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PAPER

GENERAL

Michael B. Alexander,[1] Ph.D.; Theresa K. Hodges,[2] Ph.D.; Daniel J. Wescott,[3] Ph.D.; and Jacqueline A. Aitkenhead-Peterson,[1] Ph.D.

The Effects of Soil Texture on the Ability of Human Remains Detection Dogs to Detect Buried Human Remains

ABSTRACT: Despite technological advances, human remains detection (HRD) dogs still remain one of the best tools for locating clandestine graves. However, soil texture may affect the escape of decomposition gases and therefore the effectiveness of HDR dogs. Six nationally credentialed HRD dogs (three HRD only and three cross-trained) were evaluated on novel buried human remains in contrasting soils, a clayey and a sandy soil. Search time and accuracy were compared for the clayey soil and sandy soil to assess odor location difficulty. Sandy soil ($p < 0.001$) yielded significantly faster trained response times, but no significant differences were found in performance accuracy between soil textures or training method. Results indicate soil texture may be significant factor in odor detection difficulty. Prior knowledge of soil texture and moisture may be useful for search management and planning. Appropriate adjustments to search segment sizes, sweep widths and search time allotment depending on soil texture may optimize successful detection.

KEYWORDS: forensic science, forensic soil, soil texture, buried human remains, cadaver dogs, human remains detection dogs, clandestine graves

Human remains detection (HRD) dogs are frequently used to locate clandestine graves in medicolegal death investigations (1–5). Performance expectations for the narcotic dog industry by the court systems, which expect annual credentialing, also apply to HRD dogs (6,7). Credentialing evaluations for HRD dogs generally comprise testing the dogs' single blind in different scenarios such as elevated, surface, buried human remains, and blank areas with no remains (8–10). However, buried human remains and blank areas with no human remains represent the area of credentialing with the least amount of success (8). One of the factors which may lower success rates for buried remains is the effect of soil texture, but no study has examined how soil texture correlates to the effectiveness of HRD dog searches on buried remains. The objective of this study was to investigate the effects of soil texture and its subsequent properties on the HRD dog's ability to detect the odor of human remains in buried scenarios. Two soil extremes, clayey and sandy, were used to evaluate the performance (accuracy and detection time) of HRD dogs in detecting buried human remains. We hypothesize that the properties associated with soil texture will make buried human remains easier for HRD dogs to detect in sandy soils compared to clayey soils. The design of the study was comparable to buried testing scenarios utilized by many national organizations credentialing standards (8–10). Understanding the effects of soil properties on the performance of HDR dogs has implications for grave detection on missions as well as training methodology, certification testing, and scene management and planning.

Soil properties that affect decomposition rates and the escape of decomposition gases also affect the performance of HDR dogs. Soil moisture content is important for soil microbes (11,12) in the degradation process, and soil temperature (12,13) and texture affect the escape of decomposition gases (14,15) that may influence the detection of decomposition odors by HRD dogs. Soils are a mixture of minerals and organic matter, and soil texture is the mineral proportions of sand, silt, and clay. How these minerals are apportioned determines some of the basic characteristics of the soil such as porosity, aeration, drainage, compactability, shrink swell potential, and water holding capacity (16–20). Properties that may affect olfactory detection include soil aeration, water holding capacity, available pore space, and sealing capacity (19). Pore space is filled with air, water, or a mixture of the two depending upon the soil moisture content. The proportion of water to air in the soil pore space affects the aeration of the soil. Clayey soils generally have high soil porosity with both macro and micro pores but have a high water capacity resulting in more pore space allocated to water. Sandy soils, on the other hand, generally have lower soil porosity but have larger pore size and are better drained allotting more of their pore space to air than clayey soils (16,19,20). Diffusion occurs in soil air to exchange gases between the atmosphere and the soil (19). Pores filled with water impede the flow of these gases. As clayey soils have higher water holding capacity than

[1]Department of Soil and Crop Sciences, Texas A&M University, College Station, TX.
[2]Department of Entomology, Texas A&M University, College Station, TX.
[3]Department of Anthropology, Forensic Anthropology Center at Texas State, Texas State University, San Marcos, TX.

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sand (higher porosity), the potential for limited gas diffusion is greater. In other words, in clayey soils the escape of decomposition gases from decomposing human remains may be hampered (19,20). Oxygen diffuses rapidly into air filled pores but up to ten thousand times slower in water filled pores (18–21). As a result, we hypothesize that the performance of HRD dogs is affected by soil texture and may be hindered by clayey soils compared to sandy soils.

Methods and Materials

Test Location

Two locations on private properties were utilized for testing. The clayey soil site was located at Renfroe Ranch in Robertson County, Texas, while the sandy soil site was at Carl Catropia Ranch in Robertson County, Texas. Both sites have stands of timber with costal Bermuda grass and have been used for cattle pasture for over 50 years (>100 years and >63 years, respectively). The HRD dog testing areas had <10% slope in open fields' void of trees to prevent any scent bias due to convection or shade.

Soil Texture Verification

The two soils differed in texture with one being primarily fine sand and the other having a B horizon of clay (25.4–63.5 cm) making it satisfactory for the experimental design. Soils which had both the A and B horizons of contiguous clay or sand profiles were preferred but unavailable. The clayey soil was classified as a Hearne Fine Sandy Loam with a profile of 0–25.4 cm Fine Sandy Loam and 25.4–63.5 cm clay (22). The sandy soil was classified as Padina Loamy Fine Sand with a profile of 0–12.7 cm loamy fine sand, 12.7–142.2 cm loamy fine sand, and 142.2–203.2 cm sandy clay loam (22).

Soil texture for both the sandy and clayey soil was verified through six samples selected from both sites by means of a drop hammer soil corer with an inner removable sleeve (AMS Inc., American Falls, ID). The samples obtained were randomly distributed throughout the testing area at each site. The corer sleeve was 4.6 cm in diameter and 15.3 cm in length. Samples were collected from the clayey soil with horizons A and B collected separately. Compaction was standard between sites with the top of the corer driven even with soil surface resulting in a 2.5 cm above the sleeve for a uniform compaction factor for all samples. The sandy soil consisted of the same soil texture for both the A and B horizons, and one core was taken representing the 15.3 cm sample and no distinct separation between horizons. Samples were oven-dried for 48 h at 105°C (23). Dry samples were ground and sieved through a 2-mm mesh sieve, and the percent of clay, silt and sand were determined using the Bouyoucos hydrometer particle size analysis standard method (24).

Human Remains Tissue and Burial Method

Human remains (HR) tissue (i.e., skin, fat, and muscle sections) from the thigh and calf of a human cadaver at 4 days postmortem was used for burial. Tissue was provided by the Forensic Anthropology Center at Texas State (FACTS) and apportioned to individual samples weighing around 0.91 kg. The HR tissue was maintained in a freezer prior to the first day of testing and thawed in a cooler the night before and maintained at refrigerated temperatures (approximately 4°C) between field tests. Prior to burial, the tissue samples were placed inside cotton soil bags.

To bury the HR tissue sample, a circular plug, approximately 7 cm deep and 18 cm in diameter, of the top vegetation was removed with a knife and set aside. The remainder of the hole was dug to a depth of 46 cm and diameter of 18 cm with a standard posthole digger. Each hole had the soil removed, sorted by relevant horizon, and placed into a labeled bag, so that the soil could be placed back into the hole after tissue burial in the appropriate order, maintaining the soil profile as closely as possible. All holes were dug 48 h prior to burials to prevent any inadvertent contamination of holes. Blank holes (burials of cotton bags with no tissue) were filled in first prior to any HR burial to further prevent contamination. Soils were replaced in the holes from which they were excavated without compacting to maintain a similar bulk density to that prior to removal. Time constraints and potential rain events required buried HR to "set" a minimum of 30 min prior to execution of the experiment to allow diffusion of gases. The removed vegetation plug was replaced into the top of the hole in a manner to prevent little visual difference from the surrounding vegetation and ground.

Subjects: Nationally Certified HRD Dog Teams

Six nationally certified HRD dog teams (i.e., HRD dog and handler) were utilized for the experiment. The dog teams are certified annually, and each dog in this study had already shown consistent accuracy of 90% or above on lineup experiments of HR-contaminated soils in 790 trails (25). Furthermore, each dog had previous recoveries on real-world missions and had achieved certifications through multiple agencies including the National Association for Search and Rescue (NASAR) (8), the National Narcotic Detector Dog Association (NNDDA) (9), and the North American Police Work Dog Association (NAPWDA) (10). All dogs (two male, four female) were border collies or border collie mixes ranging in age from 3 to 13 years. The dogs were trained by members of the same canine search team (26). Three of the dogs used were trained solely for HRD, while three of the dogs used were cross-trained to locate live subjects as well. Four of the six dogs had passive trained final responses (three "down" and one "sit"), while two had "active dig" trained final responses (TFR) to indicate the presence of a target odor source (27).

Experimental Design

At both the clayey and the sandy soils, six rows of five square plots (7.62 × 7.62 m squares) arranged in linear fashion (Plots 1 through 5) were searched by each HRD dog team (Fig. 1). Each plot was marked with construction flags on every corner and surrounded on three sides with a temporary 1.21-m barrier fence when searched (Fig. 2). Roughly in the center of the plot, one hole, 46 cm deep by ~18 cm in diameter was dug; thereby, each row would contain five plots with five holes. Three of the five holes were randomly assigned to receive HR, while two holes were left blank.

Experiments were run on two consecutive days on a Saturday and Sunday morning (September 28, 2013 and September 29, 2013) in an attempt to control for major seasonal temperature fluxes in weather. Temperature, humidity, barometric pressure, wind speed, and direction were verified through online weather archives for the location of each site (28). As weather conditions affect the movement and location of available odor and are often governed by time of day and location of the sun, both test series were run during the morning hours. One dog team ran the row of five plots in sequential order either from Plot 1 to Plot 5 or

	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	
Row 6	5	<4	<3	<2	<1	Dog 6
Row 5	1>	2>	3>	4>	5↑	Dog 5
Row 4	↑ 5	<4	<3	<2	<1	Dog 4
Row 3	1>	2>	3>	4>	5↑	Dog 3
Row 2	↑ 5	<4	<3	<2	<1	Dog 2
Row 1	1>	2>	3>	4>	5↑	Dog 1
TRIALS						
Wind Direction ↑						

FIG. 1—*A diagram of the layout of the plots and the associated wind direction, each plot measuring 7.62 × 7.62 m (25″ × 25″). Based on the wind direction in this example, dog number six ran the first row of five plots left to right, then dog five ran the next row of five plots right to left.*

FIG. 2—*A temporary fence was placed around each plot prior to the dog working it. When finished, the fence was moved to the subsequent plot.*

from Plot 5 to Plot 1 (Fig. 1). Upon the completion of each plot, the fencing was moved to the next plot successively until the five plots were completed. Each HRD team searched one row of five successive plots once for a completion of five trials per soil type, resulting in 30 trails for each soil or a total of 60 trails. The rows of plots were arranged so that the HR materials were upwind of the dog upon the start of the search.

Each HRD dog team was allowed 60 sec to search each plot. Prior to the start of the trial, the handler was asked to identify their dog's TFR. The handler was instructed to stand roughly in the middle of the open side of the fencing but not allowed to enter the search plot while the dog was working. The handler was instructed to verbally call a TFR when it occurred. Alternatively, at the conclusion of the 60 sec period, if the dog had not alerted, the handler was asked to indicate if the dog had given a TFR and instructed to enter the plot and indicate the exact location their dog was offering the TFR with a flag. Handlers were instructed to call an area blank if their dog did not offer a TFR.

All observational data, such as the dog's behavior and handler interference, were recorded. The handlers had no knowledge of location or number of buried HR. Testers recording data had knowledge of the exact locations of buried HR; however, testers remained silent during the testing phase of each trial and were obscured from sight of the dogs and trainers to eliminate any types of cues to dogs and their handlers. Response accuracy was scored by the testers on each trial with one of three responses: (i) correct, (ii) false positive, or (iii) false negative. Testers also recorded (i) the dog's first actual TFR on both buried HR and blanks, (ii) any attempts to leave the area on blanks, (iii) the length of time required for the initial response, and (iv) observational data pertaining to how the dog covered the area. The time required for the handler to call the TFR or a clear (i.e., dog displayed no TFR) and accuracy of the handler's call were recorded separately (3,27). Handler-called responses and dogs responses were recorded separately because handler interference or lack of confidence in calling TFR's has been noted previously (3,29). The purpose of this study was to determine differences in odor accessibility and detection by the dog's utilizing time as a test parameter, not the handlers confidence in calling their dog's TFR. Therefore, initial TFR's were recorded immediately when they occurred by the testers, as well as when the handler chose to call the TFR. Video recordings of the tests were used to confirm all data included in the results of this article.

Statistical Analysis

Data were tested for normal distribution prior to statistical analyses. Response accuracy was calculated through chi-square analysis between soil textures and between dog responses and handler-called responses. Response times were evaluated using a one-tailed independent *t*-test with an $\alpha = 0.05$ between textures clay and sand and between dog responses versus handler-called responses. Differences between dog response times and handler-called response times were evaluated through a paired two-tailed *t*-test with $\alpha = 0.05$. Observational data pertaining to how fluently the dogs covered the area and scenting behavior were also recorded for further evaluation for any difference between the two sites. SPSS V16 was used for statistical analysis.

Results

Soil Texture Percentage

The two horizons of the clayey soil were evaluated separately. The A horizon consisting of Hearne Fine Sandy Loam at a depth of 0–25.4 cm was comprised 70% sand, 10% silt, and 20% clay. The B horizon was the clay fragment of the soil at a depth of 25.4–63.5 cm and comprised 40% sand, 8% silt, and 52% clay. The sandy soil (Padina Loamy Fine Sand) to a depth of 142 cm comprised 85% sand, 6% silt, and 9% clay.

Weather Conditions

The temperature did not exceed 29.44°C (85°F) on either day of the trial (Table 1). Previous work has identified 29.44°C as the critical temperature point when humidity must be taken into account to assist in heat stress prevention for working dogs (30). Ambient air temperature was lower on the Sunday (September 29) testing but humidity was higher making the average working conditions for both days approximately the same. On both days, there was light drizzle and overcast skies with a rising or steady barometric pressure. Wind speeds and direction were fairly consistent throughout the two testing periods.

Response Accuracy

Each dog's five plots took approximately 30 min to run through all the stations. Human remains detection dog responses were 98.33% accurate, whereas handler-called responses were 91.67% accurate. Handlers called the dog response correctly 94% of the time for HR-buried targets but only 58.3% of the time for blanks. Handlers called responses generally occurred within a 15- to 20-sec latency period. Collectively, five incorrect responses were called by handlers. There was no significant difference between the percentages of correct responses for dog responses versus handler-called responses. Chi-square analysis showed that the correct response rate by both handler ($X^2 = 41.667$ [DF = 1; $p < 0.0001$]) and dog ($X^2 = 56.067$ [DF = 1; $p < 0.0001$]) was significantly above chance. Soil texture had no effect on accuracy of correct response ($X^2 = 0.067$ [DF = 1; $p = 0.80$]). No significant difference was detected between the accuracy of the HRD only dogs and the cross-trained dogs.

Time Difference Measures

The amount of time spent searching before coming to a final response was measured to determine any difference in difficulty in obtaining odor (Table 2). There was a significant difference between the time it took for dogs to come to TFR on sand versus clay ($p < 0.0001$) as well as a significant difference between the time of the dog's TFR and the handler's called TFR ($p < 0.0001$). Time differences between clay and sand were not significant with handler-called TFRs, but dog-called TFRs showed a significant difference between clay and sand with a one-tailed *t*-test ($p < 0.001$; Table 2). There was also a significant difference between handler-called TFR's and dog TFR's (paired *t*-test $p < 0.001$) verifying the latency between the dog's response and the handlers call of the response.

Observational Data

Search methods by the dogs differed depending on soil type. Dogs search behavior on the clayey soil consisted of slow methodical sweeps quartering back and forth across the predominant wind. Dogs on the clayey soil carried their nose much closer to the ground than on the sandy site. All dogs had to cross directly over the hole to show a change in behavior or alert behavior recognized by the handler (27). Dog search behavior on the sandy soil was considerably faster and consisted of generally taking one sweep across the wind close to the fence and then turning, head up into the area which contained the target. Initial changes in behavior on the sandy soil were generally much faster than on the clayey soil, but the dogs appeared to have more difficulty pinpointing the exact location of the odor.

TABLE 2—*Response time for dog trained final responses and handler call by soil type.*

	Mean Response Time (sec)			
Response	Clay	Sand	Std. Error	*t*-Test Significance
Dog TFR	37.9	20.5	2.46	<0.0001
Handler calls	45.5	37.6	4.02	0.173

Discussion

This is the first known study to examine the effect of soil properties on a HRD dog's performance in locating and alerting on buried human remains in field conditions. While a controlled environment cannot be achieved in field conditions, this study controlled for land use, grass cover, burial time, general weather conditions, dog breed, training team, and dog certification. Results of this study supported our hypothesis that sandy soils would be easier for odor detection than clayey soils for HRD dogs and have implications for training and certification as well as site management and planning.

Training and Certification

Courts have deemed that detector dogs must show they are trained, certified, and reliable (19). HRD dogs are generally held to the same accuracy expectation as narcotic dogs through case law (6,7). However, industry standards for narcotic dogs do not endorse fielding un-certified dog teams (6,7), whereas, this practice is still performed with some volunteer search dog teams. Proficiency assessments are generally weekly for bomb detector dogs and bi-weekly or monthly for narcotic detector dogs. HRD dog teams should hold their dogs to the same standard, as case law pertaining to narcotic dogs is generally accepted for use with HRD cases (6,7). Case law for minimal narcotic dog accuracy has ranged between 54% and 67% depending upon the state (6,7) for the last several decades. However, recent court cases (6,7) have better clarified accuracy, training, and certification expectations of the court. Florida versus Harris was recently reviewed by the U. S. Supreme court (6) that concluded that "if a bona fide organization has certified a dog after testing his reliability in a controlled setting" (or "if the dog has recently and successfully completed a training program"), "a court can presume (subject to any conflicting evidence offered) that the dog's alert provides probable cause to search."

TABLE 1—*Hourly weather conditions for Hearne, Robertson County, Texas, on September 12 and 13, 2013*. Clay was day 1 and sand was day 2.*

	Temperature		Humidity		Barometric Pressure		Wind Speed (mph)		Wind Direction	
Time†	Clay	Sand	Clay (%)	Sand (%)	Clay	Sand	Clay	Sand	Clay	Sand
8 am	77.9	68.4	86	94	Rising	Rising	11.5	5.8	SE	W/NW
9 am	77.7	68.2	89	94	Rising	Rising	5.8	8.1	SE	NW
10 am	79.7	70.0	86	91	Rising	Steady	6.9	5.8	SE	NW
11 am	82.6	70.3	75	89	Rising	Steady	8.1	8.1	S	NW

*Data collected at Easterly Airport. Both clayey and sandy sites were within a 10-mile distance from downtown Hearne where weather conditions were collected.

†All tests were completed prior to 11:30 am.

Most law enforcement agencies are now moving toward outside third-party certifications, but this practice is still not uniform among volunteer search dog teams. Many volunteer search dog teams still test with in-house certifications which may not be set up in a manner that truly challenges the team. Furthermore, most in-house tests evaluate the dog teams' ability to locate the same aids which the dogs routinely train on, rather than appropriate novel aids of human remains. Our study utilized novel human remains which the dog teams had not previously trained with but would be consistent with potential real-world cases. Assessment using aids that dogs regularly train with may be more indicative of the dog's capabilities to find their own training aids rather than novel human remains odors as would occur in real-world scenarios.

Human remains detection dog accuracy is important because evidence located by HRD dogs can render the handler in court for testimony. United States v Cedano-Arellano (332 F. 3d 568 [2003] Ninth Circuit) determined that a detection dog's records, both training and certifications, are discoverable by the defense (6). This allows for assessment of the dog's reliability by the defense. Therefore, training records should be maintained for all detector dogs which include a reliability percentage, which is determined through controlled environment single-blind certifications and proficiency assessments (6,7).

In this study, handlers were on average 15–20 sec latent in calling dog TFR's. This discrepancy may be due to handler routine in training or confidence levels. Some handlers develop a routine with a "show me" command for their dogs to pinpoint or put their nose to the source of the target odor. Testing purposes made it essential to parse out when the dog actually detected and reported the odor to the handler from the potential training routine or handler confidence to adequately test our parameters. Handlers called the dog's responses correctly 94% of the time for HR-buried targets but only 58.3% of the time on blanks. The discrepancy on blanks may be attributed to handlers repeatedly sending the dogs back into the search area when the dog attempted to leave on offering no TFR. A HRD dog leaving the area after thoroughly checking it, including sniffing the blank hole, should have been an indication of no response and therefore called as a blank area. In three of the five false alerts called, the dogs never gave a full trained final response. Handlers called the area as an HR hole due to interest and repeated returns to a specific location which turned out to be the negative hole. This suggests that the handler assumed that "some" interest but no alert meant the dog had failed to offer a TFR. More time should be invested by teams in working both negative scenarios where no HR is present and scenarios with nontarget odors present to build handler confidence in their dogs assessment when no odor is present.

The results of this study also emphasizes the need for inclusion of blank or negative areas which do not contain any HR materials within the normal training regime both known, blind, and double blind (31). Dogs are not trained to specifically give a trained response indicating no target odor found, so it is imperative that handlers learn to read the body language that their dogs exhibit when searching an area void of a target odor. Likewise, behavioral differences are also often noted with nontarget odors such as dead animals or food (2,8,31). Handlers must also train with various distractor odors to verify dead animal odors will not elicit a TFR and also to learn their dog's body language with nontarget but odors of interest to the dog. Achieving true independence of work also requires the handlers to pressure the dogs in training in the same manner they would on an actual mission or test to ensure the dogs learn that even with handler pressure, in the lack of the target odor, the only correct response is no response (2,31,32).

There is no mandatory single national standard to become and maintain proficiency as a search dog handler and some organizations assign persons with no previous canine experience as a dog handler (33). Testing standards also vary from organization to organization; however, most HRD evaluations include a buried search scenario as part of the team's certification. This variability among testing also includes variability in methods used to conduct the test. For example, varying amounts and types of tissue, 14 g up to 60 lbs (8–10) are utilized. Some organizations allow the alternate use of substances such as hair, nail clippings, and pseudoscent or rags infused with pseudoscent, permeated with indirect contact with human remains or impregnated with blood or decomposition fluids, which are then buried in the ground (34). The viability of these various target odors as accurate substitutions for full bodies necessitates further research. Depth requirements generally range from as minimal as 15 cm up to 76 cm (6–30 inches). Actual depth utilized on any given test depends on the organizations standards, the experiences of the evaluator, availability and size of materials to bury, instruments to dig with, and the texture, profile, and moisture content of the soil. Methods for placement of the HR also vary greatly between evaluators. Some evaluators utilize leaves, rocks, sticks, and other materials to increase aeration of the hole, whereas others utilize cylinder core plugs. Core plugs are analogous to a cork in a bottle, some remove only a section of vegetation and top soil while others pull a plug as deep as the soil will allow. The entire plug is removed generally with a posthole digger and set aside, HR placed at the bottom of the hole, and the soil plug is replaced and compacted in a manner to decrease chances of handlers seeing the location of the burial. Clayey soils, which already have poor aeration and less gas diffusion and have been shown to be more difficult to detect odor, work best for this method due to clay soils stickiness and tighter structure. This method typically compacts the soil more, contributing to an even more difficult detection scenario. The size of the HR typically used (14–30 g) is not comparable to a human body nor has decomposition occurred in the area so the soil is void of the typical cadaver decomposition island (CDI) and the accompanying gaseous diffusion and nutrient dispersal associated with an actual decomposing corpse (8–10).

Organizations also vary on the length of time required for the burial to "set" prior to testing, anywhere between a half hour to twelve hours (8–10). Short deposition or set times may result in a lower release of decomposition gases. Soils which are packed down into the hole compact the soil after burial of the HR and may also greatly reduce the amount of gases that can escape as the natural structure and pore space of the soil has been disturbed and adequate time to return to normal structure cannot be obtained in the given time frame of the test. The results of the trials conducted in our study indicate that the method utilized resulted in adequate escape of odor, while still impairing visual identification of the target holes by the handlers. This more correctly mimics visual conditions found in most real-world searches on older cases.

Scene Management and Planning

Differences in the aeration between clayey soils and sandy soils have important implications for actual mission deployments of HRD dogs searching for clandestine graves. Knowledge of the soil texture can assist search managers and HRD dog teams when planning strategies and apportioning search area sizes and approximate sweep widths to cover the area efficiently but with best precision by HRD dog teams. The more clayey the soil, the poorer the aeration, which will require slower more methodical searching with decreased sweep width on grids. We recommend that soil texture be taken into account when apportioning the size of search sectors and the time allotted to search the area. Soil texture can be obtained through either field hand texturing with minimal training or through online formats such as the USDA web soil survey website or the smart phone application "Soil Web" which operates with the GPS function of the phone and gives the soil series and other pertinent information such as soil texture at each soil horizon accurate up to one meter of the location of the user.

Though somewhat counter intuitive, greater pore space in clayey soils is mainly due to the large surface are of clay particles coupled with a larger number of micropores resulting in a greater potential to hold water than sandy soils. This water retention limits aeration and escape of gases (11,19,20). Wet soil may result in the odor moving laterally instead of straight up through the soil. Visualization of the potential movement of odor due to wind effects can be accomplished through the use of smoke bombs, and scent detection dog handlers are generally trained in "scent theory" or the study of the transport of odor (2). Furthermore, observations of the dogs may provide clues to odor diffusion. Dogs in the clayey site worked with their head low to the ground, whereas at the sandy soil site the dogs worked with their heads up. Further support of this was indicated by observable changes in behavior only when the dog passed directly over the burial hole in the clayey site, whereas change in behavior was noted as soon as the dog was downwind of the hole at the sandy site. This suggests that the sandy site had enough odor emanating from the burial to develop a significant scent cone which is the zone of odor resembling a triangle (Fig. 3) due to gas escape. On the other hand, at the clayey site the gas escape and therefore scent cone may have been significantly smaller and fainter. Changes in behavior (COB) can vary between dogs but generally accepted COB's are sudden changes in direction when passing through a scent cone by turning back into the odor zone, changes in tail carriage, head carriage, ear position, body position such as erectness or crouching closer to the ground. Handlers generally know through prior training experience, the COB's that indicate their dogs have entered scent cones and are working to the origin of the odor; however, dogs can also indicate COB's with nontarget odors. Because handlers are visual, even if the dog is just checking an anomaly that may not be a target odor, handlers may interpret the COB as the detection of a target odor. This may cause handler interference which results

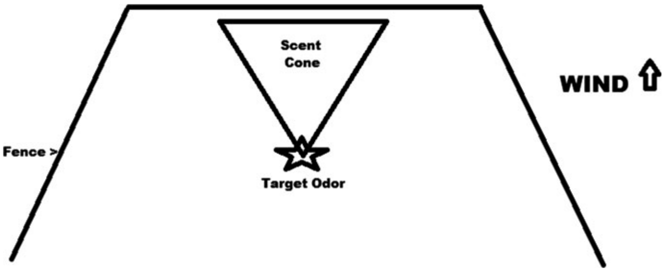

FIG. 3—*Illustration of theoretic scent cone radiating downwind from target odor within the fenced search plot. Dogs were started on open side and had to cross behind the buried target to cross within the area of the odor plum.*

the handler pressuring the dog until a nonproductive TFR is offered. Despite handlers maintaining their position out of the search area, verbal cues and pointing gestures to check areas were allowed and may have contributed to the incorrect TFR's that were offered (32).

Temperature, humidity, wind speed, and direction are generally accepted conditions tracked by most handlers in their training logs. Temperature and humidity are of special consideration in terms of heat conditions and efficiency of scenting by the detector dog and should be taken under consideration to safely work a dog without causing excessive heat stress (30).

Conclusion

Consideration of soil texture and subsequently the moisture and porosity can be a useful tool for HRD dog training, testing and mission deployments of buried remains. Law enforcement, search managers, and HRD dog teams can benefit from researching soil profiles of designated areas prior to activities to best determine strategies that will lead to successful outcomes for HRD dogs.

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Additional information and reprint requests:
Michael B. Alexander, Ph.D.
Department of Biology, Lower Division Biology
Texas A&M University
College Station, TX 77843-2474
E-mail: malexander@bio.tamu.edu