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Validation of the Working Dog Advanced Threat Assessment System (WD ATAS)

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The U.S. Army Combat Capabilities Development Command Chemical Biological Center (Aberdeen Proving Ground, MD) personnel are developing a Working Dog Advanced Threat Assessment System (WD ATAS) to address current and emerging threats that are not contained within the standard issue Department of Defense canine explosives detection training aid kit. The WD ATAS would allow for the rapid production of additional canine detection training aids while eliminating many of the issues associated with manufacturing, packaging, transporting, handling, custody, accessing, storing, replacing, and disposing of current canine explosive training aids that contain bulk material. To address these complex issues, the WD ATAS combines two current technologies: (1) the training aid delivery device (TADD) and (2) inkjet-printed coupons. The goal is to provide inkjet-printed explosive coupons safely contained within TADDs to mimic the odor profile of their bulk counterparts despite utilizing significantly less explosive material.

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PREFACE

The work described in this report was authorized under project no. BL2 and task order TO1 by the U.S. Army Next Generation Combat Vehicles Cross-Functional Team (Warren, MI). The work was started in September 2022 and completed in April 2023.

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EXECUTIVE SUMMARY

The U.S. Army Combat Capabilities Development Command Chemical Biological Center (Aberdeen Proving Ground, MD) is developing a Working Dog Advanced Threat Assessment System (WD ATAS) to address current and emerging threats that are not contained within the standard issue Department of Defense canine explosives detection training aid kit. The WD ATAS would allow for the rapid production of additional canine detection training aids while eliminating many of the issues associated with manufacturing, packaging, transporting, handling, custody, accessing, storing, replacing, and disposing of current canine explosive training aids that contain bulk material. To address these complex issues, the WD ATAS combines two current technologies: the training aid delivery device (TADD) and inkjet-printed coupons. The goal is to provide inkjet-printed explosive coupons safely contained within TADDs to mimic the odor profile of their bulk counterparts despite utilizing significantly less explosive material. Over the course of several testing and evaluation (T&E) iterations with detection teams, our data imply that inkjet-printed coupons have the potential to serve as a viable substitute for bulk explosive material in maintenance training scenarios where working dogs (WDs) have already been imprinted on bulk explosive material. The metric that is typically used to determine whether a detection team has adequate discrimination of target odor over a non-target odor is to achieve >90% alert rate on target items while having a ≤10% false alert rate on non-target items. Many of the detection rates and false alert rates from the T&Es fall in line with teams who hold certifications, thereby indicating that coupons could be a viable option for use in training.

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VALIDATION OF THE WORKING DOG ADVANCED THREAT ASSESSMENT SYSTEM (WD ATAS)

1. INTRODUCTION

U.S. Army explosive detection canines are trained to recognize odors with the aid of a standardized canine explosive scent kit (CESK). A CESK consists of a standardized series of contained bulk explosive material commonly referred to as training aids. The fielded CESK is currently undergoing its first evaluation and update since 1972 to contain more field relevant threat odors, though it is not feasible for the kit to contain all possible threat odors since novel threats are rapidly emerging.

Because the CESK contains bulk levels of explosive materials, there can be issues associated with the manufacture, packaging, transport, handling, custody, access, storage, replacement, and disposal of current canine explosive training aids. The U.S. Army Combat Capabilities Development Command Chemical Biological Center (DEVCOM CBC) has developed a Working Dog Advanced Threat Assessment System (WD ATAS) to address current and emerging threats that are not incorporated within the standard issue Department of Defense canine explosives detection training aid kit. The WD ATAS will also reduce the inherent risk associated with procuring and transporting bulk quantities of explosive materials. Additionally, the WD ATAS would allow for the rapid production of additional canine detection training aids while eliminating many of the issues associated with a kit containing bulk levels of canine explosive training aids.

The WD ATAS combines two current technologies to provide an alternate option to using bulk quantities of explosives in the CESK: the training aid delivery device (TADD) and inkjet-printed chemicals on inert substrates. Inkjet deposition methodologies were developed by DEVCOM CBC under the Army Explosives Forensics Advanced Technology program in support of the Next Generation Combat Vehicle – Foundational Technologies. Inkjet printing deposition techniques can be used to deposit small quantities of chemicals on inert substrates. The goal of the WD ATAS is to combine the technology of inkjet-printed explosive coupons and the TADD to create a training aid that mimics the odor profile of their bulk counterparts despite utilizing significantly less explosive material. This is made possible due to the surface area of a chemical being more vital to the quantity of odor released versus changing the mass of the contained material.

A Lackland Institutional Animal Care and Use Committee approved Test and Evaluation with Operational Military Working Dogs (MWD) Protocol (#2021-05) was used to determine if MWDs trained to detect bulk potassium chlorate (PC) could also detect PC inkjet-printed coupons containing various quantities of target material.

A test and evaluation (T&E) was performed with a small cohort of MWDs to determine what an appropriate printing density of PC on coupons was for odor recognition in WDs previously imprinted using bulk levels of target material. A total of three (3) MWD teams

participated in the first iteration of the test held on 27-28 September 2022 at Aberdeen Proving Ground, MD.

A second iteration of this T&E was performed similarly to the first T&E held in September 2022, but with a larger cohort of MWDs. A total of eight (8) MWD teams participated in this test held on 25-28 October 2022 at Aberdeen Proving Ground, MD.

The third iteration of this T&E was performed in Fort Leonard Wood, MO at the 2023 Maneuver Support, Sustainment and Protection Integration eXperiments (MSSPIX) exercise. A total of nineteen (19) Working Dog (WD) teams participated in the MSSPIX exercise held on 3-7 April 2023. The WDs were split in to two groups: twelve (12) MWD teams performed odor recognition testing of inkjet-printed PC coupons on scent carousels and seven (7) mine detection dog (MDD) teams performed odor recognition testing of inkjet-printed 2,4,6-trinitrotoluene (TNT) coupons that were buried outdoors.

2. MATERIALS AND METHODS

2.1 Test Materials

All target materials were contained within TADDs (SciK9, LLC; See Figure 1.). Target materials included either bulk PC (Sigma Aldrich; 25 gram (g) and 2.5 g), inkjet-printed PC coupons with the following approximate mass loadings: 20 mg, 2 mg, and 0.2 mg (or 200 µg) (See Figure 2), or inkjet-printed TNT coupons with the mass loading of 2mg. All inkjet coupons were printed on 50mm Whatman cellulose filter paper, Grade 4. TADDs containing inkjet-printed PC coupons either contained one (1) or two (2) coupons of each mass loading amount. Table 1 provides a summary of the test articles used in each iteration of the T&E.

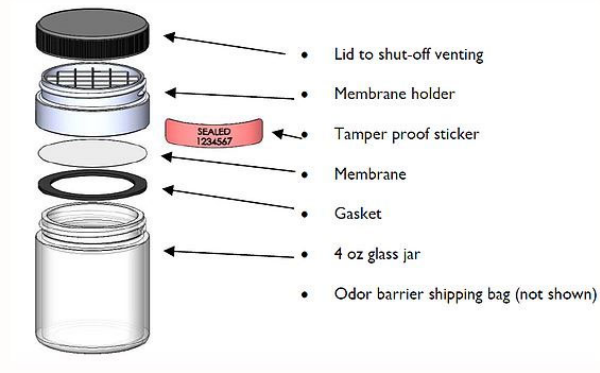

Figure 1. Training Aid Delivery Device (TADD) components.

Figure 2. Potassium Chlorate contained within TADDs (L to R: 25g, 2.5g, 20mg printed coupon).

Table 1. Materials and Methods Overview

T&E Iteration	**September 2022**	**October 2022**	**April 2023 (MSSPIX)**	
Target	PC	PC	PC	TNT
Mass Loadings of Target	0.2mg, 2mg, 20mg, 2.5g	0.2mg, 2mg, 20mg, 2.5g	0.2mg, 2mg, 20mg, 2.5g	2mg
Number of Coupons per Mass Loading per TADD	1 or 2	1	1	1
Test Format	Scent Carousels	Scent Carousels	Scent Carousels	Buried
Number of MWDs used	3	12	12	-
Number of MDDs used	-	-	-	7

Control items were also utilized in the test to ensure the MWDs and MDDs were alerting to the specific odor of the target material and not a background odor contained within the overall odor picture. Controls consisted of empty TADDs, TADDs containing unprinted Whatman paper, TADDs containing Whatman paper that underwent the printing process, and articles used to manipulate test items such as gloves and deionized water wipes.

2.2 Scent Carousel Test Format

Individual target items and controls were contained within stainless steel shaker cans and placed within Tactical Directional Canine Systems (TDK9) scent carousels as shown in Figure 3. The search of a single scent wheel containing six (6) stainless steel shaker cans constituted one (1) trial. Within a trial, the trial could either contain a single target, or be blank meaning no target item was present (i.e. a mixture of control items and empty cans).

Figure 3. TDK9 Scent Carousel.

For the T&E held in September and October of 2022, a series of five (5) scent carousels were used for the odor recognition test, as shown in Figure 4. This series of five (5) trials searched sequentially by each MWD team constituted a single session. For the MSSPIX 2023 T&E, a series of ten (10) scent carousels were used for the odor recognition test. The series of ten (10) trials searched sequentially by each MWD team constituted a single session. The average blank percentage (trials that did not contain a target item) was 30% for the September T&E, 18% for the October T&E, and 16% for the MSSPIX T&E.

Figure 4. Odor recognition test layout.

Each MWD team ran each session individually, without knowing the location of any target items beforehand. A test administrator watched each MWD team from behind blinds in the center of the test area, as shown in Figure 4, to prevent inadvertent signaling to the team as to which trials/cans contained target items. Each team was instructed to sample odor from each can in a trial before deeming a trial blank and moving to the next trial in the session. If a MWD alerted to a can, the handler would communicate the alert to the test administrator, and the test administrator would confirm whether the MWD had alerted to a target item with either a thumbs up or down. If a MWD correctly alerted to a target item, the handler would then reward the MWD; if the MWD alerted to a non-target item, the handler would be notified, and the MWD would be scored with a miss (false alert). The handler would then make the decision to either continue to search the trial for a target or move on to the next trial in the session. The test administrator recorded all handler confirmed alerts to both target and non-target items on a Microsoft Surface tablet loaded with the Canine Assessment Tool software previously developed by Excet, Inc.

2.3 Buried Target Test Format

At the MSSPIX 2023 T&E, a separate evaluation was performed using MDDs stationed at Fort Leonard Wood, MO. The goal of this evaluation was to see if MDDs could detect inkjet-printed TNT coupons when they were buried underground. The holes were dug using a golf hole cutter and were approximately eight (8) inches deep and four (4) inches wide. The training area was divided in to two (2) lanes and were structured as pictured in Figure 5. Each lane contained ten (10) holes; four (4) holes had empty TADDs used as controls, three (3) holes had TADDs containing the target item, and three (3) holes were dug and then filled back in. Prior to being buried, the caps were removed from each TADDs whether they contained a test item or a control item. Targets were buried approximately three (3) hours prior to the start of MDD teams searching the lanes. The targets were left buried overnight after the first day for an additional day of testing (two days total). Due to the design of the TADDs itself and the non-hazardous nature of the inkjet-printed coupons, there was no concern for contamination of the ground or the surrounding areas that the TADDs were buried in, and no compromise of the coupons from the act of burying due to their containment.

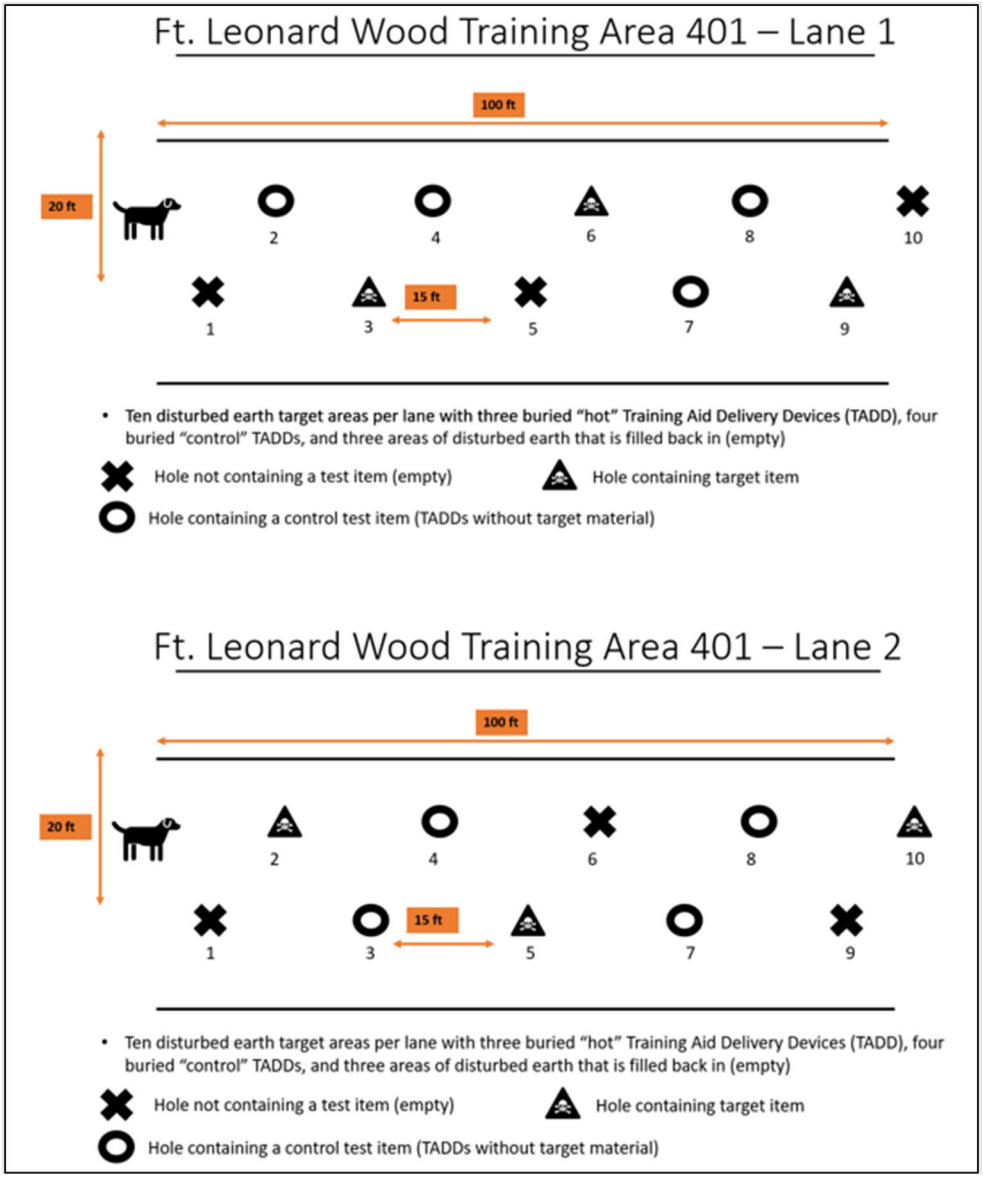

Figure 5. MSSPIX 2023 MDD test layout.

3. RESULTS

3.1 Detection Rates of Potassium Chlorate in Scent Carousels

Table 2 summarizes the percent detection for each target item from the September iteration of the T&E. This T&E was comprised of three (3) canine detection teams. Statistical analysis was not performed due to the limited nature of this data set.

Table 2. September Target Detection Rates

Target Item	**Total**	
	Alert/Exposures	**Percent Detection**
25 g PC	2/6	33%
2.5 g PC	21/22	95%
2 x 20 mg PC on Whatman paper in TADD	13/14	93%
20 mg PC on Whatman paper in TADD	5/8	63%
2 x 2 mg PC on Whatman paper in TADD	16/16	100%
2 mg PC on Whatman paper in TADD	12/12	100%
2 x 0.2 mg PC on Whatman paper in TADD	13/13	100%
0.2 mg PC on Whatman paper in TADD	10/11	91%
Total	**92/102**	**90%**

Table 3 summarizes the percent detection for each target item from the October iteration of the T&E. This T&E was comprised of eight (8) canine detection teams. All participating MWDs had a sensitivity of 83% (95% CI 78-87%). All participating MWDs correctly alerted on 82.6% of targets (219 alerts on 265 attempts), and these results are statistically significantly better than random guessing (p-value < 2.2e-16). All individual MWDs with a sufficient number of trials outperformed random guessing.

Table 3. October Target Detection Rates

Target Item	Total	
	Alert/Exposures	Percent Detection
2.5 g PC	43/56	77%
20 mg PC on Whatman paper in TADD	67/82	82%
2 mg PC on Whatman paper in TADD	66/75	88%
0.2 mg PC on Whatman paper in TADD	43/52	83%
Total	**219/265**	**83%**

Table 4 summarizes the percent detection for each target item from the MSSPIX iteration of the T&E. This T&E was comprised of twelve (12) canine detection teams. All participating MWDs for the MSSPIX23 test had a sensitivity of 65% (95% CI 60-69%). All participating MWDs correctly alerted on 64.6% of targets (266 alerts on 412 attempts), and these results are statistically significantly better than random guessing (p-value < 2.2e-16). All individual MWDs with a sufficient number of trials outperformed random guessing.

Table 4. MSSPIX Target Detection Rates

Target Item	Total	
	Alert/Exposures	Percent Detection
2.5g PC	86/124	69%
1 20mg PC on Whatman paper in TADD	61/106	58%
2mg PC on Whatman paper in TADD	70/109	64%
0.2mg PC on Whatman paper in TADD	49/73	67%
Total	**266/412**	**65%**

3.2 False Alert Rates for Non-Target Items in Scent Carousels

Table 5 summarizes the false alert rate for each non-target item from the September iteration of the T&E. This T&E was comprised of three (3) canine detection teams. Statistical analysis was not performed due to the limited nature of this data set.

Table 5. September False Alert Rates

Control Item	Total	
	False Alerts/Opportunity	Percent Detection
Gloves	2/145	1%
Deionized Water Wipes	4/145	3%
TADD	26/145	18%
TADD with Whatman Paper	24/145	17%
TADD with Printed Whatman Paper	35/145	24%
Empty Cans	3/43	7%
Total	**95/768**	**12%**

Table 6 summarizes the false alert rate for each non-target item from the October iteration of the T&E. This T&E was comprised of eight (8) canine detection teams. All participating MWDs had a specificity of 94% (95% CI 92-95%).

Table 6. October False Alert Rates

Control Item	Total	
	False Alerts/Opportunity	Percent Detection
Gloves	58/320	18%
Deionized Water Wipes	2/288	1%
TADD	7/263	3%
TADD with Whatman Paper	12/320	4%
TADD with Printed Whatman Paper	22/320	7%
Whatman Paper Only	0/32	0%
Empty Cans	6/112	5%
Total	**107/1655**	**6%**

Table 7 summarizes the false alert rate for each non-target item from the MSSPIX iteration of the T&E. This T&E was comprised of twelve (12) canine detection teams. All participating MWDs had a specificity of 85% (95% CI 84-86%).

Table 7. MSSPIX False Alert Rates

Control Item	Total	
	False Alerts/Opportunity	Percent Detection
Gloves	21/525	4%
Deionized Water Wipes	25/525	5%
TADD	100/525	19%
TADD with Whatman paper	128/525	24%
TADD with printed Whatman paper	119/525	23%
Empty Can	21/173	12%
Total	**414/2798**	**15%**

3.3 Detection Rates of Buried TNT Coupons

Compiling data from the MDDs proved to be a difficult task. MDDs are trained differently from the standard MWD detection team – MDDs are trained to clear an area rather than to find discrete target odor locations, so the canines will be rewarded based on if they clear an area where a target is present, not if they find each individual target. The lanes in the MDD T&E had three (3) targets each, it was counted as an overall hit if the MDD alerted to one (1), two (2), or all three (3) targets. Statistical analysis was not performed due to the limitations in data collection and interpretation.

On the first day of the MDD T&E, there was one (1) hit on a target item between the seven (7) MDDs used. However, six (6) out of the seven (7) MDDs showed interest in the target items in both lanes. Additionally, the non-target items that were placed in front of and behind the target item had a high incidence of false alerts and interest.

On the second day of the MDD T&E, only five (5) out of the seven (7) enrolled MDD teams returned to complete the first lane and only three (3) out of the seven (7) returned to complete the second lane. There was a total of five (5) hits between the two (2) lanes with one MDD that hit two (2) targets in one lane. All five (5) of the participated MDDs showed interest in the targets in the first lane and two (2) out of the three (3) MDDs showed interest in the targets in the second lane. Similarly to the first day, the non-target items that were placed in front of and behind the target items had a high incidence of false alerts and interest.

4. DISCUSSION

When WD teams become certified to detect an odor, the metric that is typically used to determine whether a detection team has adequate discrimination of target odor over non-targets is to achieve over a 90% alert rate on target items while having a 10% or less false alert rate on non-target items. Many of the detection rates and false alert rates from both T&Es fall in line with teams who hold certifications, therefore indicating that coupons could be a viable option to use in training. Sections 4.1 and 4.2 discuss specific cases in which the detection rates or false alert rates fall outside of this benchmark.

4.1 Potassium Chlorate Target Odor Detection in Scent Carousels

4.1.1 First Iteration of T&E – September 2022

In the first iteration of the T&E, the three (3) canine detection teams had previously participated in DEVCOM CBC T&Es that utilized TADDs and TDK9 scent carousels, therefore the testing format was not novel, only the addition of printed coupons was novel. Training was not provided prior to beginning the data collection due to the familiarity of each team with the test format, target odor, and target containment.

Twenty milligrams (20mg) of PC on Whatman Paper and 25g bulk PC had the lowest detection rates of 63% and 33%, respectively. This was likely due to the fact these items had the fewest number of overall presentations in the T&E; consequently, teams missing target items had a more profound effect on the overall detection percentage.

Teams were able to positively identify 2.5g of bulk PC 95% of the time, therefore teams not being able to detect 25g was not of concern as these samples were placed early in the T&E where incidences of false alert rates tend to be the highest while the MWDs are learning the "game" of the T&E.

Because the detection rates for the coupons was similar to the detection rate for the 2.5g bulk PC, it was determined that the selected target coupon amounts were in an appropriate range of detection for MWDs imprinted with bulk material.

4.1.2 Second Iteration of T&E – October 2022

For the second iteration of the T&E, the total number of target item types was reduced to increase the number of exposures each team had to each target item type. Because detection rates for two (2) coupons of the same mass loading were similar to detection rates for their single coupon counterpart in the first iteration of the T&E, a single coupon per mass loading was used in this iteration.

Out of the eight (8) teams that participated, seven (7) teams had not been exposed to TADDs or TDK9 scent carousels, therefore teams were provided an opportunity to train prior to the data collection portion of the T&E. Teams were provided with 25g of bulk material

contained within TADDs and empty TADDs to proof them off the odor of the containment of the target material.

Though slightly under the typical threshold of detection for canine teams that have certifications, the detection rate for all target items was 82.6%. With increased training, the rates of detection could be increased, but for a test and evaluation where these WDs do not typically train with target material as low as what was presented on coupons, this data indicates that the coupon levels presented could possibly be used as a maintenance tool in WDs previously imprinted with bulk levels of target material.

4.1.3 Third Iteration of T&E – MSSPIX 2023

The same mass loadings of the PC target items were used in the 2023 MSSPIX T&E as in the second iteration. However, the sample size was increased in the third iteration by increasing the number of MWDs used, and the number of trials and sessions completed per MWD team thereby increasing the number of exposures to each target item. Most of the MWDs used in the third iteration had not been exposed to inkjet-printed coupons before (2 out of 12 of the MWDs had prior exposure to coupons). This was to ensure that a true assessment was performed to assess if the coupons could be substituted for bulk material. Once an MWD has been exposed to the coupons, learning takes place, and it is no longer a true assessment of whether the MWD can generalize from bulk material to coupons.

The detection rate for all target items was 64.6% which is much lower than the detection rates in the first and second iteration. This could be due, in part, to the MWDs not having as much training on the bulk material prior to completing the T&E. Three (3) MWDs did not perform as well as the others and had a sensitivity value lower than 25%. The sensitivity values for all MWDs used in this T&E ranged from 15% to 94%. Although it is important to keep outliers in the overall data percentages to ensure an accurate representation of the actual population, this could explain why the detection rate was so much lower in this iteration. The data indicates, however, that MWDs can detect far lower concentrations of target material when printed on to the inkjet coupons. The detection rates were similar between bulk PC and inkjet-printed PC, which supports the notion that the surface area of a chemical is more vital to the quantity of odor released than the mass of the material itself. With increased training on trace amounts of material presented on inkjet coupons, the rates of detection could be increased.

4.2 False Alerts on Non-Target Items in Scent Carousels

4.2.1 First Iteration of T&E – September 2022

In the first iteration of the T&E, non-target items with the highest false alert rates included TADDs with printed Whatman paper, followed by TADDs and TADDs containing Whatman paper, with detection rates of 24%, 18%, and 17%, respectively. The higher incidence of false alert rates for these items are to be expected because prior to this T&E, these MWDs had not been trained to intentionally ignore these specific items. Odors from these non-target items make up a portion of the overall odor picture of TADDs containing printed Whatman paper, therefore a higher incidence of false alert rates to these particular items was to be expected.

In a typical training scenario, to prevent false alerts, MWDs would be trained to ignore the non-target portion of the odor picture. Over the course of the two-day T&E, the frequency of false alerts drastically decreased, therefore demonstrating the ability of the MWDs to specifically detect the target odor. It should also be noted that the overall false alert rate was 12% which is similar to the standard of less than 10% that certified teams achieve.

4.2.2 Second Iteration of T&E – October 2022

During the second iteration of the T&E, the non-target item with the highest false alert rate was gloves with a detection rate of 18%. Out of the false alerts on gloves, over half of those false alerts came from two (2) of the eight (8) teams. Gloves were not provided in the training scenario, and therefore may explain the higher false alert rate on that item specifically.

The next highest false alert rate came from TADDs containing printed Whatman paper with a false alert rate of 7%. In this T&E, these MWDs had not been trained to ignore the printed Whatman paper odor, hence the higher false alert rates on these items.

The false alert rates from the second iteration of the T&E were lower than the false alert rates from the first iteration this T&E and is likely because there was an initial training session provided during the second iteration of the T&E. Consequently, the MWDs were able to learn to discriminate between target odor and odor from the containment device prior to the start of the data collection portion of the T&E.

It should also be noted that the overall false alert rate was 6% which is similar to the standard of less than 10% that certified teams achieve. With training, false alerts on non-target items could be decreased even further.

4.2.3 Third Iteration of T&E – MSSPIX 2023

In the third iteration of the T&E, the non-target item with the highest false alert rate was the TADD with blank Whatman paper with a detection rate of 24%. The TADD with inkjet-printed Whatman paper was a close second for false alerts with a detection rate of 23%. The odor profile of these items is likely similar to the odor profile of a TADD containing Whatman paper printed with explosive material, therefore a higher incidence of false alert rates is to be expected. In addition, many of the MWDs used in this T&E had no previous exposure to TADDs or the TDK9 scent carousels. As a result, they may have had a more difficult time discriminating between the TADDs containing the target materials and the TADDs being used as controls.

This data highlights the need to increase the presence of these non-target items in future trainings so that the MWDs will learn to ignore the parts of the odor profile that are not representative of the target material. With additional training the false alert rates would decrease as the MWDs learned to discriminate between background odor that should be ignored (i.e., empty TADDs) versus the actual target material.

4.3 TNT Detection

The data collected from the MDDs at Fort Leonard Wood was both unique and insightful to the potential uses of the inkjet-printed coupons. The MDDs face similar barriers to training with bulk explosive material due to the potential hazards associated with the handling and use of this material. In addition, the mine detection teams must consider how the material is contained to ensure that it does not interact with the environment outside of it.

The results from the mine detection teams proved to be difficult to interpret. Burying the targets in an outdoor environment presents additional variables that are challenging, if not impossible, to control. For instance, during one of the sessions it had begun to rain and the MDDs started to hit on the target odors, but away from the actual target location. This could be due to the rainwater dragging the odor away from its actual burial site. Unlike the T&E iterations using the scent carousel which only had one (1) target per carousel, the MDD T&E lanes contained three (3) targets within each lane. Some of the WDs were alerting to one (1) or two (2) targets, but not to all three (3). In these instances, it is difficult to define success as simply "hit" or "miss".

5. PATH FORWARD

An important next step in understanding the efficacy of use of the inkjet-printed coupons in place of bulk material is to complete headspace analysis, shelf-life, and service-life studies. Headspace analysis of coupons will evaluate how much odor is coming off of the coupons and the effect that the various printing loads has on the available odor. Knowing what the odor profile of bulk material is in comparison to the inkjet-printed coupons will validate our hypothesis that increasing the surface area of the mass loadings can make a small amount of chemical smell like a larger amount. Shelf-life and service-life studies will aid in quantifying the amount of time that inkjet-printed coupons will last both in the CESK and once they have been opened and used for training.

With continued success of MWDs being able to detect coupons, an additional operational WD T&E could be a next step to determine the canine limit of detection of the explosive threats on the coupons contained within the TADD. Additionally, data from headspace-verified bulk TADDs could be compared to the headspace of their matching inkjet-printed counterparts. If it is determined that the headspace between the bulk material and the inkjet-printed counterparts are similar in concentration and composition, this would allow for more robust data collection and confidence in the inkjet-printed coupons being a viable substitute for training. Continued research could be also conducted to expand out to additional threat materials. This information will provide additional insight to the MWD program stakeholders as to whether inkjet-printed coupons could be utilized as a training maintenance tool within areas that may not allow for use of bulk counterparts.

Additional information can be obtained by contacting the Olfactory Sciences Team at usarmy.apg.devcom-cbc.mbx.olfactory-sciences@army.mil.

ACRONYMS AND ABBREVIATIONS

CESK	Canine Explosive Scent Kit
MDD	Mine Detection Dog
MSSPIX	Maneuver Support, Sustainment and Protection Integration eXperiments
MWD	Military Working Dog
PC	Potassium Chlorate
TADD	Training Aid Delivery Device
T&E	Test and Evaluation
TNT	2,4,6-trinitrotoluene
TDK9	Tactical Directional Canine Systems
WD	Working Dog
WD ATAS	Working Dog Advanced Threat Assessment System

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