washed away with water. This requires washing the tube with tap or reagent water to remove any unbound enzyme conjugate. A chromogenic substrate is then added to the tube and incubated for 10 minutes. During this time, the enzyme conjugate bound to the antibody sites on the tube catalyzes a change to a blue colour. An acidic stopping solution is then added after the incubation time to halt the reaction at exactly 10 minutes; the absorbance of standards and samples are then measured in a spectrophotometer with darker colours representing lower concentrations and vice versa.

The process sounds complex but is actually relatively easy to run. Within 30 minutes, the field person can see positive 'hits' and identify samples that do not contain contaminants.

Interpretation, Results and Corrective Action

In this project, the 0.5 ppm BTEX standard was used as the criterion for whether the water would be released or not. As long as the measurement was below 0.5 ppm, the water was released to sewer and lagoon. During the process, a total of 205 samples were analyzed using immunoassay systems to control releases; only 11 exceeded the BTEX criterion (Table 1).

Table 1: Comparison Between Laboratory and Immunoassay Results

Laboratory Analysis for: BTEX - GC/PID/FID	**Immunoassay Analysis for: Total BTEX**
241 Discharge Samples Analyzed	205 Discharge Samples Analyzed
38 water samples analyzed were no detect	194 samples were below 0.5 ppm and discharged
None, all samples were in low ppb range xylenes being the highest 38 sample in the 10 to 20 ppb range	11 samples exceeded 0.5 ppm, but were less than 1.6 ppm
No lab analysis was done on pre-treatment material because the material was recycled	38 incidents of pre-treatment measurement and recycling

Samples that exceeded the 0.5 ppm criterion were only slightly above and three of these samples were less than 1.6 ppm. In these events, the contractor had three contingency options ascending in effect to mitigate hydrocarbon 'spikes' as follows:

1. activating a recirculation line that returned post-treatment water to the initial sedimentation tank (two-hour reserve storage),

2. slowing the dewatering extraction pumps for greater residence time in the TORR™ oil-water separator and air tower, or

3. activating a 100% diversion line to emergency surface storage tanks (12-hour storage at minimum dewatering rate).

The majority of the hydrocarbon 'spikes' were remedied by implementing the first corrective action without the need to disrupt the dewatering system or fill emergency tankage. Many of the corrective events occurred during the initial start-up and first month of operation, as hydrocarbon concentrations stabilized at a low baseline once steady-state flow conditions were achieved.

Summary of Immunoassay Experience

The use of immunoassay technology and continuous on-site testing enabled contractor staff to be advised of pre- and post-treatment hydrocarbon concentrations and also urgency of any corrective actions to increase water treatment, as required. Over the four month duration of site dewatering and water treatment, 15,000 m^3 (3.3 mega gallons) of water was successfully treated and released without indications of detrimental effects on the Town sewer or lagoon.

On-site immunoassay testing demonstrated to the Town and regulatory agencies that water from the dewatering was being treated appropriately with close attention to the project water quality objectives for protection of the Town's sewer and lagoon. Without on-site testing, three to five days would have elapsed until 'emergency' laboratory results would have been available, i.e., after releasing 500 to 750 m^3 of over-objective water.

As all of the laboratory samples were air-transported from the site, there was some uncertainty regarding volatile loss in transit. For projects in which air travel is a component, it is recommended that spiked laboratory samples be sent from the laboratory and checked by immunoassay, and returned to the laboratory for re-testing to evaluate the possible loss of volatile hydrocarbon loss.

Overall, the immunoassay technique was found to bias high (factor 100 times higher) compared to laboratory analysis, but still gave precise control over the water treatment process.

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