REST Sampling: Landmine Detection Using a Fido Device

Using ultra-sensitive vapor detection sensor tools like Fido, Remote Explosive Scent Tracing (REST) techniques are bringing innovative and interesting developments to the mine action community. These tools could very well put greater technology in the field alongside conventional detection techniques.

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Introduction

Once a landmine is deployed, a complex process begins in which the environment near the mine becomes contaminated with explosives and explosive-related compounds (ERCs) derived from the charge contained in the mine. It has been known for decades that mine detection dogs can detect the chemical vapor signature of explosives emanating from landmines.[1] More recently, detection of landmines by vapor-phase sensing of key chemical signature compounds using ultra-sensitive chemical sensors has been demonstrated. As part of the Defense Advanced Research Projects Agency's (DARPA's) Dog's Nose Program, Nomadics Inc., first demonstrated chemical vapor detection of landmines using an electronic vapor sensor in 1998. This sensor, known as Fido, utilizes novel fluorescent polymers to detect ultra-trace concentrations of explosives (TNT) and other nitro-aromatic compounds emanating from landmines. The sensor has recently been adapted to enable analysis of modified REST filters. Using the REST methodology, Nomadics and Mechem Division of Denel (Pty), Ltd., participated in testing of the Fido sensor and the Mechem Explosive and Drug Detection System (MEDDS) as a tool for minefield area reduction. This work, funded by the U.S. Army Night Vision and Electronic Sensors Directorate (NVESD) Humanitarian Demining (HD) Program, enabled comparison of the Fido sensor with canines as a tool for minefield area reduction. While more testing is needed, the initial results were promising.

By performing laboratory analysis of soil samples collected near landmines, researchers have been able to learn more about landmine chemical signatures.[2–6] The results of studies published thus far suggest that the chemical contamination emanating from mines tends to be non-uniformly distributed and can be dispersed a significant distance from the mine. In general, the concentration of signature compounds decreases as the distance from the mine increases but, depending on a myriad of environmental factors, may not fall to zero (or below detection limits of dogs or the Fido sensor) for a significant distance from the mine. While much has been learned in recent years regarding the release of explosives into the environment near landmines, more studies are needed. Most of the information available in the literature is derived from data gathered on a limited number of mines and at only a few test sites. While our field test results are largely in agreement with much of the data that has been published, more data of this type is needed before general conclusions should be drawn.

If the conclusion is that the chemical signature of landmines is often non-uniformly dispersed and not localized directly over the mines, it would be logical to conclude that it would be difficult to pinpoint the exact location of the mine using trace chemical detection methods. From discussions with mine detection dog handlers, free-running mine detection dogs usually indicate within a meter to, at most, a few meters from a mine. Similar results have been obtained using the Fido sensor. However, the use of REST sampling methods appears, in many cases, to extend the range of detection to many meters from the mine position. This is because the REST sampling method can be used to concentrate low levels of contamination that may occur many meters from a mine onto a filter prior to analysis by dogs or a chemical vapor sensor. The vapor-concentrating effects provided by REST sampling enables recognition of low-level landmine chemical signatures that may be present a substantial distance from a mine. Thus, being sampled, concentrated and detected by dogs or a sensitive chemical sensor can occur at a distance much farther away from the mine than may be possible by direct searching with a dog or sensor.

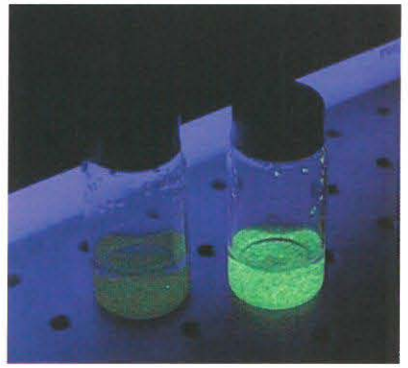
The REST method, while not particularly useful for determining the exact location of a mine, is possibly quite useful for isolating the location of a mine to within a well-defined area. In theory, this makes the method ideal for use as a minefield area reduction tool.

Fido Sensor Principle of Operation

To our knowledge, Fido was the first chemical vapor sensor to detect landmines under field conditions. In these blind field tests administered by DARPA, the sensor was able to detect buried TMA5 and PMA1A landmines with the fuses and detonators removed, with shipping plugs capping the detonator well. Canines were also tested at the site during these tests. The performance of Fido was comparable to that of the canines in this test.[6]

The Fido sensor has been described in detail elsewhere,[7] so only a brief description will be presented here. Fido detects TNT and other explosives that contain TNT such as Composition B. It is approximately 1000 times more sensitive than most explosive detection systems currently used for passenger screening in airports. This extreme sensitivity is necessary to detect the explosives vapors released from landmines. This sensitivity is achieved by using novel polymer materials developed by collaborators at the Massachusetts Institute of Technology (MIT).[8] In the absence of TNT, the polymers fluoresce (emit visible light) when exposed to light of the correct wavelength. When molecules of TNT are present, the intensity (brightness) of the fluorescence is greatly reduced, and a sensitive photo detector then detects the drop in fluorescence intensity. The sensor detects TNT, 2- and 4-DNT, amino-dnt's and other nitro aromatic compounds derived from TNT. In laboratory tests, the sensor has demonstrated lower limits of detection of one femtogram (1×10^{-15} grams) of TNT.

The sensor is small (handheld), weighs about four and a half pounds and can run for approximately eight hours on a battery charge. It is projected that production cost of the sensor will be comparable to a metal detector.



These vials contain beads coated with the fluorescent polymer in an aqueous solution. The vial on the right contains TNT while the vial on left does not.

Nomadics REST Filter Design

The REST method is derived from the MEDDS. Using this methodology, the scent of an area suspected of being mined is sampled and transported to a detector dog for analysis. Samples are collected by drawing large volumes of air and entrained soil particulates from a suspect area through a specially designed filter created to trap vapors of explosives. High-volume air pumps are used to draw air through the filters. After collecting a sample on an inexpensive and disposable filter, the filter is presented to highly trained dogs for analysis. These dogs are trained to detect traces of TNT that may have been collected on the filter during sampling of a mined area. When a dog indicates the presence of TNT on a filter, the area from which the sample was collected is regarded as contaminated, which is then investigated using traditional methods. If no explosive scent is found in a sample area, the local community returns it to productive use. Because most areas that are suspected of containing mines are actually free of mines, this method has the advantage of preventing unnecessary and costly demining efforts. Once proven as a minefield area reduction tool, the REST concept, using an on-site vapor sensor, will enable real-time analysis of samples, allowing rapid screening of large areas for contamination by mines. If successful, this will result in a dramatic reduction in demining costs and will increase the rate at which areas can be declared free of mines.

Because of incompatibilities of the MEDDS filter with Fido, Nomadics designed a REST-type filter that was compatible with Fido and with dogs. The filter is the same basic geometry and size as the REST filter, and can be used with traditional sampling pumps without modification of the pumps. The filter is constructed from a thin-walled metal tube packed with small, spherical beads coated with a thin film of a proprietary material. The beads are held in place within the tube by metal screens. Testing of this filter using the Fido sensor yielded promising results. In addition, after a limited amount of training on this filter, canines initially trained to analyze the MEDDS filter were able to analyze the Nomadics filter with good results. Hence, the filter is compatible for use with both the Fido sensor and canines. This enabled direct comparisons of the sensor and canine performance on the same sample. To our knowledge, this is the only filter currently available that has been proven compatible with sensors and dogs.

Laboratory Comparison of Fido and Canines Using the Nomadics REST Filter

A comparison of the performance of the Fido sensor to MEDDS canines was performed at the MEDDS facility in Pretoria, South Africa, in February 2003. These tests were conducted using the Nomadics REST filter. At the time of testing, the MECHEM canines had been trained on the Nomadics filter for approximately four months.

Positive, blank and interferent samples were prepared using standard methods. All samples were marked by sampling personnel in a manner that made it impossible for analysts to determine the composition of the sample during analysis. Nomadics personnel and dog handlers were not given any information on sample identity until analysis of samples was completed and results were submitted for scoring (i.e., the tests were conducted in a "blind" fashion).

Samples were first analyzed by the canines and were then analyzed by Fido. Samples were analyzed in two batches. Each batch contained positive, blank and interferent samples. Batch 1 contained a total of 25 samples, four of which were positive. Both Fido and the canines detected three of the four positives. The

The Nomadics REST sample collection filter.

sensor and the dogs missed the same sample. All samples from Batch 1 were analyzed at room temperature. In the second batch of samples, there were three positive samples out of 24. Fido and the canines detected all three positive samples. Prior to presentation of samples in the second batch to Fido, the samples were heated slightly to enhance the vapor phase concentration of target analytes in the samples. As would be expected, responses to the positive samples that were heated were stronger than the room temperature samples. The performance of Fido and the canines against interferents was also identical. Of the 20 potential interferents included in the test, Fido and the canines responded to the same interferents, detecting two of the 20 interferents.

John Sikes, a project manager with Nomadics, presents a filter to the Fido sensor for analysis.

The results of the laboratory comparison were promising. The performance of the sensor during this series of tests was comparable to that of the canines. One outcome of these tests was the notion that the Fido sensor could possibly be used as a canine training aid. For example, when positive samples are prepared, there is currently no easy way to determine if the samples are actually positive. The sample that was missed by the canines and by Fido was prepared in exactly the same manner as the three samples that were detected, yet this sample was not detected. If the sample in question were used as a positive sample during training, but was actually blank, confusion of the dog could occur, reducing the effectiveness of the training session. In addition, a properly designed electronic sensor should exhibit reproducible and quantifiable levels of performance from day to day. The performance of canines can vary for a variety of reasons, and it can be difficult to determine when a dog is not performing at its best. The sensor could possibly be used to help verify the performance of canines. This is not to say that the performance of Fido is presently adequate to replace dogs in certain roles, but it may have a role in enhancing and complementing the performance of dogs.

Field Test Results

From July 2001 to August 2003, Nomadics and MECHEM performed a series of trials at a test minefield in Europe. This effort tested the ability of both the Nomadics and Mechem trace chemical vapor collection and analysis systems in detecting the presence of mined areas within a larger area clear of landmines.

The test field consisted of two segments. The first was a 40,000-sq m "blind area" laid out in a grid pattern and containing eight to 15 mines with locations, type and burial depth unknown to the team. The second was a "proximity area," which contained three each of four different mine types (12 mines total) at known positions separated by 30 m. The purpose of this area was to determine how far explosive contamination could be detected from a mine.

REST samples were taken from the field prior to mine emplacement and analyzed by both the Fido sensor and trained canines. All samples collected were negative for explosives contamination, showing that the area was free of explosive contamination prior to emplacement of the mines.

Over the life of the project, five samplings were taken after burial of the mines, in environmental conditions ranging from hot and dry to moderately cold and damp. In every sampling both systems detected the presence of explosive contamination. Even three days after burial of the mines, both systems detected the presence of mines in the blind test area. This was a surprise to the team, because it was expected that there would not have been time for explosives to leach from the mines to the soil surface. In general, there was an increase in contamination of the area with time, with more positive samples being obtained as the time the mines were in the ground increased.

In the proximity area, samples were taken along and two meters to each side of three-, seven-, and 11-meter radii marked around each mine during each sampling event. Fido and the MECHEM canines routinely detected contamination up to 11 m from the mine centers. Because of the layout of the test field (the mines were only 30 m apart), it was impossible to determine if contamination spread past 11 m from the mines. Results from the blind test area suggest that contamination spread more than 11 m, but it was not possible to determine on average how far the contamination spread from a given mine location.

Based on the test results, it was determined that both systems could detect mined areas. In retrospect, the blind test area probably contained too many mines and did not contain a large area that was free of mines. Because of the large number of mines in the area, contamination of the test area was widespread. Hence, in these tests, it was not possible to delineate a mined area from a non-mined area. It should be again noted that both systems found the area to be free of contamination prior to emplacement of the mines.

Certain results from the field tests were somewhat surprising. The locations of positive samples as determined by Fido and the dogs were largely uncorrelated. One possible explanation for this is that the dogs were trained to detect TNT, while the Fido sensor detects TNT as well as other nitroaromatic compounds derived from TNT. Hence, Fido and the dogs may not have been detecting the same scent compounds in all samples. Another interesting finding was that a portion of the test area that was positive in one sampling was not necessarily positive in other samplings. This suggests that the contamination in a minefield is dynamic, changing along with changes in environmental conditions. Ultimately, it was concluded that the systems detected contamination of the test field with mines, but that there is still much to be learned about the spread of explosive contamination from mines.

**All photos courtesy of the authors.*

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