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Final Report

Applied Testing of Airdar's Air Detection and Ranging System

Prepared for
Airdar Inc.

Prepared by
Chris Apps, MSc, PEng

Reviewed by
Corey Drake, PEng

February 2024
F472-TR-1-Rev1

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PROJECT TEAM

Applied Testing of Airdar's Air Detection and Ranging System	C-FER Project: F472-TR-1-Rev1	
Task/Deliverable	**Contributors**	**Responsible Professional**
Project management/conclusions and recommendations	Chris Apps, MSc, PEng	Chris Apps, MSc, PEng

REVISION HISTORY

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1. INTRODUCTION

1.1 Overview

Airdar Inc. ("Airdar") contracted C-FER Technologies (1999) Inc. ("C-FER") to perform applied testing of Airdar's Air Detection and Ranging System. This report outlines the results of this applied testing.

1.2 Background

C-FER has extensive experience in carrying out test programs for leak detection systems that supplement traditional computational pipeline monitoring (CPM) systems. These supplementary leak detection systems are typically deployed to detect releases below the thresholds of CPM systems. Described herein is the test program that C-FER has developed specifically for Airdar's supplementary leak detection system, Air Detection and Ranging System.

Airdar's Air Detection and Ranging System (hereafter the "System") uses measurements of ambient concentrations and wind data to identify and locate sources of emissions. Such measurements can be made with relatively inexpensive sensors and, when combined with wind direction and speed, can be analyzed to identify and locate the emissions source, as well as estimate the emission rate of the source.

The System uses a central sensing unit with remote sampling sites to allow a single unit to be deployed and monitor a site. The remote sampling sites are an inlet with tubing, which continuously draws air through the tube that runs back to the central unit. The air is sampled for a short period of time and then cycled through each sampling site, allowing data to be obtained from each site. The System also uses several volatile organic compound (VOC) sensors for redundancy, thereby improving the reliability of the system.

1.3 Objectives

The key objectives of this test program were to demonstrate the ability of the System to detect and locate controlled releases of hydrocarbon products. The key metrics were the amount of time required to detect the release and the accuracy with which the System was able to determine the location of the source.

2. TEST DESIGN

2.1 Test Setup

The System was set up in C-FER's yard at their Pylypow location. A Google Earth image of the facility is shown in Figure 2.1. The yard is 80 m (262 ft) wide by 100 m (328 ft) long and is fenced on three sides, with the building on the fourth side. The Pylypow constructed wetlands are to the north and east of the yard. The wetlands consist of storm ponds and grasses with few trees to obstruct the wind. To the west there is a neighbouring facility with pipes in the yard, and on the south side of the yard is C-FER's building. Along the east fence there is standard 120VAC power.

Figure 2.1 Google Earth Image of C-FER's Pylypow Location (1)

The System was placed along the east fence, and tubing was run along the fence line to seven sampling locations (shown in Figure 2.2). Photographs of the sampling location inlets are shown in Figure 2.3. The lengths of tubing running to each sensor location were the same to allow all sensor inlets to have equal transport time through the tubes to the System. The excess lengths were coiled, as seen in Figure 2.3b.

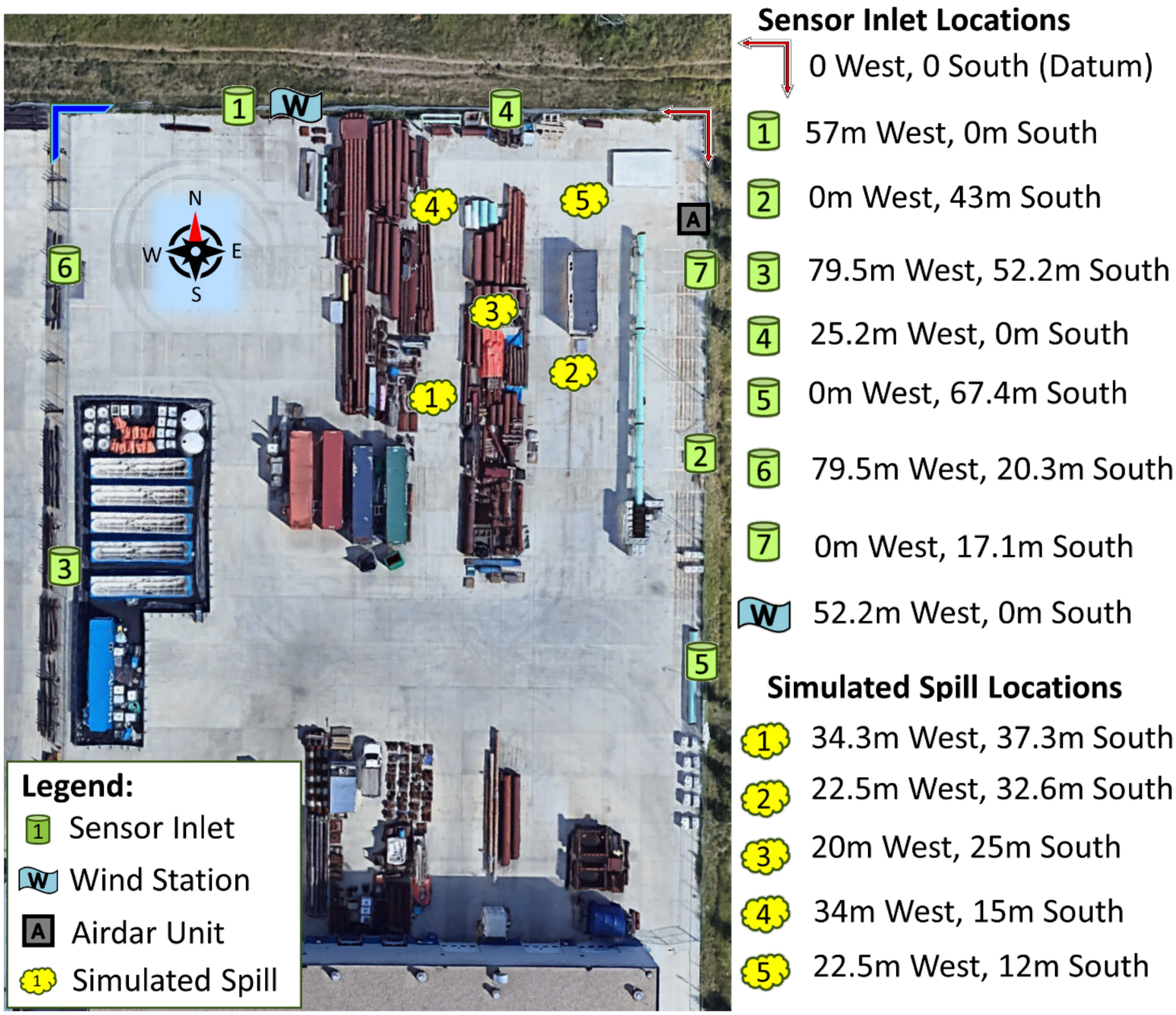


Figure 2.2 Simulated Spill and Sensor Inlet Locations

a) Sensor Inlet 4 **b) Sensor Inlet 4 (with Coil of Excess Tubing Length)**

Figure 2.3 Photographs of Sensor Inlet 4

Once the System was installed and set up, it was monitored to establish a baseline background concentration to help reduce the risk of false alarms. Originally, this was expected to be four to five weeks, but after less than two weeks, Airdar determined that they had sufficient baseline data to proceed. It was also recognized that any downtime between tests could be used to further define the baseline.

To simulate a product spill, a small volume of test fluid was placed in an open tray. This was intended to simulate a short duration leak that does not continue and is, therefore, a conservative test of the capability of the System. Under these conditions, the fluid would be expected to weather over time, and the vapours originating from the stationary product would diminish. In contrast, an 'active' leak would continue to release fresh product and increase the total volume over time. Additionally, there would be agitation of the released fluid due to the movement of the fluid that would further increase the volatilization of light products.

2.2 Test Fluids

The primary test fluid was readily available white gas (i.e. Coleman camp fuel or light hydrotreated distillate). This is a highly volatile light hydrocarbon, which was considered a good baseline to determine whether small liquid volumes can be detected using the System. Some preliminary testing was also performed using Access Western Blend (AWB), a high total acid number diluted bitumen.

3. TEST RESULTS

3.1 Overview

Five simulated spill events were tested over the course of the project (as outlined in Table 3.1). Three tests were “open”, where the timing and locations of the simulated spills were provided in advance to Airdar. The other two tests were “blind”, where the date, time, and exact locations of the simulated tests were unknown to Airdar. The locations of all simulated spill locations are provided in Figure 2.2.

Test No.	Blind/Open	Fluid	Volume (L)	Container Configuration	Start Time and Date	End Date and Time
1	Open	White Gas	3.7	Open Pan	11/29/23 14:42	11/30/23 15:21
2	Blind	White Gas	3.7	Open Pan	12/7/23 12:57	12/8/23 14:00
3	Open	AWB	20	Drum with Open Bung	12/12/23 16:00	12/13/23 16:00
4	Blind	AWB	5 +5	Open Pan Open Pan	12/19/23 11:55 12/20/23 15:20[1]	— 12/21/23 11:00
5	Open	White Gas	3.7	Open Pan	1/11/24 13:49	1/16/24

Table 3.1 Overview of Simulated Leak Events

3.2 Test 1

Test 1 was performed to validate the test setup and verify that the System was operational. This was a fully open test where Airdar was informed where and when the simulated spill was performed. A total of 3.78 L of white gas was placed in an open container (10 in × 13 in × 3 in) and left for 24 hours. During this test, the System was operational and monitored by Airdar but the alarm system was not activated.

Figure 3.1 shows an image from the Airdar Client Dashboard showing the VOC concentration and wind direction over the course of the test. The VOC concentrations increased considerably, relative to the baseline, approximately 2 minutes after the simulated spill was introduced, with an initial

[1] An additional 5 L of AWB was added 24 hours after starting testing.

peak of approximately 32 ppb. The peak concentrations then dropped to between 5 and 10 ppb for much of the test duration.

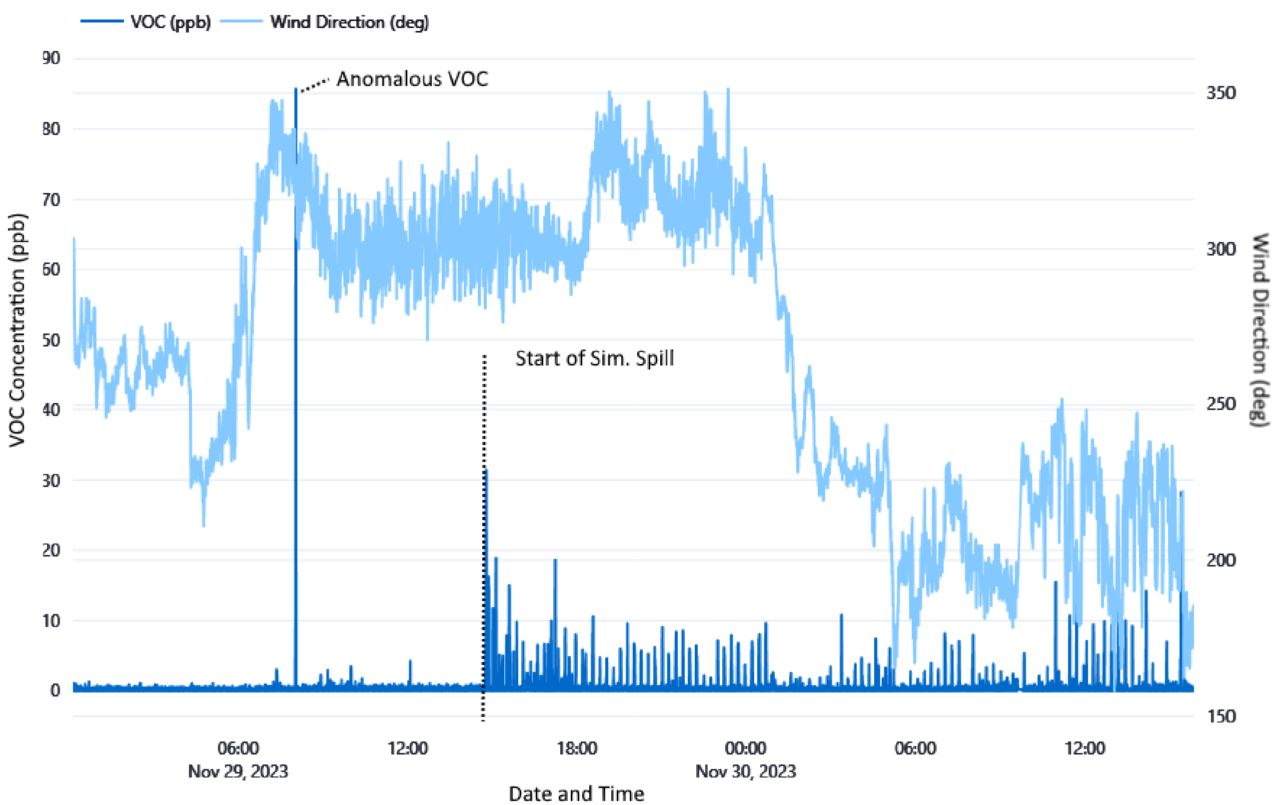


Figure 3.1 Test 1: VOC Concentrations and Wind Conditions (from Airdar Client Dashboard)

Figure 3.2 shows a plot of the VOC concentrations and inlet numbers. As discussed previously, the System used in this test cycles through air samples from each sensor inlet for short durations (2 minutes each for this test). This is illustrated in Figure 3.3. Only sensors that were downwind of a source show increased VOC concentrations. As seen in Figure 3.1, the wind direction was from approximately 300° (NE wind) for the first half of the test, then shifted to approximately 200° (SSW wind) for the remainder of the test. This corresponds to the higher concentrations being observed during the sampling from Inlets 2 and 5 for the first half of the test and Inlets 4 and 7 for the second half.

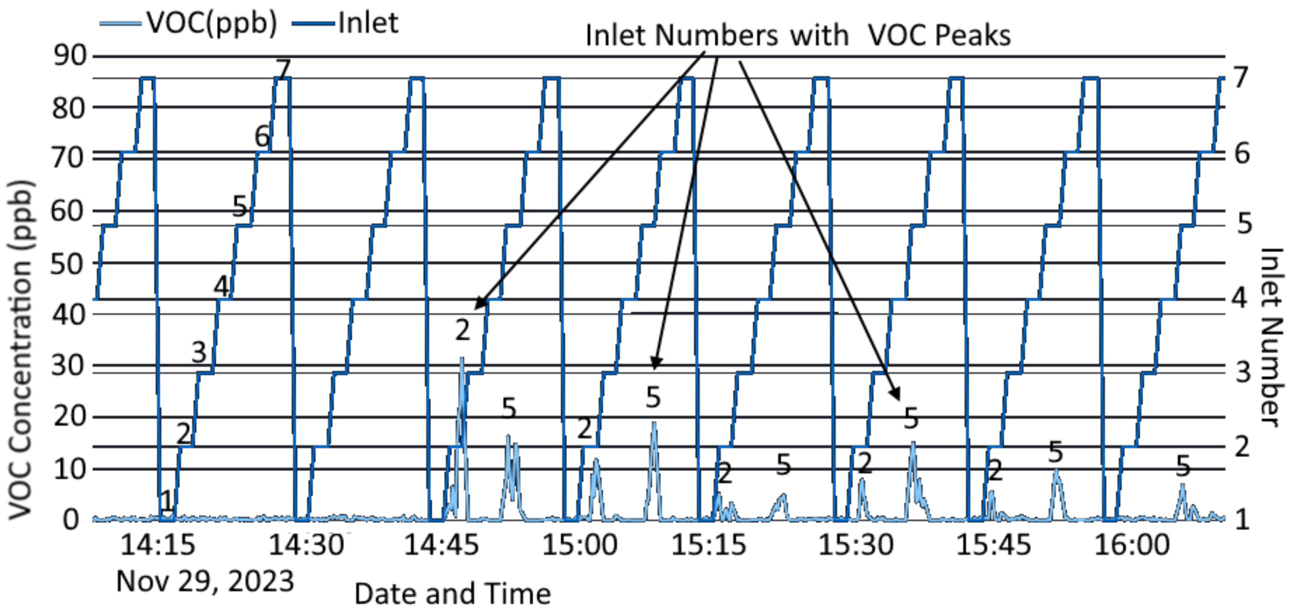


Figure 3.2 Test 1: VOC Concentration and Inlet Number, Annotated with Inlet Number (from Airdar Client Dashboard at Start Time of Simulated Spill 1)

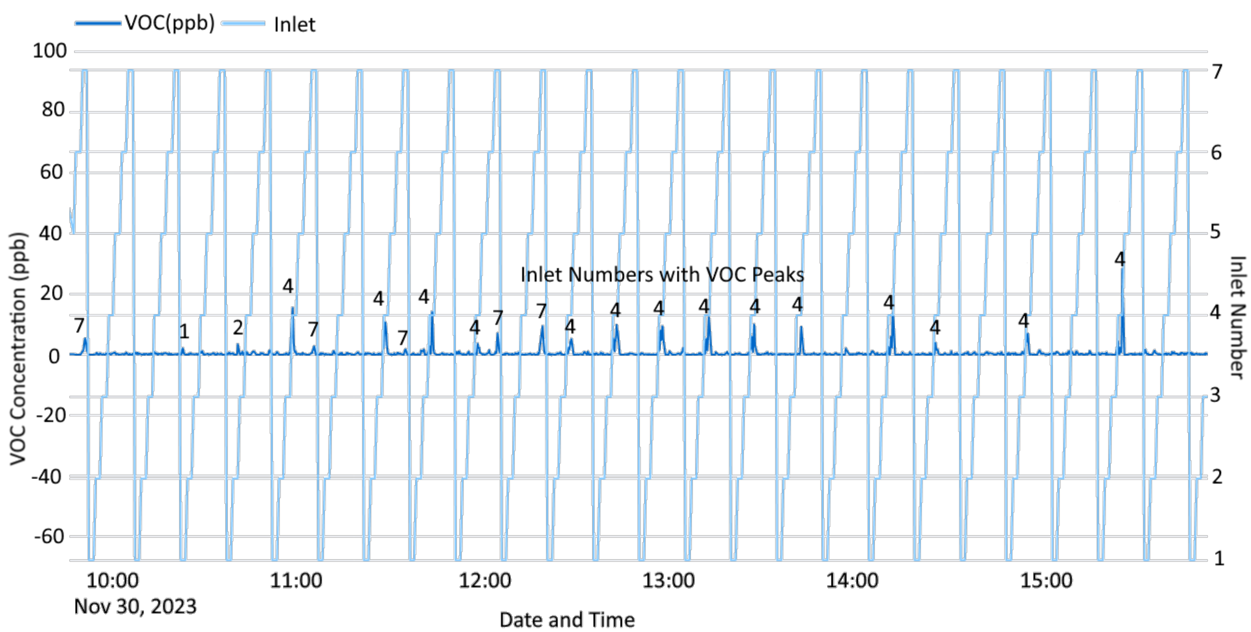


Figure 3.3 Test 1: VOC Concentration and Inlet Number, Annotated with Inlet Number (from Airdar Client Dashboard at End Time of Simulated Spill 1)

There was also an anomalous, short duration (1 sampling cycle) increase in VOC concentration observed at 8:02 AM the morning of the test. Figure 3.4 shows the VOC concentration (86 ppb) and inlet number (Inlet 6) during this anomalous spike. Inlet 6 was located along the west fence, and the wind direction was from 320° (NE), as shown in Figure 3.1, indicating that this was from a source offsite. It is suspected that there was activity in the neighbouring yard, resulting in a short duration VOC release; however, this could not be confirmed. The System did not flag this as a potential leak and was able to determine that this was an offsite source without issue.

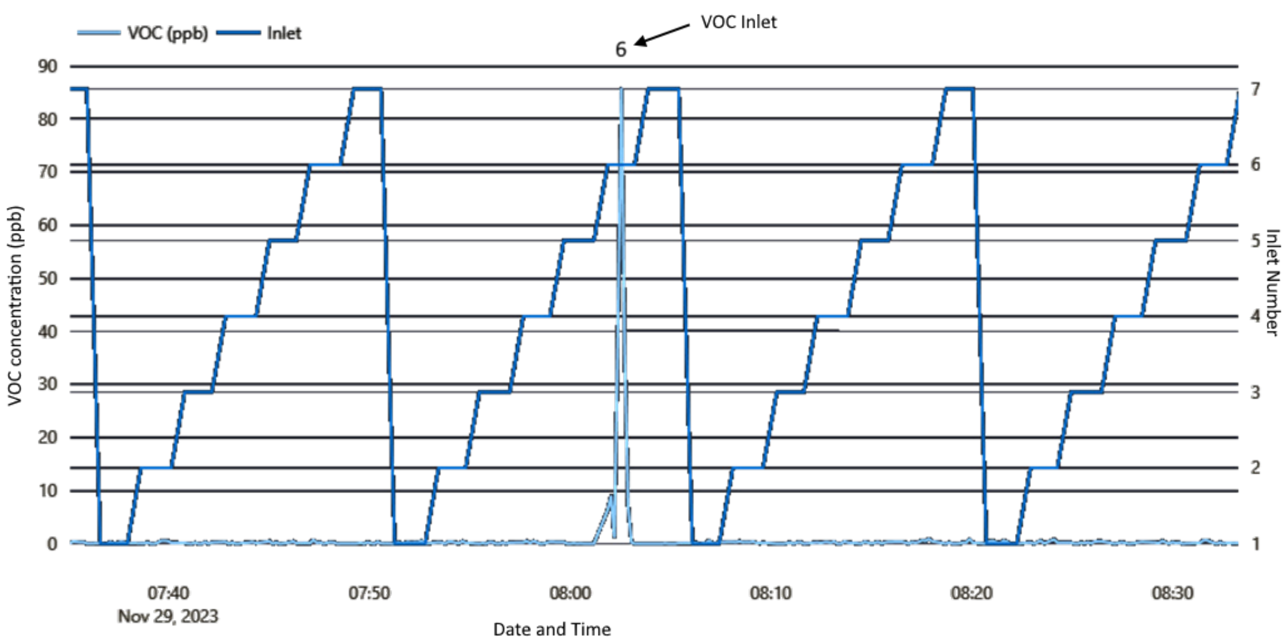


Figure 3.4 Test 1: VOC Concentrations and Inlet Number at Anomalous Spike Prior to Spill (from Airdar Client Dashboard)

3.3 Test 2

Test 2 was a blind test where Airdar was not informed of the day, time, or exact location of the simulated spill. During this test, the alarms were active. The location is provided in Figure 2.2. As with Test 1, a total of 3.78 L of white gas was placed in an open container (10 in × 13 in × 3 in) and left for 24 hours.

The VOC responses from the System are shown along with the air temperature in Figure 3.5. The System recorded a response 6 minutes after the start of the spill. This corresponds to the first sample from Inlet 2, which was located downwind from the spill location. Figure 3.6 shows the concentrations and wind directions during the start of this test. The peak concentration reached was 170 ppb at the start of the test, and then it dropped to between 5 and 45 ppb for the duration of the test. At the start of the test, the wind was coming from approximately 300°, placing Inlets 2 and 5 directly downwind. After a few hours, the wind shifted to approximately 250°, resulting in Inlet 7 recording increased VOC levels. The wind then fluctuated between approximately 100° and 200°, which led to intermittent VOC level increases at Inlets 1 and 4 to the north, 6 to the west and 7 to the east.

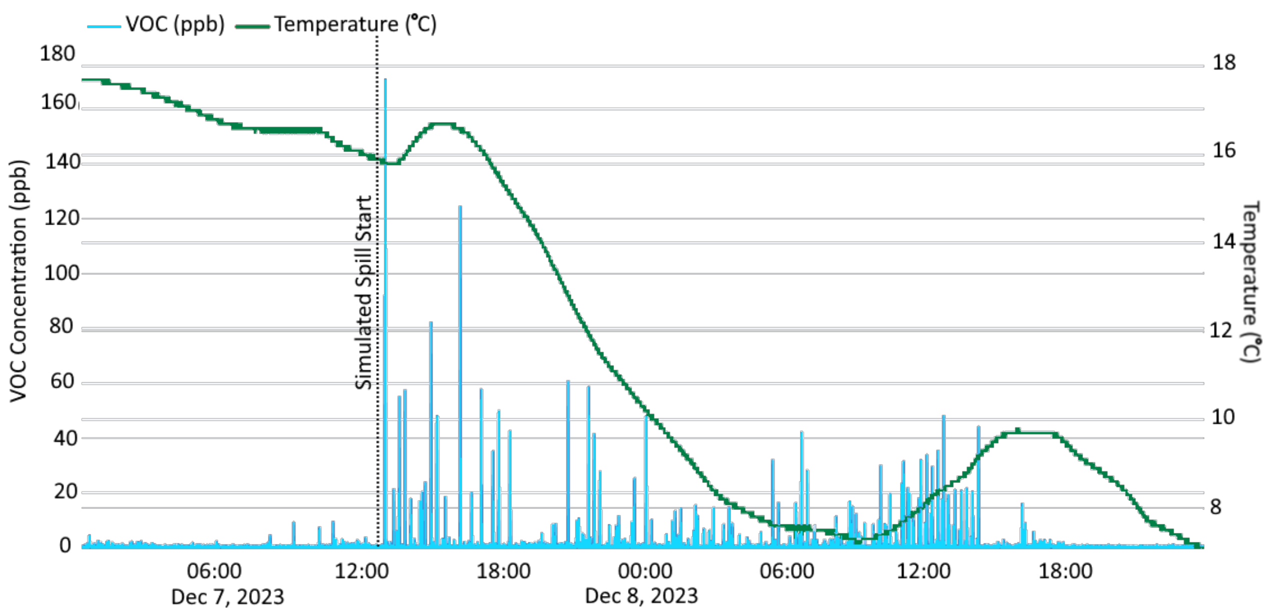


Figure 3.5 Test 2: VOC and Temperature

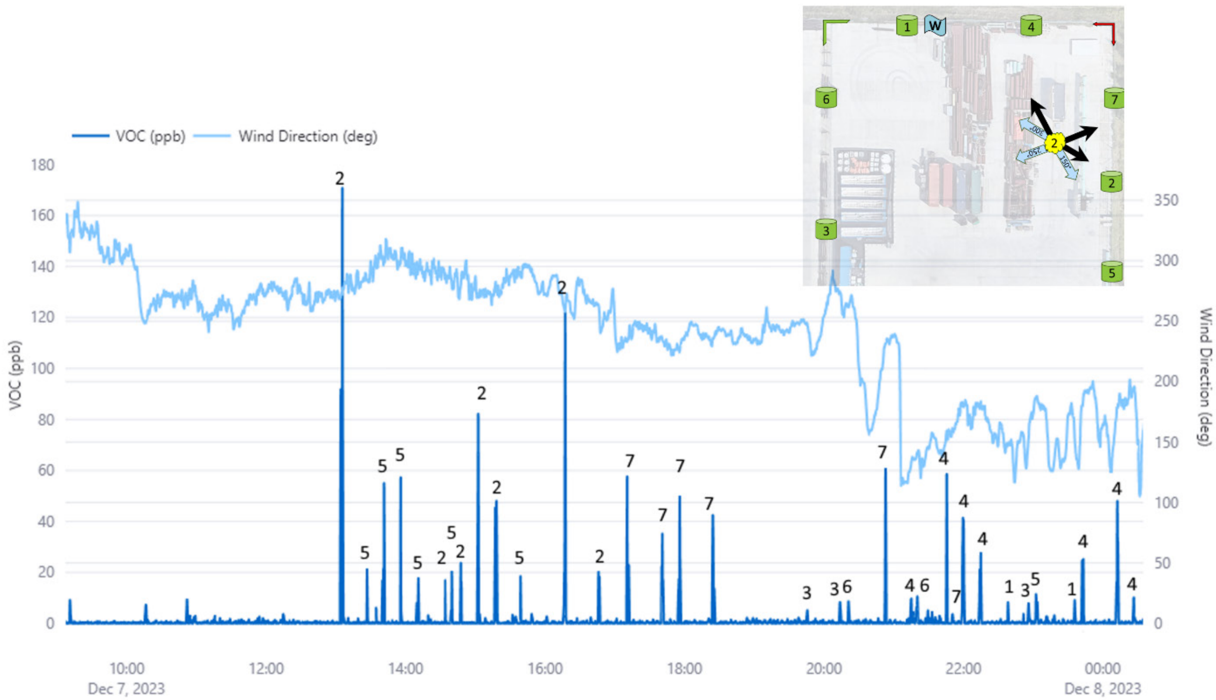


Figure 3.6 Test 2: VOC and Wind Conditions with Sensor Inlet Numbers and Inset Map of Sensor Locations at Start Time

Figure 3.7 shows examples of alarms sent by the System, including the time that the anomalous readings initially occurred. Figure 3.7a shows radial plots generated by Airdar to identify the location of a source of emissions. These plots are generated using a combination of wind direction, windspeed, and VOC concentration to obtain information on the location and magnitude of the emissions. As shown in Table 3.2, the time from the start of release to the first indication was 6 minutes, the time to report the potential onsite leak was 54 minutes, and the time to report a confirmed leak was approximately 3.5 hours.

YELLOW ALARM - Potential Onsite Leak Detected

The Airdar leak detection system has detected anomalous readings at 13:53 on January 11, 2024 that indicate the potential for an onsite leak.

Data is currently being reviewed by Airdar to verify the oil leak and identify leak location(s). An update will be provided once the review is complete.

a) Example of Yellow Alarm from Airdar System

ORANGE ALARM - Potential Onsite Leak Persists

The Airdar leak detection system has continued to detect anomalous readings initially detected at 13:53 on January 11, 2024 that indicate an onsite leak.

Potential leak location(s) have been identified and preliminary results can be viewed through the user dashboard. Confirmed leak locations will be provided once verification is complete.

b) Example of Orange Alarm from Airdar System

RED ALARM - Onsite Leak Confirmed

The Airdar leak detection system has continued to detect anomalous readings initially detected at 13:53 on January 11, 2024 and has determined an onsite leak is present.

Preliminary leak location(s) and their emission rates can be viewed through the user dashboard. Airdar will continue to monitor this leak to provide real-time updates through the user dashboard as more data is collected and work with the primary contact to address this issue.

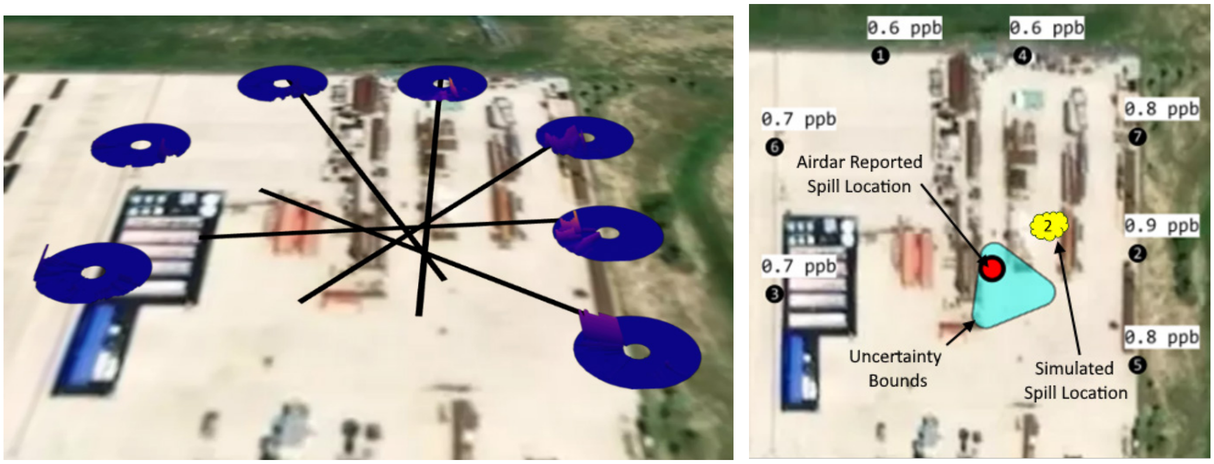
c) Example of Red Alarm from Airdar System

Figure 3.7 System Example Alarms

Test No.	Date	Start of Spill	1st VOC Indication	Yellow Alarm Email Received	Orange Alarm Email Received	Red Alarm Email Received
2	12/7/23	12:57	13:03	13:51	15:10	16:32
5	1/11/24	13:49	13:53	14:22	15:19	16:24

Table 3.2 Table of Alarm Times

Figure 3.8 shows the simulated spill location as predicted by Airdar (approximately 18 m from the actual location), along with an area of uncertainty based on the amount of available data. The positional error is likely due to the effect that the buildings and other equipment in the area had on the path of the wind within the yard.



a) Map with Radial Plots **b) System Predicted Spill Location**

Figure 3.8 System-predicted Spill Location

Figure 3.9 shows a summary of data produced by Airdar indicating the wind conditions, the raw sensor data, the processed VOC concentration data, and the times that alarms were generated.

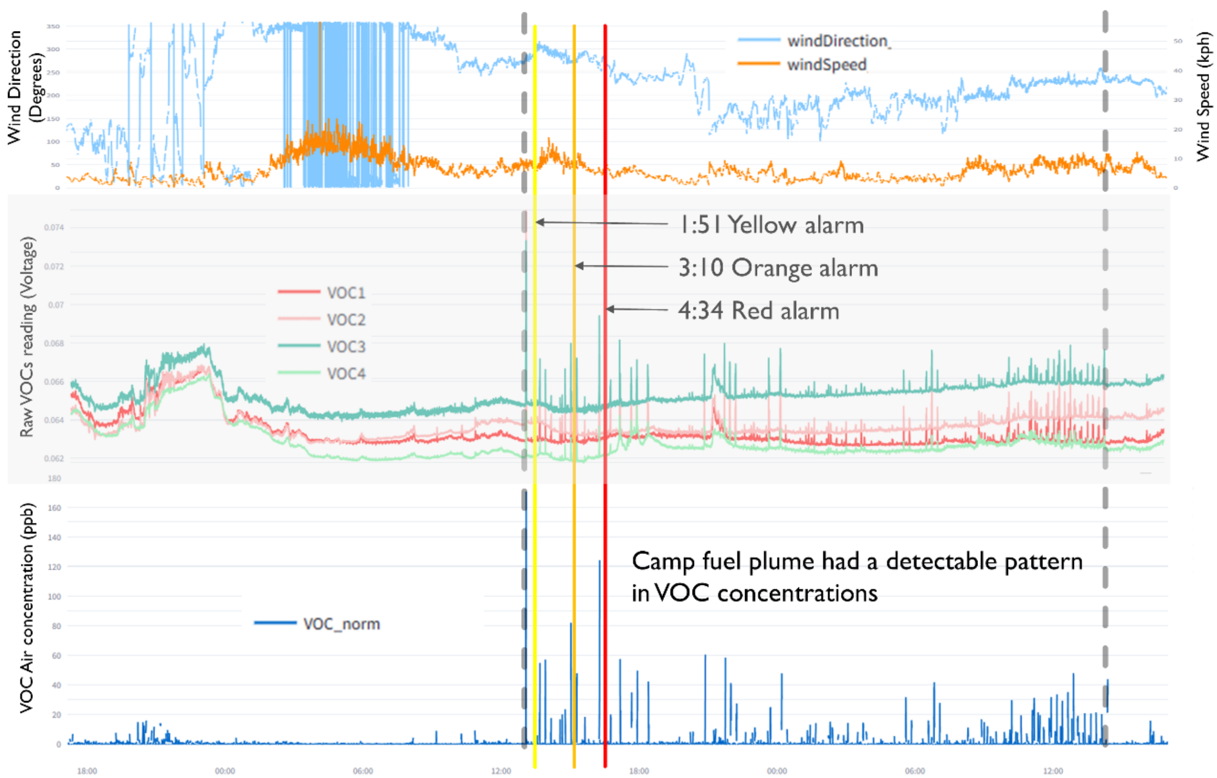


Figure 3.9 Test 2: Airdar Summary of Alarm Status

3.4 Test 3

For Test 3, the test fluid was AWB. Prior to performing the full test, a verification that the sensors would respond to the volatiles was performed. The System was configured to draw air only from a single inlet for the preliminary verification. A 20 L open drum of AWB was placed immediately adjacent to the operating inlet, which resulted in a strong response from the sensor (see Figure 3.10), indicating that the full test could proceed.

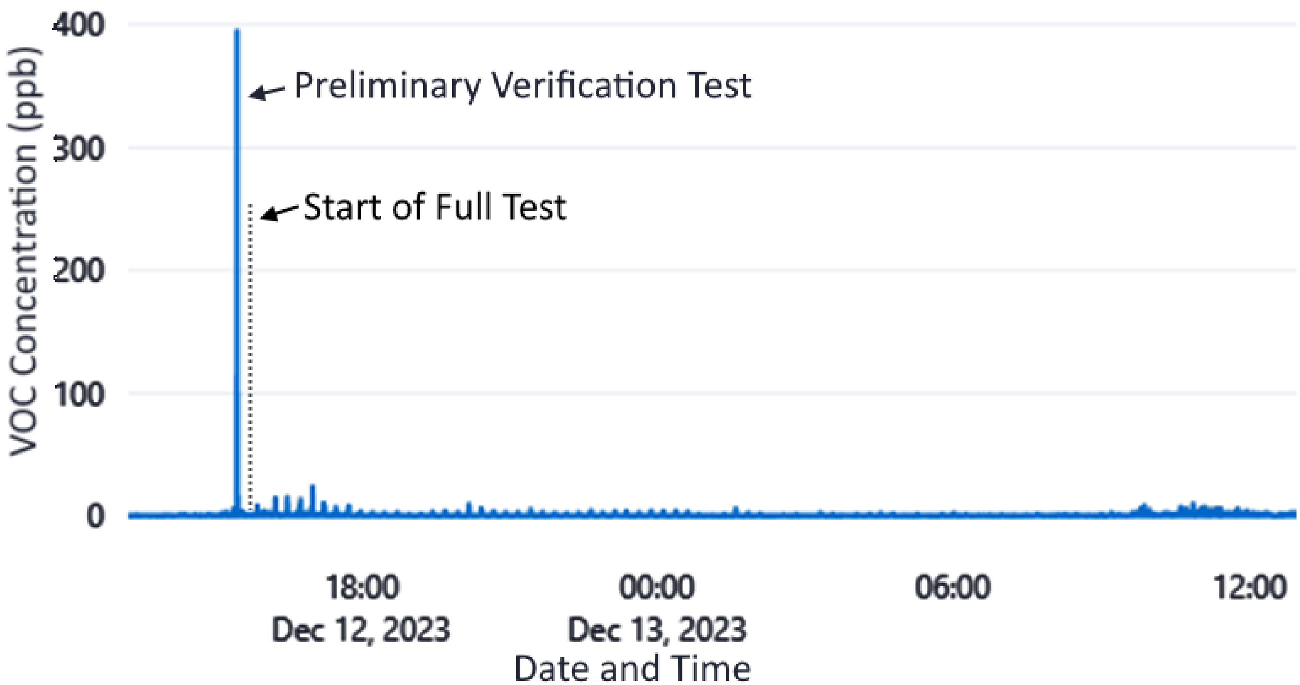


Figure 3.10 VOC Concentration for Preliminary Test with AWB

The full Test 3 was performed by placing a 20 L open drum and three open 2 L jars of AWB in the C-FER yard (see Figure 3.11). The drum had a standard 2-in bung, which resulted in a limited area for vaporization of the volatiles. The jars each had an opening of approximately 3 in. As this was a fully open test, Airdar was informed where and when the simulated spill was performed. The test was monitored but alarms were not active during this test.

Figure 3.11 Photographs of Test 3 Configuration

During the start of the test period, the wind direction was primarily from 200° (SSW) and was directed towards Inlet 4. Figure 3.12 shows the VOC concentrations recorded during the start of the test period. There were very clear signals from Inlet 4 for several hours. As discussed previously, a leak would continue to supply fresh un-weathered product, thereby increasing the available detectable VOCs. Additionally, the exposed surface area of the fluid would typically be considerably larger and be agitated by the active leak, leading to increased available detectable VOCs.

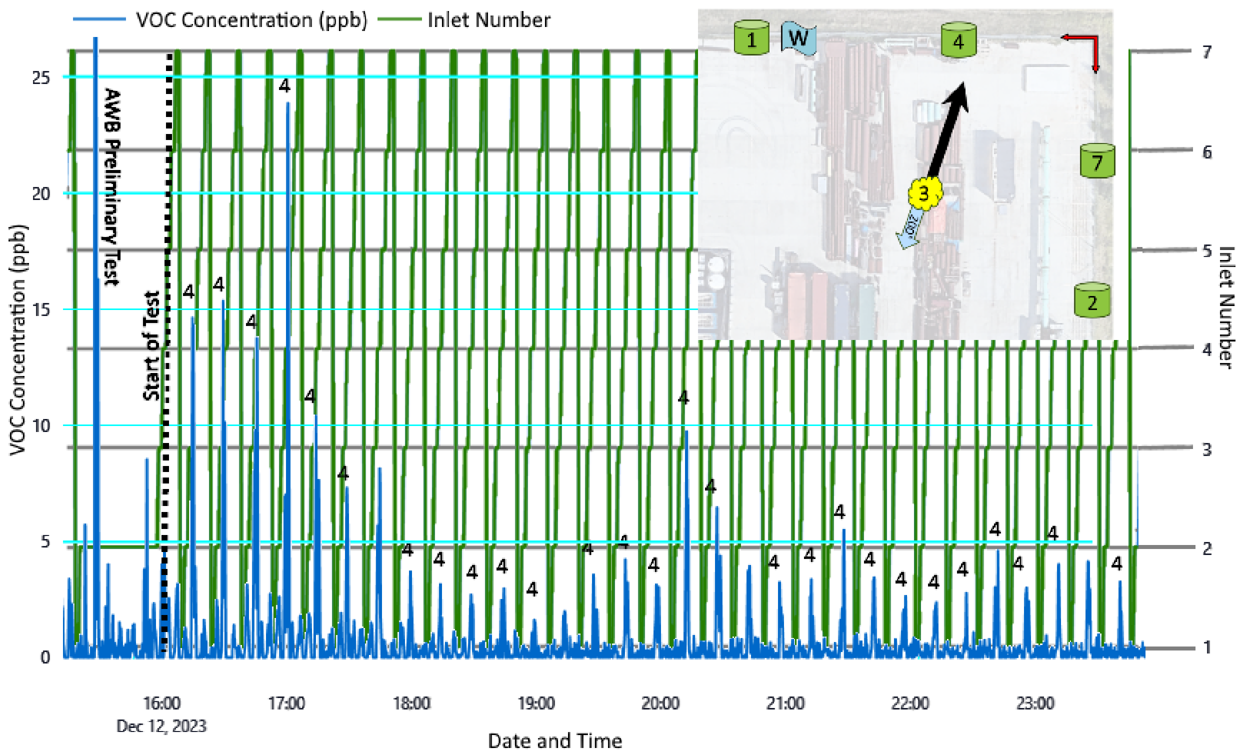


Figure 3.12 Test 3: VOC and Wind Conditions with Sensor Inlet Numbers and Inset Map of Sensor Locations at Start Time

3.5 Test 4

Test 4 was a blind test where Airdar was not informed of the day, time, or exact location of the simulated spill. During this test, the alarms were active. Like the previous white gas tests, an open tray containing 5 L of AWB was placed in the yard (see Figure 3.13). After 24 hours with no alarms from the System, an additional 5 L was added to the tray. Figure 3.14 shows the VOC concentration, wind direction, and the location of the simulated spill in the yard. The increased VOC levels also did not produce any alarms because either the levels were not sustained or the sensor inlet and wind direction indicated offsite sources. During this test, the wind direction varied between 100° and 200° at 15 to 20 kph. This direction may have caused any potential plume to pass between the sensor inlets.

Figure 3.13 Photographs of Test 4 Configuration

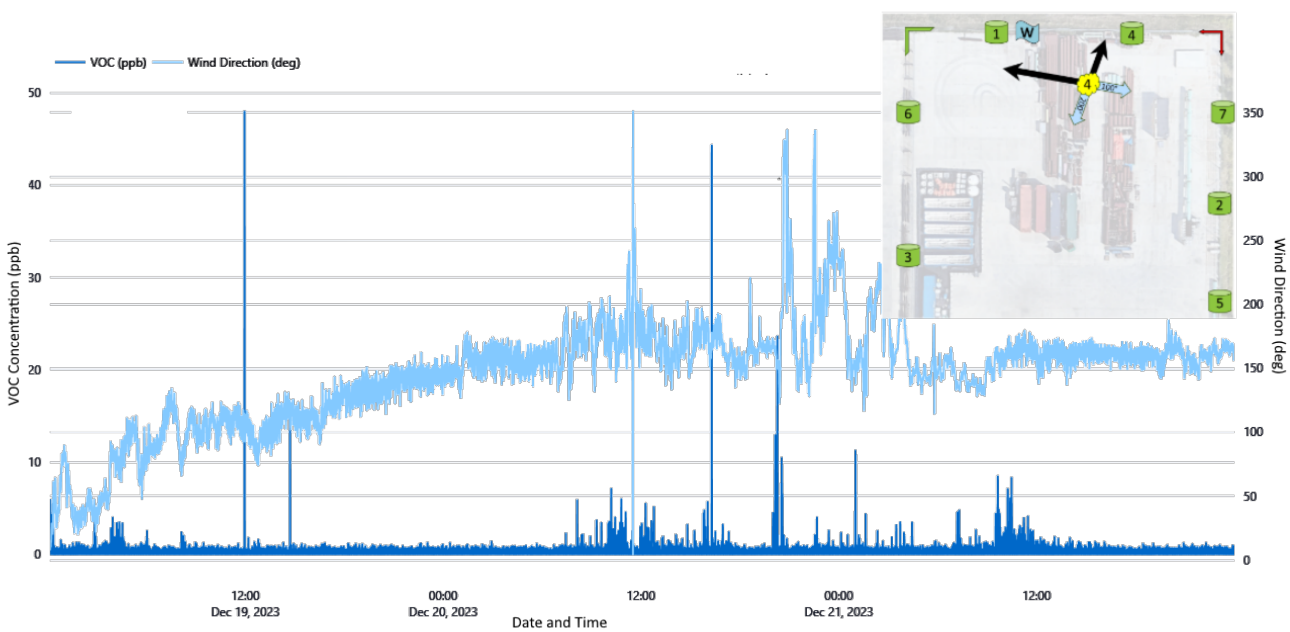


Figure 3.14 Test 4: VOC and Wind During Test with Inserted Location Map

3.6 Test 5

Test 5 was performed to evaluate the System's performance at cold temperatures. The test was similar to the successful Test 2, but it was an open test and the System was placed in a different location. This test was conducted over a 5-day period where the ambient temperature ranged from -28 °C to -45 °C. The temperature in the Airdar central sensing unit remained above -10 °C and continued to operate throughout this test. Airdar successfully performed a bump test of the

System while the ambient temperature was -31 °C. The System also successfully identified the simulated spill, with the first indication showing 4 minutes after the start of the test. Yellow, orange, and red alarms being emailed 0.5 hour, 1.5 hours, and 2.5 hours after the start of the test, respectively. The System also provided a location estimate that was 13 m away from the actual spill location. However, the actual spill was only 6 m away from the window of uncertainty that was provided by the System.

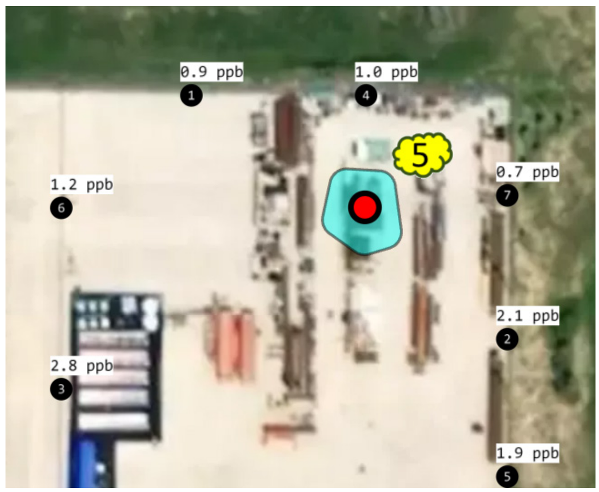


Figure 3.15 Test 5: System-predicted and Actual Spill Locations

3.7 System Baseline

The data obtained between tests was used to evaluate the levels of background VOC concentrations from the areas surrounding the test site to prevent false alarms on typical background VOCs that may be in the area. For instance, there is a waste oil processing facility approximately 1.2 km to the east of the C-FER facility, and Airdar noted elevated VOC concentrations from an offsite source coming from that general direction. There were also elevated VOC concentrations that came from the south. During testing, these elevated VOC concentrations were properly ignored as offsite sources, indicating that the System is capable of distinguishing offsite sources from onsite sources. However, areas with large amounts of offsite sources will affect the sensitivity of the System as they increase the noise floor, thereby requiring increased VOC concentrations to reliably distinguish onsite from offsite sources.

4. CONCLUSIONS

This test program successfully demonstrated that the System is capable of identifying and locating small liquid spills. There were no false alarms reported during the test period, and any offsite signals were filtered as being from offsite sources. The location identification was also adequate to enable use of visual inspection to accurately locate the emissions source.

The preliminary testing with diluted bitumen (AWB) showed that the sensors used are able to detect the vapours from diluted bitumen. The System was also able to detect the vapours from an open drum from a distance of over 50 m under some wind conditions. However, the System failed to detect any indications during the subsequent test. This may have been due to the wind direction causing the vapour plume to miss the active sensors entirely (a risk which can be mitigated through increased sensor placement density, increased monitoring time and/or reduced times between monitoring at each sensor location). Further investigation is needed to determine the limitations and capabilities of the System under various wind conditions and sensor configurations.

Note that there are several ways to adjust the sensitivity and resolution of the System. Increasing the number of inlet points would reduce the risk of missing a plume of vapours spatially but would also increase the time between samples at any given inlet position. Adding multiple sensors to allow more inlets to be monitored simultaneously would reduce the time that any sensor is inactive, resulting in improved likelihood of detection.

5. FUTURE WORK

In order to evaluate the System for use with pipelines, further testing using a selection of pipeline products is suggested. These tests should include the introduction of an active leak where there is a source of product to ensure a continuous source of vapours for a more accurate simulation of a leak and increased probability of detection.

It is also suggested that testing be performed with an increased number of inlets and monitor each inlet continuously. With these changes, the data can be analyzed with various degrees of multiplexing and different sensor configurations by including different portions of the available data to determine what effect the number of sensor locations and multiplexing have on the System's detection limits.

Adding additional wind monitoring to obtain the local wind direction at each sampling inlet could also be used to further enhance the ability of the System to identify the location of the source.

Finally, there would be significant value in gathering a "ground truth" concentration baseline using either Tedlar® bags or Summa® cannisters to collect samples at intervals throughout the test to compare the data produced by Airdar with a more accurate standard.

6. REFERENCES

1. Google Earth. Google, Landsat / Copernicus; c2014-2022 [accessed 2024 Jan 30]. https://earth.google.com/web/search/C-FER+Technologies+Inc.+(C-FER+East),+Roper+Road+Northwest,+Edmonton,+AB/@53.49639602,-113.40009184,696.05049512a,211.84571497d,35y,25.4604293h,66.0404845t,360r/data=CigiJgokCTL48sts30pAERXxgU55wkpAGfhy2o09VlzAIYiQ0ScLclzAOgMKATA.