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REST Sampling: Landmine Detection Using a Fido Device

by Mark Fisher, John Sikes and Kip Schultz, Nomadics, Inc.

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. Nomadics has developed landmine detection dogs that can detect the chemical signature of explosives emanating from landmines. More recently, testing 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) Dog’s Nose Program, Nomadics Inc., first demonstrated chemical vapor sensitivity using an electronic vapor sensor in 1998. This sensor, known as Fido, utilizes novel fluororesence 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 fibers. Using the REST methodology, Nomadics and Mecem Detection Systems (MDS) executed a joint testing program in testing of the Fido sensor and the Mecem Explosive and Drug Detection System (MECEDS) as a tool for minefield area reduction. This work, funded by the U.S. Army Night Vision and Electro-Optics Directorate (NVEES) Humanitarian Demining (HID) 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.

However, the use of REST sampling methods appears, in many cases, to extend the detection distance 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. 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-normally distributed 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 are usually indiscriminate within a meter or, at most, a few meters from a mine. Similar results have been obtained using the Fido sensor.

This sensitivity is achieved by using novel polymer materials developed by collaborators at the Massachusetts Institute of Technology (MIT). 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, 4- and 2, 4, 6-NTN, ammonites 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 gr) of TNT.

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 TMAS and PMMA landmines with the fuses and detonators removed, with shipping plugs capped and intact, with a true positive rate of 95%. The sensor principle of operation was also tested at the site during these tests. The performance of Fido was comparable to that of the canines in this test.2

The Fido sensor has been described in detail elsewhere,3 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 in airfields. This extreme sensitivity is necessary to detect the explosives vaporized released from landmines.

These vials contain beads coated with the fluorescent polymer in an aqueous solution. The vials contain the right composition of TNT that will react with the Fido sensor.

The REST method is derived from the MEDES. Using this methodology, the sensor 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 renews its in productive use. Because most areas that are suspected of containing mines are actually free of mines, this method has the advantage of decreasing 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 MEDES 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 filters 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 MEDES 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 MEDES canines was performed at the MEDES facility in Pretoria, South Africa, in February 2003. These tests were conducted using the Nomadics REST filter. At the time of testing, the MEDES canines had been trained on the Nomadics filter for approximately four years.

Positive, blank and intercept samples were prepared using standard methods. All samples were masked 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 review. (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 2 batches. Each batch contained positive, blank and intercept samples. Each canine contained a total of 25 samples, four of which were positive. Both Fido and the canines detected three of the four positives. The

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3. This methodology uses a cold vapor technique to concentrate volatile compounds from a soil sample on the inside of a vial. A filter is then put on the vial, and the vials are then run in fluorescence intensity. The sensor detects TNT, 2, 4- and 2, 4, 6-NTN, ammonites 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 gr) of TNT.

4. However, the use of REST sampling methods appears, in many cases, to extend the detection distance 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. 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.

5. If the conclusion is that the chemical signature of landmines is often non-normal 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 are usually indiscriminate within a meter or, at most, a few meters from a mine. Similar results have been obtained using the Fido sensor.

6. This sensitivity is achieved by using novel polymer materials developed by collaborators at the Massachusetts Institute of Technology (MIT). 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, 4- and 2, 4, 6-NTN, ammonites 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 gr) of TNT.
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 mixed with environmental conditions of soil, either hot or cold, some positive samples were detected, thereby providing an opportunity to determine if the samples are actually positive. These samples were then analyzed for the presence of explosive contamination, and a positive result was obtained. The canines and Fido were trained in exactly the same manner as the three samples that were used in the previous study, yet this sample was not detected. If the sample in question were used as a positive sample during training, it 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 2003 to August 2003, Nomadics and MECHEM performed a series of trials at a test minefield in Europe. This effort tested the ability of both of the Nomadics and Mischel 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 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 explosive 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 an environmental condition 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 no 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 two meters to each side of three-, seven-, and 11-meter radio marked mines 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 from the mines. Results from the blind test area suggest that contamination spread more than 11 m from the mines, 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 noted again 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 nitramine compounds derived from TNT. Hence, Fido and the dogs may not have detected 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.*

**References**


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