ENVIRONMENTAL FORENSIC TOOLS HELP ANSWER LEGAL, GROUNDWATER CONTAMINATION PROBLEMS

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Recent court decisions have interpreted regulatory liability for contaminated lands in ways that expand the liability of polluters and, in some instances, innocent owners of contaminated sites. Facing such risk in enforcement proceedings (and civil cases as well), polluters and contaminated site owners should consider developing their technical positions early in a case.

By demonstrating the strength of technical evidence, defendants can state a clear intention to advance their case and encourage discussions that may lead to a cost-effective resolution of the matter. As such, an investment in forensic analysis early in litigation can bring significant momentum to a defendant's position.

In one case, site assessment reports had not uncovered a separate source of the "hot spot" on the downgradient site. Such circumstances are challenging, but not unusual, in historical industrial areas and anecdotal reports will not be sufficient to influence a regulator or a plaintiff.

As the differentiation of source was central to the scoping of the remediation order and the defense against enforcement, forensic analysis was considered a worthwhile endeavour. Unfortunately, a traditional assessment of the chemical fingerprints of groundwater impacts was not enough to distinguish source. Time and budget allowed for the additional step of conducting two advanced forensic techniques, a passive soil-gas survey and a compound specific isotope analysis (CSIA). This resulted in evidence that could differentiate the impacts, and thus the sources.

In highly technical cases, clear narratives and visual interpretations are necessary to relay the strength of evidence and weight of conclusions underlying scientific analysis. Passive soil-gas surveys and CSIA can be described so as to clearly differentiate areas of impacts and source, even to laypersons.

As well, the visual tools used to demonstrate such distinctions can bridge difficult discussions among parties and their

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consultants, or allow a judge or tribunal member to understand otherwise opaque information. Whether in "without prejudice" settlement discussions, or in litigation proceedings, such forensic evidence can be a critical support to a defendant's case, establishing clarity on an issue that may underlie significant aspects of the dispute.

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PASSIVE SOIL-GAS INVESTIGATIONS

Passive soil-gas investigations are high-resolution surveys of the distribution of chlorinated and petroleum hydrocarbon vapours (such as trichloroethylene [C_2HCl_3] and benzene [C_6H_6]) in the subsurface, released by volatile chemicals in the soil and/or groundwater. Since deployment of these samplers does not require a drill rig, survey costs for intensive networks of sample locations are reasonable.

Soil-gas sampling devices are small probes that are inserted into small-diameter, shallow drill holes. These probes remain in place for a period of time (commonly two to three weeks). During this time, volatile gases are released from impacted soil and/or groundwater in the subsurface and adsorb onto a hydrophobic cartridge within the sampling device. On retrieval, sampling devices are sealed and then shipped to a specialized lab where volatile chemicals are desorbed from the cartridges and tested.

Concentrations of the selected volatile compounds are reported in nanograms and can be mapped, using the sampling locations to identify "hot spots." These maps can be used to focus subsequent subsurface investigation to determine soil and groundwater quality in the hotspots. It is important to note that these maps indicate areal distributions of the underlying chemicals. However, they do not identify the depth of the impacts nor differentiate between soil impact from groundwater impact. In addition, the type of surface cover, such as pavement versus grass, can affect the outcome.

COMPOUND SPECIFIC ISOTOPE ANALYSIS (CSIA)

Isotopes are versions of atoms that differ in their behaviour in the environment because of differences in the mass of the nucleus. For example, the element car-

bon has two stable isotopes: carbon-12 (^{12}C), and carbon-13 (^{13}C). ^{12}C is a carbon atom with six protons and six neutrons in the nucleus, while ^{13}C has six protons and seven neutrons in the nucleus.

Simply put, molecules that have relatively more ^{12}C are lighter and more active during physical and biological processes, whereas molecules that have relatively more ^{13}C are heavier and less active during physical and biological processes.

The same applies to the heavier and lighter isotopes of chlorine and hydrogen that occur in chlorinated and non-chlorinated hydrocarbon molecules.

With CSIA, specialized laboratories can first remove individual chemicals dissolved in a groundwater sample, such as trichloroethylene (TCE), and then determine the ratios of $^{13}C/^{12}C$, $^{37}Cl/^{35}Cl$, and $^{2}H/^{1}H$ in the sample. These can be used in two ways. First, dual isotope plots of $^{13}C/^{12}C$ versus $^{37}Cl/^{35}Cl$ for groundwater samples may be used to distinguish between the TCE from two different manufacturers.

Second, during biodegradation, TCE molecules with lighter isotopes are preferentially involved. As a result, the remaining TCE molecules become relatively enriched in the heavier isotopes. If biodegradation is occurring, the trend of isotopic values will be toward progressively heavier isotopic versions of TCE molecules along a groundwater flow path from hydraulically upgradient to downgradient locations.

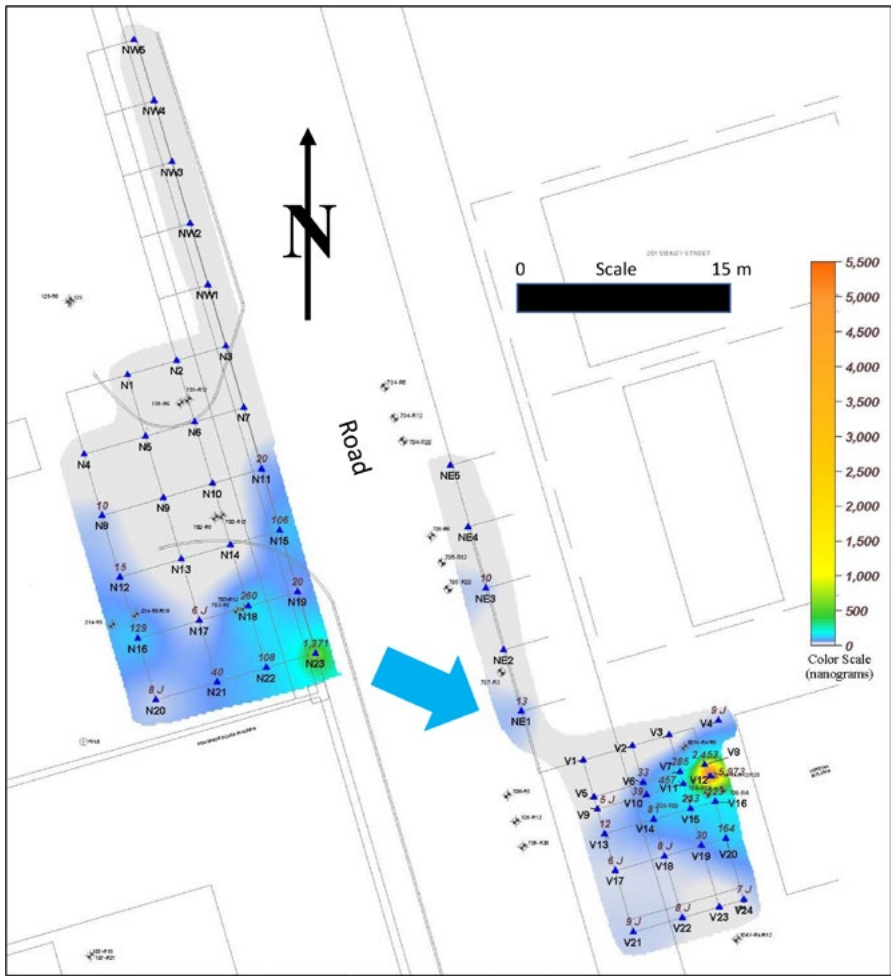

Figure 1. *Passive soil-gas TCE concentrations for TCE case study. The blue arrow indicates the general groundwater flow direction.*

CASE STUDY

This case study involves a legal dispute about whether there were one or two sources of TCE in a groundwater plume. The site includes a known release of TCE on the west side of a road, a groundwater plume with progressively declining TCE concentrations moving essentially eastward beneath that road, and a TCE hotspot on the east side of that road.

The hotspot on the east side of the road aligned with the trajectory of the plume originating from the west side of the road. The hotspot had a similar (but not exact) groundwater chemistry fingerprint as the source on the west side and appeared to be a separate source as the TCE concentrations from the west side source were diminishing in the downgradient direction.

The geology underlying the site (including both properties and the road) is a thin overburden layer over fractured bedrock, where the groundwater resides. There are utility trenches under the roadway that could act as preferential pathways for transport of the TCE impacts. The Phase I and II reports for the eastern property indicated no historical TCE use and no TCE in the soil.

The regulator disagreed that there was a second source and essentially stated that there were unknown fracture pathways that could provide a preferential pathway for TCE under the road, despite having data from many monitoring wells along the road that did not support this theory. In other words, no matter how many borings and wells were placed between the two TCE groundwater hot spots, the regulator indicated there would not be enough data to prove that the TCE was not being transported from the west side to the east side.

Counsel for the west side property owner asked Dragun Corporation for other techniques to shed light on the issue. We suggested two technologies that are independent of the groundwater flow pathways, a passive soil-gas survey and CSIA investigation, be completed across both properties to overcome the "unknown fracture pathways" hurdle.

Figure 1 shows the passive soil-gas survey sampling grid used. The sampling network was designed with (1) sample spacing that was smallest near the hot areas on either side of the road, and (2) two curbside lines to determine whether the TCE plume crossed from the west side of the road to the east side.

Figure 1 also shows the TCE distribu-

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tion in soil-gas that clearly indicates that the hotspot on the east side is a separate source both by the bullseye pattern and by the lower concentration swath along the eastside curb.

Figure 2 summarizes the CSIA data for the various groundwater samples collected from the east and west sides of the road and from beneath the road. The dual isotope data ($^{13}C/^{12}C$ versus $^{37}Cl/^{35}Cl$) trend indicates TCE biodegradation is occurring. Although there were no site specific samples of TCE product available, Figure 2 includes the known isotopic signatures of the various manufactured TCEs from the scientific literature.

Since all the site data fall on a biodegradation trajectory originating from the lighter manufactured TCE (more negative isotope values on the left side of the graph), we could not solve our problem of whether the east and west side hotspots are the result of separate releases based on different TCE manufacturers. The differences in the isotopic data on the west and east side could be explained by degradation of the same TCE product over time.

However, where the isotopic data for the various monitoring wells sit on the biodegradation trajectory arrow indicates two separate releases. If the TCE hotspot on the east side of the road originated from the west side of the road, that TCE would have been released earlier than the TCE on the west side of the road.

Therefore, we would expect more of a biodegradation effect in the east side hotspot groundwater, that is, more positive isotope values on the right side of the graph. However, our data indicate the opposite. The CSIA data, therefore, are consistent with the passive soil gas survey results that indicate two separate releases.

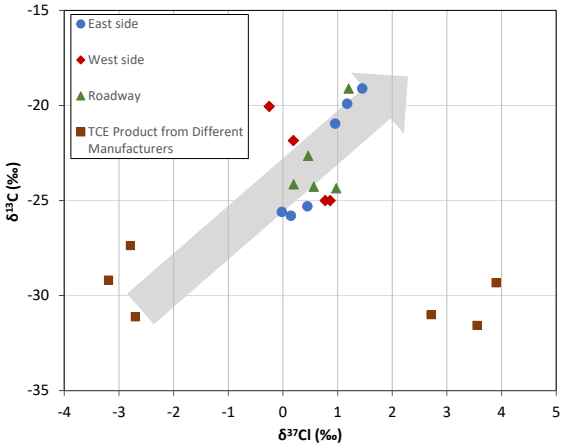

Figure 2. *Dual isotope plot for TCE case study (carbon and chloride isotope concentrations are expressed in delta notation as parts per mil differences relative to standards). The gray arrow indicates the expected TCE biodegradation trend in the groundwater flow direction assuming a single source on the west side of the road.*

We were still left with the Phase I and II data from the eastern property that indicated TCE was not used. In deeper research into the site history on the east side of the road, we found that the soil had been scraped away to bedrock and replaced by clean soil during development and that there was an anecdotal report of TCE use on the site.

Therefore, the Phase I and II reports missed the potential source of TCE on the eastern property.

CONCLUSION

Sometimes the typical approaches to groundwater flow and contaminant transport are not enough to build a convincing legal case, especially in complex hydrogeological environments, such as fractured rock and meandering stream deposits.

Adding investigative tools that are independent of the typical approaches to groundwater flow and contaminant transport can help to build a more robust case when trying to determine sources and pathways. We used a passive soil-gas survey combined with compound specific isotope analyses to help with this legal issue. In addition to clearly defining who is responsible, these techniques can also be used to optimize remediation by clearly delineating the contaminated media. ■

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